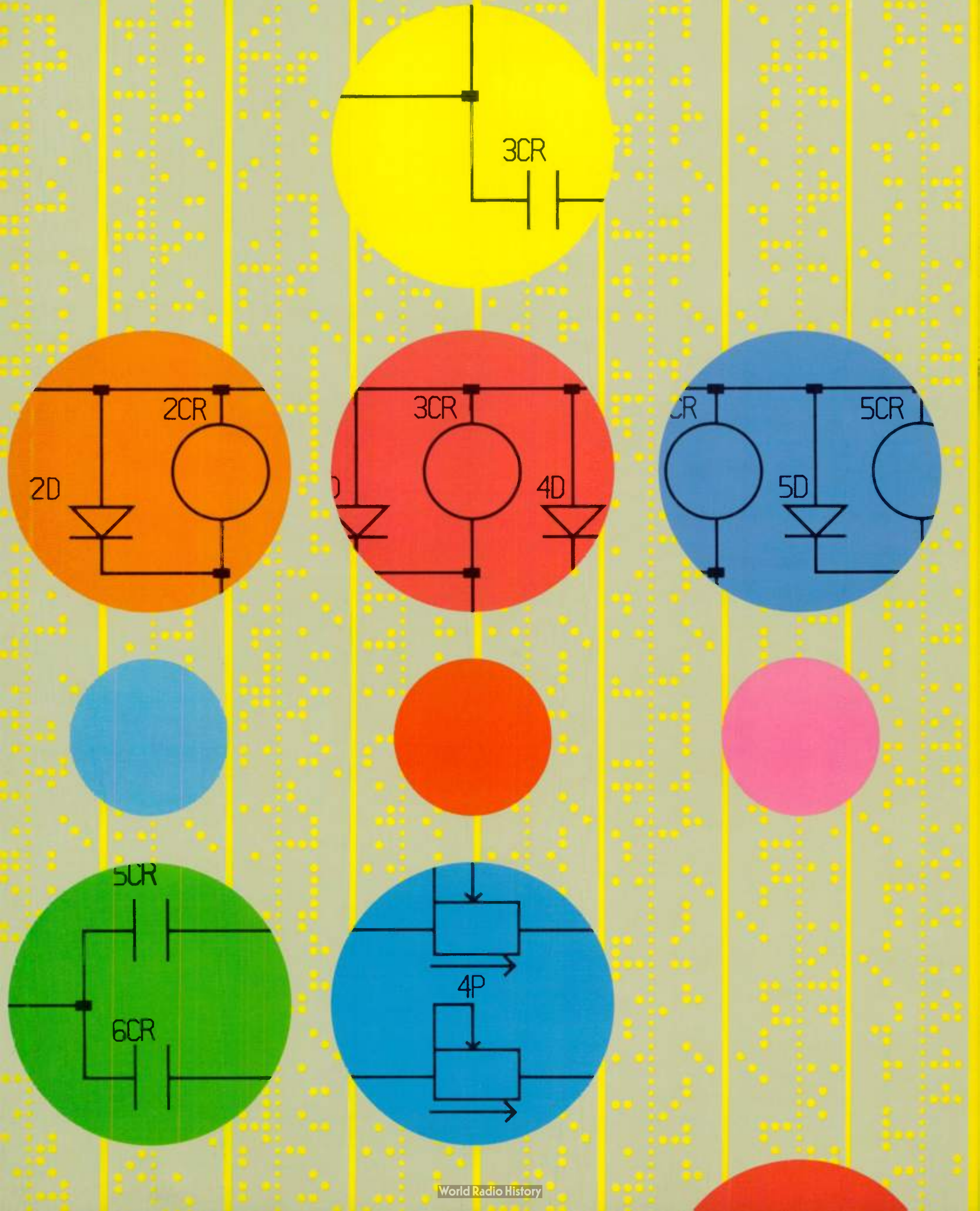
Westinghouse ENGINEER

May 1973



Integrated Plant Produces Equipment for Water and Wastewater Treatment

A new manufacturing plant in Culpeper, Virginia, gives the Westinghouse Infilco Division unified facilities for both design and fabrication of a complete line of water and wastewater treatment equipment for industrial, municipal, electric-utility, and marine applications. The in-house fabrication capability is an important innovation in the water and wastewater industry, where sub-contracting of fabrication has been common. Combined with efficient plant layout, modern equipment, and new production methods, it allows substantial control of product quality, scheduling and shipping.

Infilco is the equipment arm of the Westinghouse Water Quality Control Division. It supplies aerators, clarifiers, filters, recarbonators, demineralizers, incinerators, instrumentation, controls, and other equipment needed to treat wastes chemically and biologically and to incinerate sludge.

All steel plates received at the plant are cleaned and primed to customer specifications before fabrication begins. A flame-cutting machine then cuts the steel to the required shapes under the guidance of an optical tracer system. Material destined for circular tanks is rolled into cylinders (Fig. 1), which are welded by an automatic unit (Fig. 2). Material for rectangular products is usually formed on a brake to reduce the number of welds required.

After initial assembly, heat-affected areas are recleaned and reprimed. Products that require little field assembly receive a final coat of paint in a spray booth (Fig. 3).

Legs, manholes, flanges, nozzles, control panels, and other ancillary items are mounted on the products at assembly stations. Much of the assembly area has been allocated for putting together, testing, and adjusting products before shipment (Fig. 4). That practice eliminates delays at the job site because of improper fit or faulty operation.

Motors, drives, and other mechanical parts are added in the final assembly area, and electrical control panels are built (Fig. 5). Products are then shipped assembled or disassembled, depending on size and customer preference.

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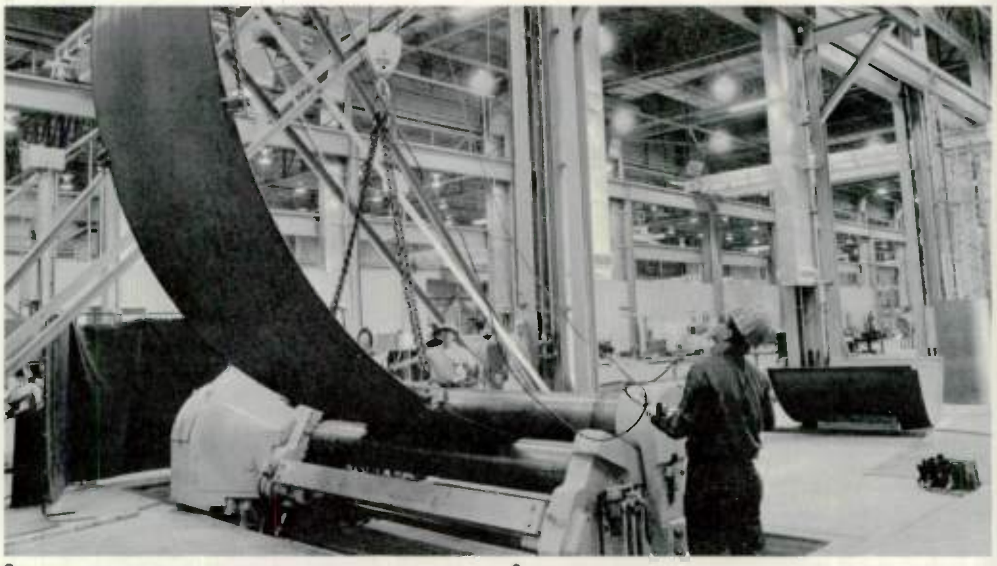

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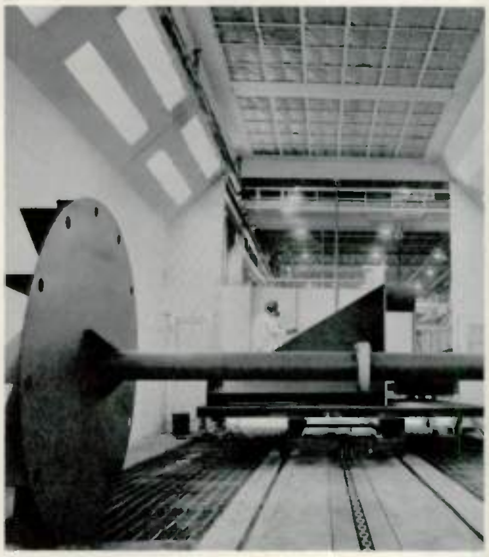

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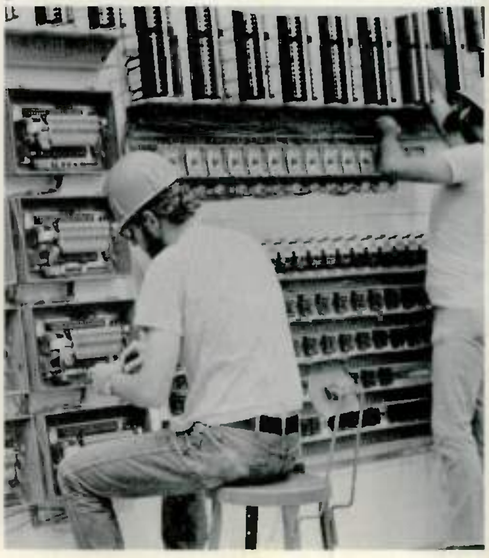

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Front Cover: Punched tape and schematic plots are two outputs of the automated drafting system described in the article beginning on the following page. The system captures much manufacturing information when drawings are entered into it in digital form, and it processes that information to provide such outputs as punched tape to operate production and test equipment.

Computerized Information Processing Translates Customer Requirements into Drawings and Control Systems

Paul E. Jacobs
Joseph L. Mueller

The Datadraft system produces finished drawings from digitized input. It captures much manufacturing information in doing so, and it processes that information to enable the shop to build products of higher and more uniform quality.

Designing and manufacturing the electrical control system for a complete industrial process such as a hot strip mill or a paper mill is an intricate task of translating the customer's specific needs into a system that will do the job. A potent aid in that task at the Industrial Systems Division is Datadraft, which is basically a computerized drawing system that converts engineers' sketches into finished drawings. It is much more than a drawing system, however, for it captures data from the sketches and processes the data for other uses. Those uses include production of the manufacturing information needed to build the control system, and production of the data that tell the customer how to interconnect the cabinets and stations making up his control system.

This article describes the particular configuration of the Datadraft system that is in use at the Industrial Systems Division and discusses the benefits it provides there. However, the system is adaptable to many other manufacturing operations, and each application would have its own kinds of benefits. Consequently, the Industrial Systems Division is now marketing the system as well as using it in its own operations.

The most obvious benefit of Datadraft to customers for the Division's control systems is that the customer now receives prints of the system drawings made from a high quality vellum original done in India ink. Less obvious but more vital to the customer is the higher quality of the finished equipment that results from use of Datadraft: once the engineer has completed his schematic system sketches and his layouts of the devices for the control panels or desks, all subsequent information to produce the finished equipment is generated by the computer, helping assure a product of uniform high quality. A third advantage is that the interconnection wiring lists produced for the customer ease and speed the initial interconnection of system components and subsequent troubleshooting or modifying.

Datadraft is an interactive system developed by Dimensional Systems Incorporated, Lexington, Massachusetts. Before it was installed at the Industrial Systems Division, information for design and manufacturing was gathered, processed, and transmitted largely by manual methods. Even where the process was computerized, it required that large amounts of input be manually coded and keypunched. (See *Before Datadraft* at left.)

Datadraft System

The Datadraft system enables an operator to digitize a sketch, which means converting the sketch information and its X-Y coordinates to computer-readable codes and numbers. The system assembles the information and stores the digitized representation of the drawing on magnetic tape. Included in the digitized representations of the drawings for a particular con-

1—The Datadraft system, indicated in color in this schematic representation, converts engineers' sketches into finished drawings. Even more important, in doing so it captures much information that is further processed to automate and standardize many manufacturing operations.

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Before Datadraft

Schematic Drawings—Engineers at the Industrial Systems Division formerly prepared the sketches required for a given order and forwarded them to the drawing room, where a detailer drew finished schematics for the shop and for the customer. Phototypesetter units and various other more or less automated approaches were tried in efforts to improve drawing speed, quality, and uniformity. All lacked flexibility, however, and none had any capability to produce manufacturing information.

Shop Wiring Information—Electrical draftsmen manually prepared wiring diagrams that detailed all of the wiring within a given control cabinet or desk. The typical wiring diagram consisted of the electrical representation of each device shown in its approximate physical location in the cabinet. All wires leaving a given device were identified by wire number, size, color, and destination.

In the first attempt to computerize shop wiring information, a draftsman gathered wiring information from the schematics and the physical location of each device from the front-view layout. He coded the information, which was then key-punched and run on a computer. Output consisted of "from-to" wire lists.

The next improvement was use of a card-controlled wire marking machine. Logic was added to the wire-list program to compute the length of each wire, and output from the program included a deck of cards to feed the machine. The machine produced a coil containing all of the wire required for manual wiring of the cabinet, marked with complete instructions for the wireman. Besides facilitating manufacturing, this system gave the customer more positive, permanent, and complete wire identification. (The machine is still used, but its input now comes from the Datadraft system's processing of the information in the drawings for the job.)

Similarly, draftsmen gathered and coded information for wiring the back planes used to interconnect printed-circuit boards. Output of the program was a paper tape to run a wiring machine. (That process, also, is now integrated into the Datadraft system.)

Assembly Information—To produce a control panel on which various devices would be mounted and wired together, an engineering aide first prepared a front-view layout. A draftsman coded the location of each cutout on the panel, and the coded information was keypunched and run on a computer. Output was a paper tape to control a turret punch press. (Again, the whole process is now handled by the Datadraft system.)

Manufacturing information also was generated manually to define the parts required, what shop section was to build the parts or what storeroom was to supply them, and how the parts were to be assembled on the panel. Cost Accounting used the completed bill of material to detail the cost of each item and thereby to establish the total cost of the order. Now, for a number of product lines, engineering parameters are coded, keypunched, and run on a computer whose manufacturing information program interrogates a master library and prints out all the information needed to produce the order. In addition, the program determines costs.

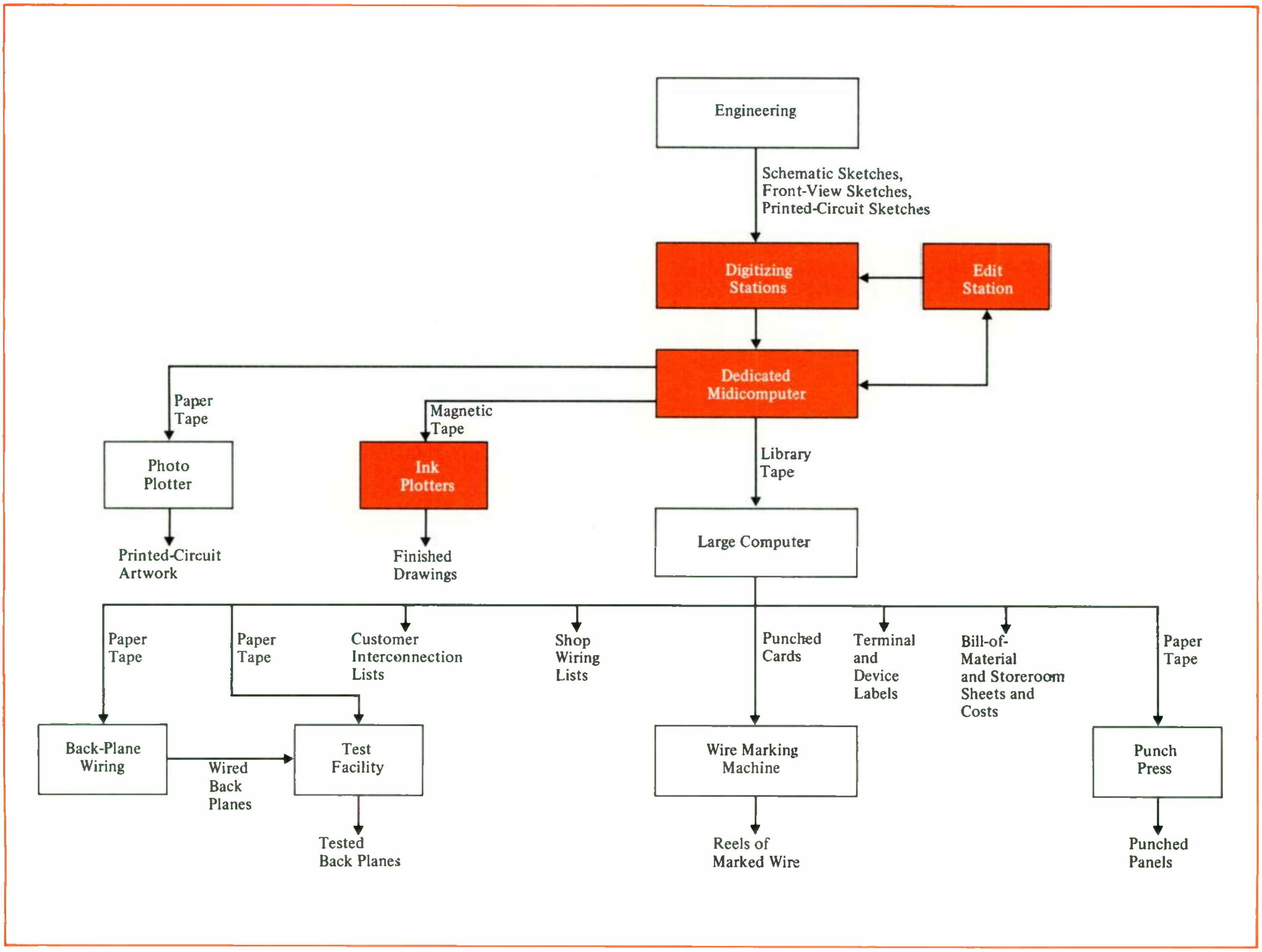
Printed Circuit Boards—A draftsman first laid out a new board on gridded mylar. A second draftsman then applied opaque tape in the form of the conducting paths and connection points for both sides of the board, a process that took about 20 hours. The taped layout then was used as a mask to produce the circuit board by standard photoengraving processes.

trol system are the data needed to manufacture the system. Therefore, further processing of the data by a computer can produce punched cards to control a wire marking machine; paper tape to control punch presses, a wiring machine, and a test facility; and printed output ordering all parts needed for the system. Datadraft is, thus, the key center of an integrated manufacturing system for the Division (Fig. 1).

The system hardware's basic block is a midicomputer and its associated input-output equipment. The midicomputer is applied as a high-speed data collector that processes small amounts of data quickly and efficiently and also feeds back information to its operators as to what they are doing and if a mistake has been made. It interacts with a larger computer, the Division's IBM 360/50 machine, which serves as a high-speed data processor that can handle huge amounts of data but need not supply instantaneous results. The midicomputer's input-output equipment presently consists of two digitizing stations, an edit station, and two plotters.

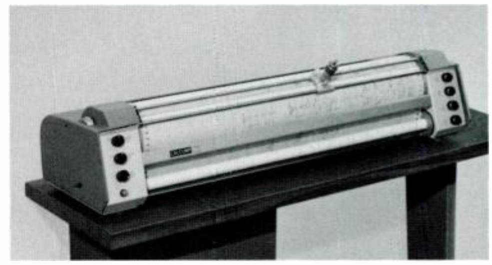
Initial entry of a drawing is done at a digitizing station, which includes a digitizer, a display unit, a teletype, and a keyboard that is connected by a cable to the station electronics (Fig. 2). The display unit provides visual feedback to the operator. Any input errors are called to the operator's attention by an audible signal and are identified by the display unit. The keyboard is used to change the operating mode of the station and to select the type of information the operator wishes to enter; it also allows the operator to request printing of the error message at the teletype or to turn the error alarm off if he already knows the problem. The teletype is used to enter text commands to the computer and to enter the text contained on a drawing.

The edit station consists of a cathode-ray storage tube, a keyboard, and an electronic graphic tablet and pen (Fig. 3). Newly digitized drawings can be viewed and edited, or old drawings can be called back



2—A sketch is entered into the system at a digitizing station, where all the relevant information on it is converted to computer-readable codes and numbers. The operator picks up symbols from a standard list with a cursor and positions them wherever they are to appear on the drawing. Lines are put in similarly, and text is entered with the teletype.

3—(Top) *Here at the edit station the system displays the newly digitized drawing on a cathode-ray storage tube. The operator inspects it and makes any needed corrections, such as replacing a symbol.*



4—(Bottom) *Corrected drawings in storage can be converted into hard copies whenever wanted and in a choice of types and sizes. The plotter produces a drawing of high quality in India ink on vellum.*

and modified to become the new drawings of a different job.

The plotters presently used are digital drum types in which both the drum and pen move in 5-mil increments at 1½ inches per second (Fig. 4). Drawing quality has been well within customers' standards and is always consistent.

Drawings actually being worked on at a digitizer, edit station, or plotter are held on disk in the midicomputer for instantaneous access by the computer. After a drawing is completed at the edit station or digitizer, it is moved from disk to a "queue tape" for short-term storage for updating, correcting, or storing new drawings. Once corrected, drawings can be transferred to a "library tape" for long-term storage. All drawings are accessible through the librarian routines that can be called at the master station, which is simply the midicomputer's console teletype.

Processing Drawings

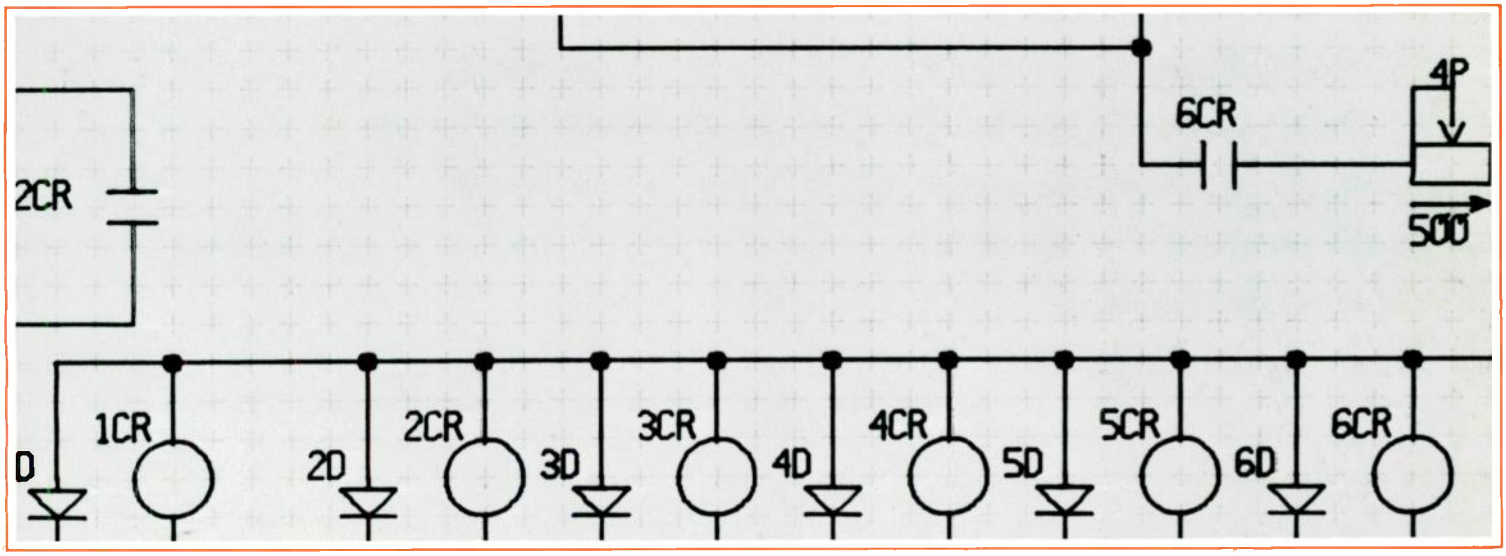
Digitizing—A typical *schematic diagram* for input to the Datadraft system has first been sketched by an engineer on 0.2-inch grid paper. The operator positions the sketch on the digitizer table and "initializes" it by identifying it, defining its size, and locating its position. The sketch is then digitized by use of a hand-held cursor connected by a cable to the station electronics. The table and cursor act as a transmitter and receiver that provide the system with the necessary X-Y coordinate information. To enter a symbol, for example, the operator selects it with the cursor from the "menu" (a list of available symbols) and positions the cursor each place on the sketch where the symbol appears, thereby identifying both the symbol and its position. When all symbols have been entered, the operator enters wires and text on the drawing.

On completion of the digitizing, the computer program assembles the information and organizes it into the separate files required for displaying the drawing and for producing the other outputs. The program then analyzes the information for such errors as unnamed wires, lack of names for devices, and lack of terminals at the ends of wires. Any errors detected are printed out, and the operator corrects them. The drawing is then stored on the queue tape.

A *front-view sketch* shows the graphic layout of all the devices to be mounted on a given panel, the punch-press labels (which define hole patterns and punch numbers) required for punching the panel to mount each device, the name of each device that is to be wired, and the style and item number of each device. It is quite different from a schematic sketch, so the digitizing method also is different.

Punch-press labels are stored on disk; to enter one, the operator digitizes the point at which the label is to be located and enters the label number with the teletype. In a similar manner, he enters device names and numbers at the desired locations on the sketch.

A *printed circuit board* starts with a draftsman laying out each side of the board at twice full size on mylar. The Datadraft operator digitizes the layout by entering all traces, pads, text, and macro-symbols, and the program generates the drawing files. (Macro-symbols are common patterns of pads and traces that are used frequently; they are digitized and stored on disk.) Output from the computer is a punched paper tape that controls a photo plotter to produce a photographic film. The same information, stored on magnetic tape, can be used to plot out the drawing if desired.



5—This section of a plotted schematic diagram shows the high quality and consistency achieved. Schematics and other drawings are plotted directly in India ink on vellum.

Editing—After a drawing has been digitized and stored on tape, the operator calls it up at the edit station to check it again for digitizing errors (Fig. 3). The station's graphic tablet contains the same menu and the same mode controls that are present at the digitizer, but the operator uses a graphic pen in place of the cursor for positioning symbols and information.

The operator views the complete drawing, minus text, on the CRT screen and selects an area to zoom in on. That area is displayed enlarged and with all the symbols, lines, and text that are within it. The operator then edits the area if necessary. Adding or replacing symbols, wires, or text is similar to the corresponding operation at the digitizing station.

Often, a schematic drawing is used many times with only a few small changes from one application to the next. For that situation, the operator calls up the basic drawing at the edit station, makes the changes called for, assigns a new number to the drawing via a keyboard entry, and transfers the new drawing to the queue tape.

Plotting—The schematic diagram is the master document to both the engineer and the customer, so it must be of consistent high quality (Fig. 5). Experiments with various drawing surfaces and inks have revealed that the quality needed for all drawings is attained with vellum and a special plotter ink. Several sizes and types of plotter output can be made. Standard sizes (in inches) are 8½ by 11, 11 by 17, 17 by 22, and 22 by 34, all of which can be rotated and all of which can be plotted half size.

Two types of plot are needed. One is a "check plot" that contains all the information entered. Since much of that material, such as wiring information, is not desired by the customer, a "regular mode" is used to produce customer drawings.

Front-view plots provide finished shop drawings and also give the Datadraft operator a quick visual check for such errors as location of devices so close together as to interfere with each other in mounting.

Producing Manufacturing Information

Even though the schematic diagram is the master document, it would be impossible to wire cabinets from it at reasonable cost in the large systems built by the Industrial Systems Division. It is still necessary to prepare some form of manufacturing information, such as wiring instructions that specify such things as wire lengths, size and color of wire, wiring paths, terminal blocks, and terminal boards.

Datadraft greatly facilitates the task. Since the drawing input captures all the manufacturing information, selected information for specific purposes can be retrieved as needed and processed further by the computers. From the front views, bills of material, sheet-metal punching requirements, and device locations are retrieved. From both front views and schematics, information for manual and automatic wiring is retrieved.

On command, the midicomputer calls up the relevant front-view and schematic drawings and processes their information. The output of its formatter program is a magnetic tape with data specially formatted for input to other programs in the large computer.

By far the largest and most complex program is the one for manual wiring. It reads the information on device location and wiring from the tape and matches it up by device name. Then, from the many sheets of schematics, it gathers each bit of wiring information together into complete circuits. The circuits are then analyzed and broken up into the various segments—customer device to customer device, control assembly to customer device, control assembly to operator desk and station (or control assembly to control assembly), and wires that stay within a cabinet and are installed in the shop. While developing those lists, the program also specifies the necessary connecting devices (terminal blocks or boards) and groups the wires going externally by their destinations. From this analysis, the program creates the following lists: intracabinet wire check list, intracabinet wiring list ("from-to" format), cross connection list (between cabinets), shipping split list (between shipping sections), and finally the customer interconnection list.

Creation of all that wiring information is done by the computer during one pass through the data in a matter of minutes, not by several passes by many draftsmen over a period of months. Therefore, when the schematics are correct (approved by the customer and by Westinghouse engineering), all the wire information is correct.

Besides providing wire lists, the program also produces punched cards that are used to control the shop's wire marking machine (Fig. 6). The machine hot-stamps the full identification on each measured length of wire. The "from" half of each length is stamped every 4 inches with the wire number, "from" device name, and terminal number; the "to" half is stamped with the same wire number, "to" device name, and terminal number. Wires are marked in the order in which they are to be used. For those wires, the wiremen need not refer to a wire list because they can read the wires directly.

Wiremen refer to the intracabinet wiring list for information on installing the few cabinet wires that cannot be marked by the machine. They refer to the cross connection list and the shipping split list for information on installing wires for which length cannot be calculated from the drawing information. Testers use the wire check list to test the circuits.

Other manufacturing information programs that are available include one that creates punched tape to control the machine used to wire the back planes of digital logic racks (Fig. 7). The input to that program is also used by the continuity program, which produces a punched tape that enables a test facility to check for open or shorted circuits and for complete and accurate wiring (Fig. 8).[1]

Another program produces paper tape used to control the turret punch press that produces sheet-metal parts for cabinets (Fig. 9). A fourth set of programs creates parts lists and manufacturing information used by the shop to assemble the desired parts in the cabinets. Information from that set is fed back to an inventory control program that in turn relays necessary information to a purchasing program.

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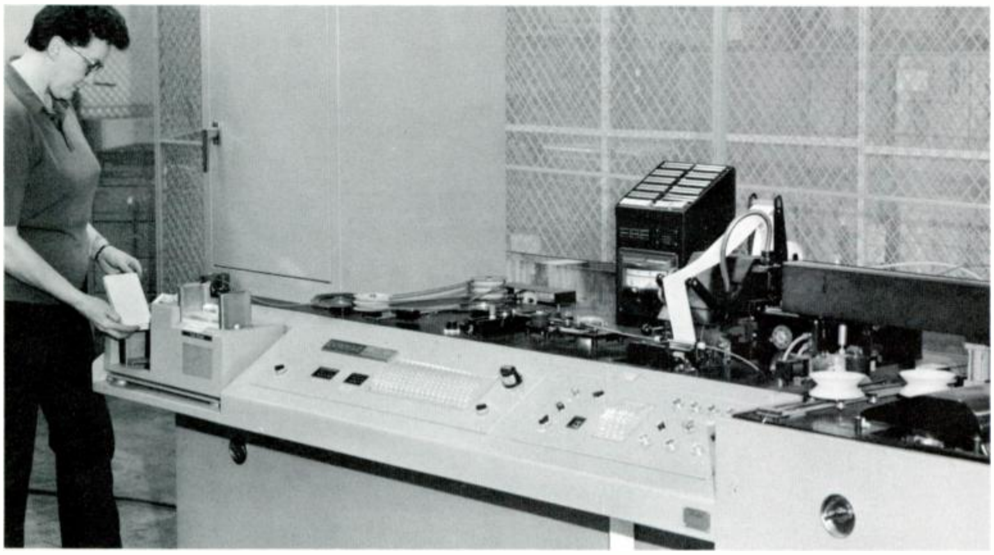

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Impact of Datadraft System

Various features of the Datadraft system have now been applied to most of the product lines of the Industrial Systems Division. Among the most tangible benefits that have accrued to the Division is the reduction in drawing time. Whereas it took a draftsman an average of 3 hours to draw a 17- by

6—Among the manufacturing information captured from the drawings is full information about the wiring needs of the job. One of the outputs of Datadraft's manual-wiring program is a set of cards for controlling this machine, which marks a coil of wire. The marks tell the shop wiremen where to cut each length of wire and also where to attach each end of each wire.

7—Another wiring program creates paper tape that controls this machine, which wires the back planes of digital logic racks.

8—The same input used by the back-plane wiring program also is used by a program that creates tape to control this test facility, which tests the wired back planes.

9—Information from the front-view drawings is used by a program that prodaces tape to control a turret punch press. The press punches the required holes in steel sheets that will be formed into cabinets to house a control system.

22-inch schematic of average density, it now takes an average of 1 hour to do the same schematic (45 minutes to digitize and 15 minutes to edit). It formerly took a draftsman 2½ days to tape a layout for a printed circuit board; it now takes an operator 3 hours to digitize the same board and produce a paper tape for doing the artwork on a photo plotter.

Besides the reduction in drawing time, there is an obvious improvement in drawing quality. Instead of being hand drawn initially in pencil, originals are now plotted directly in India ink on vellum. Hand-drawn symbols, lines, and text are now replaced by plotted symbols, lines, and text that are precise, uniform, and of high quality.

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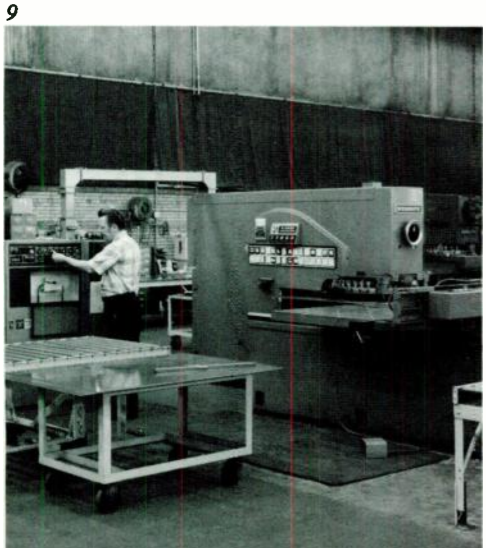

By capturing manufacturing information, Datadraft has reduced the production of wiring information by the drafting department from a manual coding-keypunch operation, averaging perhaps 3 hours per cabinet, to a negligible amount of time that is now included in the time to digitize a scheme. In a similar manner, it has eliminated all of the manual coding-keypunch operation formerly required to produce the paper tapes that control the back-plane wiring machine and the back-plane test facility. Now all of that information is automatically captured in the course of digitizing the schematic sketches.

Digitizing a front-view drawing captures data about the devices to be located in a cabinet panel, thereby enabling Datadraft to produce a paper tape that controls the punching of the panel. Moreover, the plotted output provides a finished shop drawing and also gives the operator a quick visual check for device interference. The old way was a manual coding-keypunch operation with no interference check.

As more numerically controlled machines are utilized at the Industrial Systems Division, it is expected that they too will be integrated into the Datadraft system.

Probably the most important data so far as the shop is concerned is the actual assembly information needed to build each order. That part of the system is not yet implemented, for the master library must first be updated, but it is quite clear what the effect will be. Under the existing system, manufacturing information for most orders is dictated by Manufacturing Information writers and the cost manually detailed by Cost Accounting; in the future, it will be generated by computer out of the parts entered on the front-view drawing.

All of the foregoing benefits aid the manufacturing operation, reducing the cost of preparing information for the shop and producing a higher and more consistent quality of input to the shop. There are also benefits to the customer besides the obvious one of higher quality finished schematics. Computer-generated manufacturing information produces products of higher and more uniform quality by eliminating many opportunities for human error. Order cycle time will decrease as personnel become more experienced in using the system, giving the customer a better product in a shorter time.

Finally, at the customer's site, field service personnel can use computer-generated interconnection lists to interconnect the various control cabinets. Those lists result from a brief computer run once all of the schematics in an order have been digitized. Even better, if the customer defines the distance between the structures that are to be interwired, the computer can output a deck of cards to feed the wire marking machine. Then, at installation time, the customer can have not just an interconnection list but a complete set of interconnection wires stamped on each end with their addresses.

REFERENCE:

[1]Neville E. Jacobs, "Multistation Test System Allows Thorough Testing of a Wide Variety of Electronic Subassemblies," *Westinghouse ENGINEER*, September 1970, pp. 154-7.

Power Plant Simulation Facilitates Dynamic Factory Operational Testing of Plant Automation and Control Systems

T. C. Giras
P. N. Papas

A new verification facility includes a computer model of PACE electric power plants. It is used to provide system quality assurance at the factory and to train plant operators under real-time conditions.

Factory checkout of control systems is normally limited to inspection and testing of the system components, with testing of the total system delayed until after it has been installed on the equipment to be controlled. For advanced control systems, testing and the associated adjustment and tuneup may require many months, during which the plant cannot be used for production.

To expedite startup with the control systems for PACE (Power At Combined Efficiencies) power plants, Westinghouse has built a verification facility capable of complete operational testing of each system before shipment (Fig. 1). In addition to increasing the reliability of the control system at the time of delivery to the plant site, the verification facility permits investigation of changes in control philosophy without field tests at the actual plant. It also is used to check out alarming and tripping functions that only operate under severely abnormal conditions, because simulation is the only practical method of verifying control response under such conditions.

Each PACE power plant includes two Westinghouse gas turbines that exhaust into two steam generators, which supply steam to a Westinghouse condensing steam turbine (Fig. 2).[1] Most plants will have a nominal rating of 260 MW, although ratings of 520 MW are also planned.

Control is provided for all elements of the system through all operating modes from hot startup to full load, including both transient and steady-state conditions. The control system includes two Prodac 2000 computers (one for control and one for information monitoring and display) and a hard-wired analog solid-state relay control system. With the computers operating, the plant can be run at any level of automation desired by the operator, depending on the status of equipment. Even if the computers are taken off line, the analog system by itself can operate the plant at an only slightly less sophisticated level of control.

The top level of automation is called plant coordinated control. It is the highest level of automation ever achieved in a power plant, and it assures optimum plant performance in any operating configuration selected by the operator. The computer can sequence all three generating units from hot start to full load in approximately one hour. After computer-controlled synchronization, the computer operates the plant to achieve optimum heat rate and produce the highest possible amount of power from a given amount of fuel.

If the operator prefers to synchronize the turbines manually for any reason, or if he wishes to control the loading rate of one or more of the turbines, he can choose to operate in the operator automatic control level through startup. In case of malfunction of the digital computer or its interface with the plant, he can operate in the operator analog level of control.

PACE control systems are assembled in modular control rooms at the factory, tested, and then shipped intact (Fig. 3). That approach enhances system reliability through factory assembly and testing and reduces field installation costs. In contrast, traditional plant control systems are completely dismantled for shipment; those control systems must then be completely retested at the customer's site to assure final system integrity.

Each PACE control module is approximately 40 feet long, 12 feet wide, and 10 feet 1½ inches high. Three modules are required for the standard PACE system. Quick disconnect devices are used between modules to minimize disruption of the system for shipping and to cut installation time at the site. (The quick disconnect devices also are used to connect the vans to the simulator for testing at the factory.) The modules are shipped overland by tractor trailer and installed on the user's prepared foundation. Final operational checkout of the installed system can begin just a week after arrival at the site.

Verification Facility

The new verification facility for the PACE control systems includes three Prodac 2000 computers. One of them generates and debugs new programs and also houses the plant simulator, which checks out overall performance of the control system. The other two are replicas of those in PACE control systems; they are used for initial program debugging, testing, and documentation, and they are also connected to the simulator to provide additional simulation support with high-speed parallel data links. The simulator and special auxiliary hardware were devised by the Westinghouse Tele-Computer Systems Corporation. The computers are standard machines built by the Computer and Instrumentation Division.

The PACE plant simulator is basically a computer model of a complete power plant, defined in terms of all the input and output signals as seen by the PACE control system (Fig. 4). All sequencing functions are modeled, as well as the dynamics of the plant as seen by the sensors. In other words, all sensor outputs are modeled, and actions are taken for all control-room actuating signals. Failures of sensors and actuators are also simulated.

A two-axis model of each generator is coupled to each turbine model by a representation of system torque and speed. The field circuits are coupled to the excitation system. Stators are connected to models of the circuit breakers and the power system.

Each gas turbine model includes the dynamics of the fuel valve, combustor shell pressure, gas flow, and exhaust temperature. Variables are related by families of performance curves, and torque is computed. The model of the steam turbine includes the dynamics of the control valve, steam conditions, and torque produced. Energy extracted from the steam is a function of flow and inlet steam conditions.

The heat-recovery steam generators are treated as heat exchangers. Dynamics include the effect of flow in both the primary and secondary sides. Steam conditions, temperature, and pressure dynamics are related by physical laws of continuity, heat transfer coefficients, and steam condition

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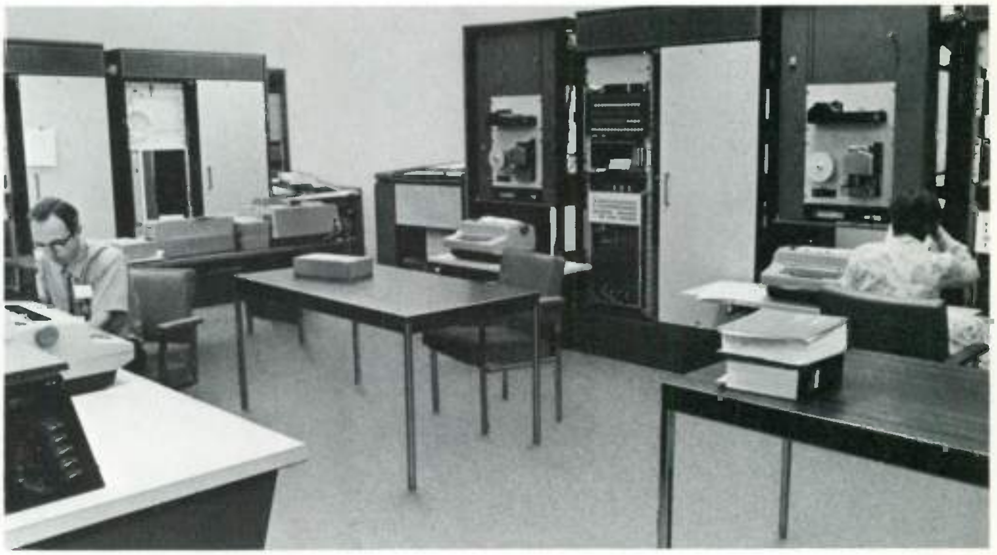
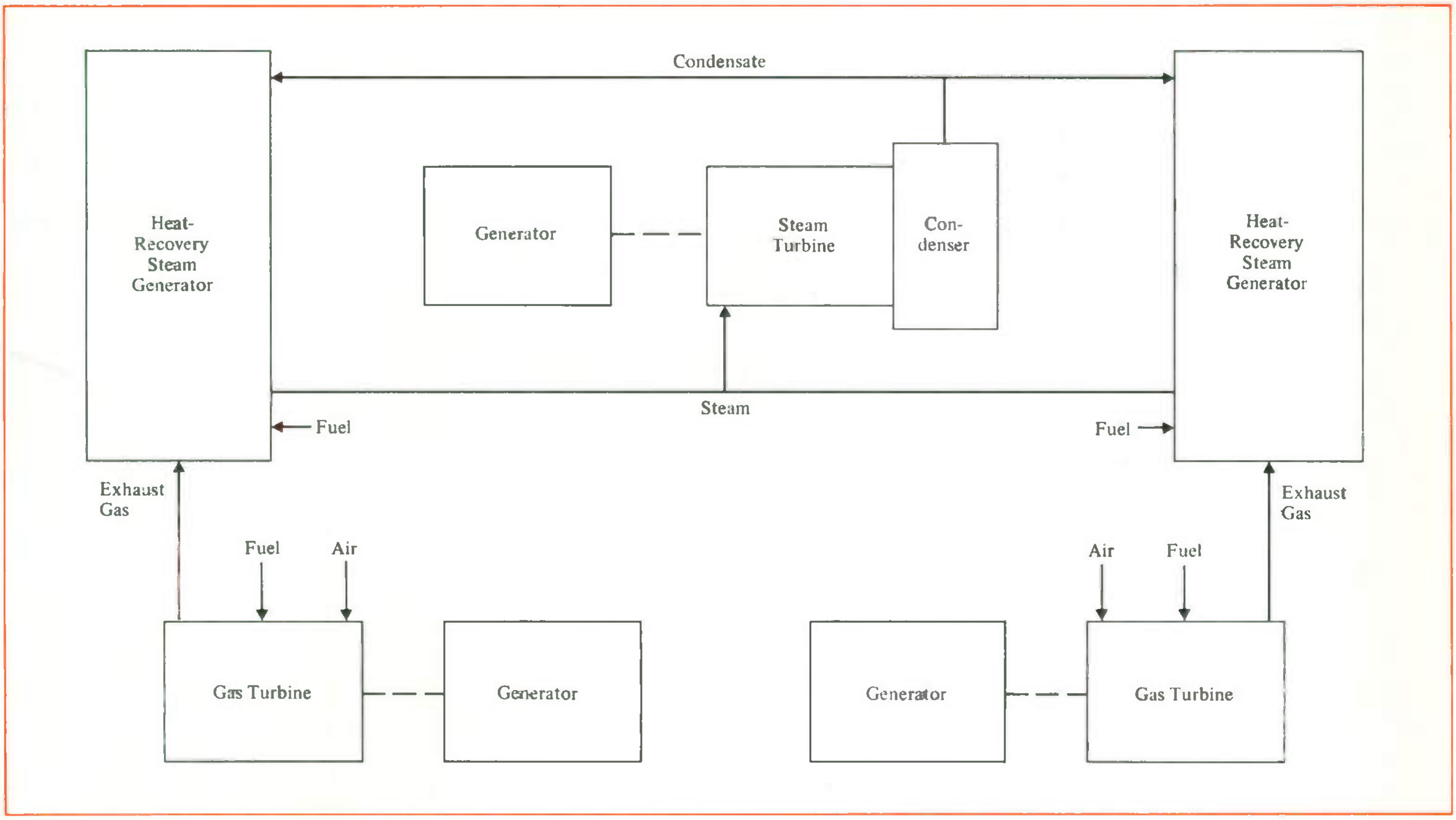


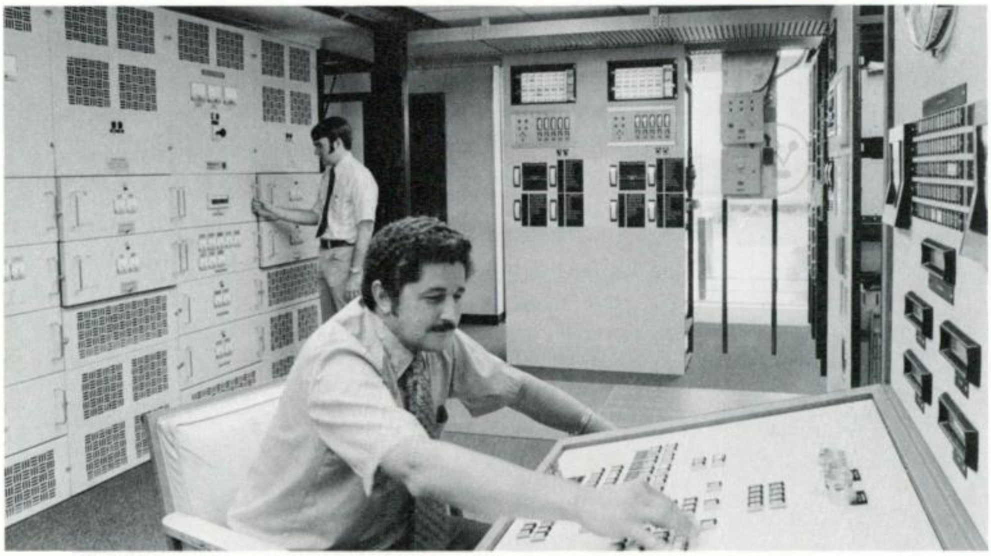


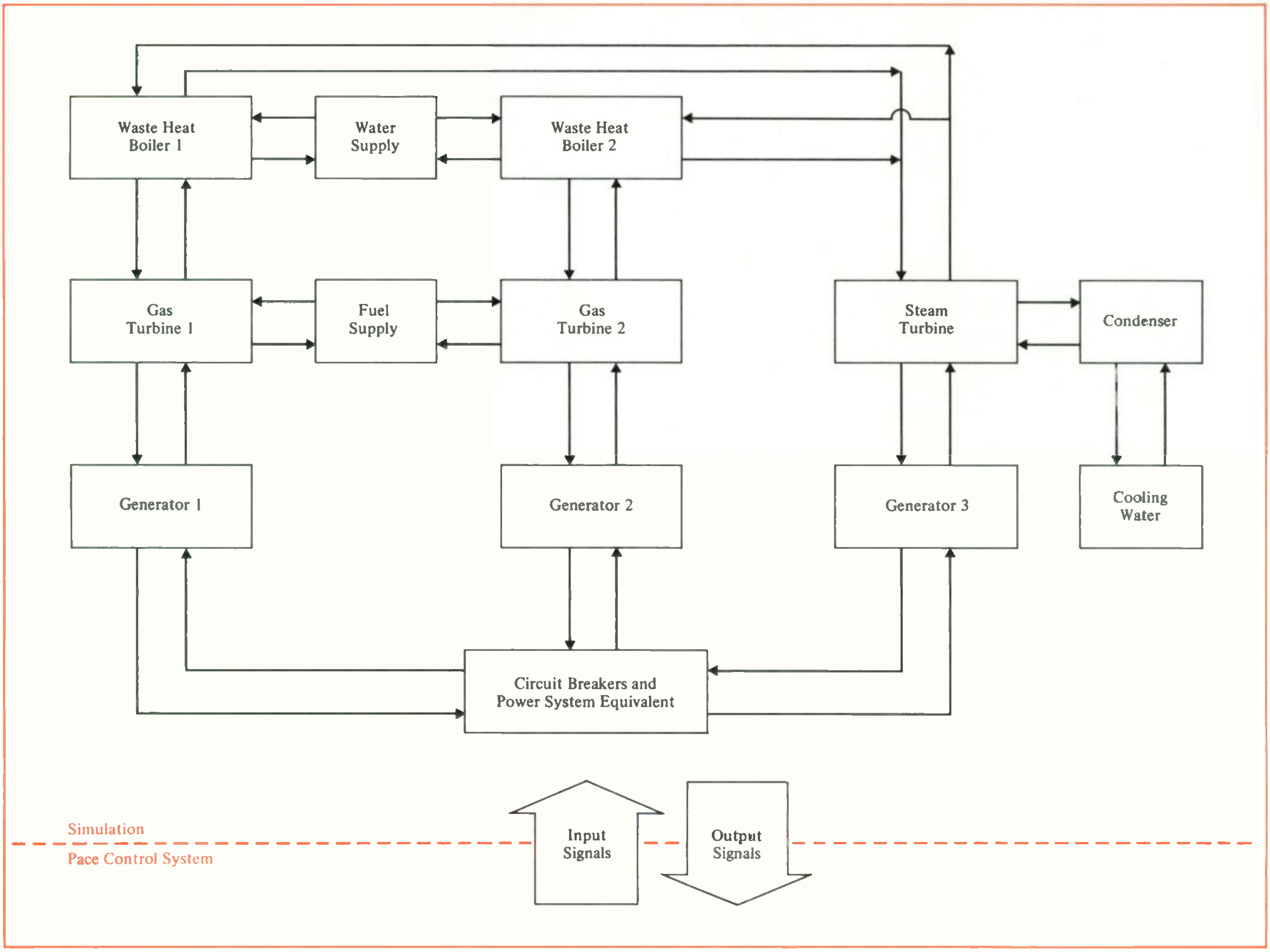
1—Verification facility includes the operator's console (top left). *The console enables an operator to start, stop, and alter a power plant simulation and to "operate" the simulated plant under various normal and abnormal conditions. The overall view* (top right) *shows, in the background, the Prodac 2000 computer that is programmed to simulate a power plant. At right in the photo are two Prodac 2000 computers that are duplicates of those used in the PACE control system; they are used for initial program debugging, testing, and documentation.*

2—This simplified schematic diagram of a PACE power plant illustrates the relationships between the two gas turbines, two steam generators that use waste heat from the gas turbines, and steam turbine. The control system for the plant includes several levels of automation.

3—(Right) *The control system for a PACE plant is assembled in a modular control room made up of transportable vans such as this one. The system is tested at the factory, and plant operators are trained there, by means of the verification facility. Then the vans are taken to the plant site without having to be disassembled.*

4—(Below) *The major elements of a PACE power plant, as illustrated in Fig. 2, are included in the computer simulation. The simulation consists of several models of various parts of the plant tied together interactively as indicated by arrows. It responds to input signals from the operator and the control system, and it puts out signals to the operator and the control system.*





curves. The thermal capacity in the metal mass is represented by a time constant, which affects heat transfer and, therefore, overall dynamics of the steam generator.

Plant auxiliaries modeled include recirculating valves, pump motors, fuel and water supplies, and the condenser loop. Water levels are represented by an integrator with limits; they are functions of inflow or outflow rates. Pumps and motors are modeled by using performance characteristic curves and equations of continuity.

Input and output signals are incorporated at appropriate points in the model, and decision tables, time delays, transport delays, and signal shaping are introduced to define the functional interfacing of the various parts of the simulator. Each part of the model thus has well defined sets of inputs and outputs and a clearly defined internal structure. Sophisticated software is supplied to run the models. This software, including a monitor and input/output handlers, is similar to that furnished with the PACE control system.

The Simulator in Use

The PACE simulator is designed for both user convenience and simulation integrity. That is, every effort has been made to make it easy to use through pushbuttons on the operator's console, but the operator cannot change the software packages of the simulator. Thus, changes made to the simulated system through predetermined allowable commands and functions cannot interfere with the basic simulation system and so invalidate the response obtained.

It is possible, however, for a knowledgeable programmer to alter any of the software by introducing changes through the programmer's console. In other words, the flexibility designed into the simulator is accessible to specific personnel, but the simulation cannot be changed accidentally by faulty operator inputs.

The operator's console allows the operator to perform the following functions: read in the software that runs the simulation; start the reading of cards through the card reader, thereby defining the state of the plant, malfunctions to be introduced, and plant operating parameters; start or stop the simulation at any point; reset the simulation to its initial state; and read in software that converts the computer to batch mode. In the batch mode, the computer is not used for control nor for any other real-time operation but as a data processing machine for such tasks as assembling or compiling programs, linking object decks, listing, and punching.

If the operator does not specify initial conditions, the model is automatically initialized to a predefined state that includes no malfunctions. When the simulation starts, the model is processed periodically on a real-time simulation basis. Once the simulation is running, the operator can, at any point, freeze time in a sense by stopping the simulation. When it is restarted, it proceeds from the point at which it was stopped unless the operator prefers to start again with the initial conditions.

Simulated System Malfunctions

An important feature of the simulator is the ease with which plant malfunctions can be introduced. Each malfunction is described on a punched card and used by the operator to check out specific alarms or control loops.

Generally, malfunctions in a plant involve sensors, actuators, or limit switches. Any of those components in the simulated plant can be caused to fail, although there is a limit to the number that can be caused to fail at any given time due to the limitation of computer memory.

Limit switches can be caused to fail in either the open or closed position. Sensors and actuators can be caused to fail at either the high or low limits set for them, or at any level of output. They may also be caused to drift from their set positions at any rate selected and in either direction. Thus, any type of plant malfunction can be simulated and the control system reaction to that malfunction can be checked.

The Simulator as a Training Device

Although the verification facility was built primarily to check out the system before shipment, it is also proving a valuable tool for training plant operators. Since Westinghouse PACE combined-cycle power plants are new to the industry (the first goes on line this summer), plant operators should be given some experience in handling the control system before they attempt to operate the actual plant. The Westinghouse verification facility has already been used to train the operators of the first plant, and continued use for that purpose is expected.

Operators for PACE plants are trained at the Computer and Instrumentation Division before the control system is shipped to the plant site. The actual control system to be installed is connected to the simulator in the verification facility, so the operators learn to use their own system. By testing plant responses to any control commands they choose to give, they learn to operate the plant without hazard to the actual equipment.

REFERENCE:
[1]P. A. Berman and F. A. Lebonette, "Combined-Cycle Plant Serves Intermediate System Loads Economically," *Westinghouse ENGINEER*, November 1970, pp. 168-73.

Opto-Acoustic Signal Processors Extend Radar and Communication System Capabilities

Milton Gottlieb

Many radar and communication applications require signals of high energy and large bandwidth generated from portable transmitters of limited peak power, such as those aboard aircraft. Such signal characteristics are commonly obtained by coding the signal to increase its time-bandwidth product (BT). *However, the extent to which the signal* BT *can be increased is limited by the* BT *processing capability of the receiver.*

Opto-acoustic processors currently being developed at the Westinghouse Research Laboratories are capable of real-time detection of signals having BT's as great as 50,000, which vastly surpasses the capability of conventional electronic processors. Possible applications for such extended capabilities include long-range high-resolution radar, secure communication systems, transmission of signals resistant to jamming, and multireceiver addressing.

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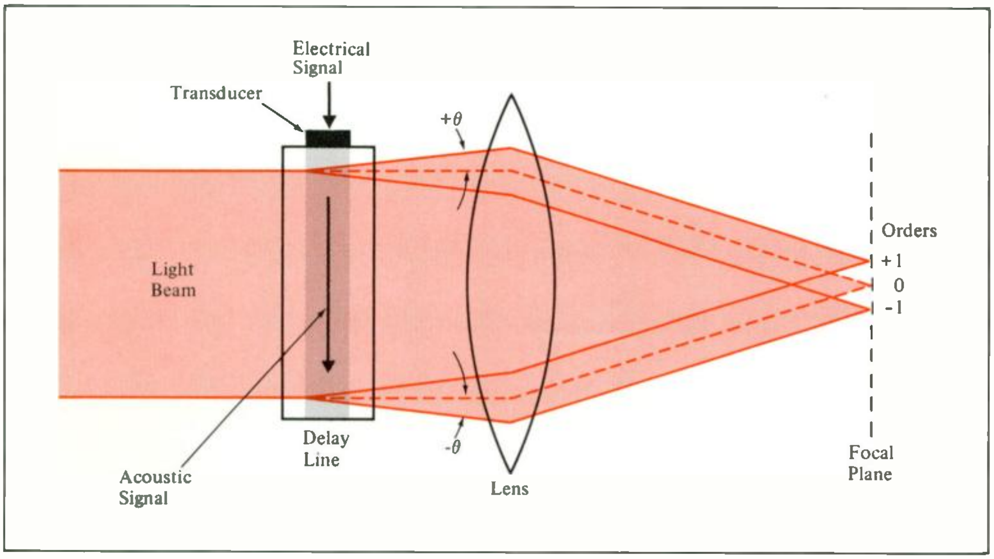
Development of the laser in the early 1960's created interest in the possibilities of optical computers, i.e., devices that use light waves to perform complex mathematical operations. Light, as a computing medium, offers two important advantages: it can process almost instantaneously both dimensions of two-dimensional information such as an image, and it has the potential of enormously large data rates, limited ultimately by its frequency.

Optical computers have evolved in a variety of forms to deal with widely different functions. One important type employs opto-acoustic information processing, which involves the interaction of light with acoustic waves in transparent materials. The technique primarily deals with one-dimensional signals and data rates up to the gigahertz range.

The basic principles of opto-acoustic processing can be briefly described as follows.[1] An electrical signal is converted by a piezoelectric transducer into an acoustic wave propagating inside a solid transparent medium called a delay line. The acoustic wave behaves much like a moving diffraction grating in that it consists of periodically alternating regions of compression and rarefaction of the medium. When a collimated beam of monochromatic light passes through this "moving grating," the beam is diffracted through angle $\pm\theta \approx \lambda/\Lambda$, where λ is the light wavelength and Λ is the acoustic wavelength (Fig. 1). In addition, the frequency of the diffracted light is "doppler shifted" by an amount equal to the acoustic frequency. These two effects cause the light to be modulated by the information contained in the acoustic signal. The modulated light is then collected and converted by a photodetector to an electrical signal, which, after amplification and filtering, is the processed output of the system.

Acoustic velocities in solid materials are on the order of 3×10^5 cm/s, which is five orders of magnitude lower than the velocity of electromagnetic radiation in free space. Thus, an electromagnetic signal occupies about 100,000 times greater distance in space than it does when converted to an acoustic signal of the same time duration in a delay line. The Westinghouse Research Laboratories have recently developed opto-acoustic delay lines that can store acoustic signals as long as 650 μs in a delay path of about 8 feet, which corresponds to about 160 miles of electromagnetic radiation in space. The acoustic path is folded in the delay lines to minimize their overall size.

The most significant aspect of opto-acoustic processing is that the delay line allows simultaneous access to all parts of the signal (parallel processing). The technique is particularly useful for processing signals that are too long for real-time processing with conventional electronic devices, which process signals bit by bit (serially). Advanced communications systems and the next generation of radar are excellent candidates for opto-acoustic processors. Under development at the Research Laboratories is an opto-acoustic signal processor that can vastly improve the range resolution (distance measuring capability) of radar systems. The work is being sponsored by the Systems Development Division of the Westinghouse Defense and Electronic Systems Center.



1—Opto-acoustic signal processing is based on modulation of a monochromatic light beam by an acoustic signal in a transparent medium called a delay line. The acoustic signal is generated from an electrical signal by a piezoelectric transducer bonded to the device. Modulation results as the acoustic signal diffracts most of the light through angle $\pm\theta$, *and the frequency of the diffracted light is shifted by an amount equal to the acoustic frequency. The frequency is either upshifted or downshifted depending on the direction of acoustic propagation. The diffraction angle,* θ, *approximately equals* λ/Λ, *where* λ *is the light wavelength and* Λ *is the acoustic signal wavelength. The diffracted first-order light (both +1 and −1 orders are shown) is separated from the undiffracted zero-order light (dashed lines) and focused by a collecting lens to a point where it can be received for further processing (see Fig. 2).*

Radar Signals and Their Processing[2]

Radar basically consists of transmitted signal pulses reflected from a target back to a receiver for processing. Appearing at the receiver display screen is a "sync" signal that marks the instant in time a pulse was transmitted, and a display of the processed return pulse. The interval between the sync signal and processed return pulse is a measure of the distance between the transmitter and target; by applying an appropriate scale factor, target range can be read directly from a calibrated grid on the screen.

Return pulses are prepared for display by a process called correlation. Essentially, the process produces an output related to the similarity between a return pulse and a stored reference pulse. Maximum output is yielded when the return pulse exactly matches the reference pulse, i.e., when the return pulse is correlated with a replica of itself—autocorrelation. The autocorrelation function is the processed return pulse that appears on the display. A valuable feature of autocorrelation is its ability to detect the return of a transmitted pulse even though that pulse may be severely masked by additive noise acquired during propagation. Signal processors based on the autocorrelation of return pulses, called correlation receivers, yield the best possible signal-to-noise ratio. (The process is described in mathematical detail in *Signal Correlation* at right on this page.)

Good range resolution depends on the autocorrelated return pulses appearing as narrow well-defined signals. The shorter the transmitted pulses, the greater their bandwidth and the narrower the autocorrelation functions. However, as the transmitted pulses are made shorter, they contain less and less energy, which decreases the range capability of the radar system. Increasing transmission pulse amplitude could restore range capability, but transmitters such as those aboard aircraft are limited in the amount of peak power they can provide. The pulse duration of the transmitted signal could be increased to gain more energy, but then the bandwidth would decrease, resulting in a broadening of the autocorrelation function.

Thus, good range resolution and long range capability depend on two seemingly incompatible features—large bandwidth and large pulse duration. Both can be obtained, however, with transmitted pulses that are long enough to provide the required high energy and are coded to restore large bandwidth. (Further discussion and examples of coding techniques are given in *Signal Coding for Improvement of Range Resolution* on page 78.)

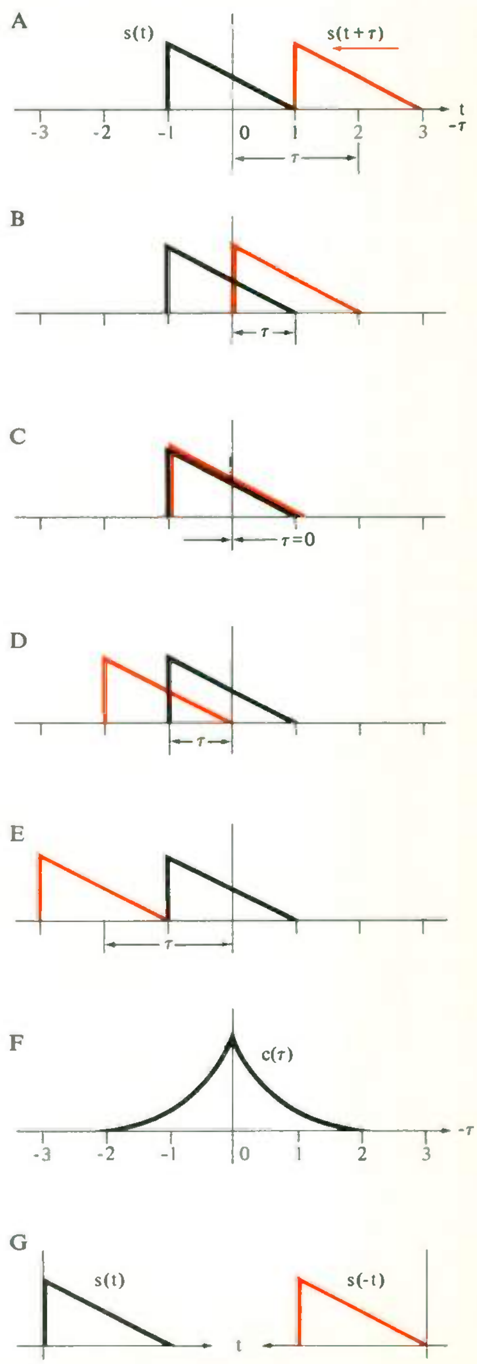
While the use of extended bandwidth signal transmission and correlation receivers chiefly concerns radar in this article, there are a number of other useful applications. For example, if it is desired to trans-

Signal Correlation

The degree of similarity between two signals, $s_1(t)$ and $s_2(t)$, can be expressed mathematically by the correlation function, which has the general formula $c(\tau)=\int s_1(t)s_2(t+\tau)dt$. Since any signal is more similar to itself than to any other signal, the greatest possible value a correlation function could assume would be when a given signal is correlated with itself—autocorrelation.

Autocorrelation of the signal $s(t)$ is illustrated graphically. In graph A, $s(t)$ (black curve) is centered about the origin, and an image of itself, $s(t+\tau)$ (shown in color), is shifted $\tau=-2$ units in time to the right; τ is the varying time interval between the signals. For each unit increase in τ, $s(t+\tau)$ slides one unit in time to the left, beginning at $\tau=-2$ in A through $\tau=+2$ in E. The autocorrelation of $s(t)$, shown as $c(\tau)$ in F, is the integration of the product $s(t)$ times $s(t+\tau)$ in the region the two signals overlap as one slides past the other. Since $s(t+\tau)$ just begins to overlap $s(t)$ in A and has just completed overlapping $s(t)$ in E, $c(\tau)$ has nonzero values only when τ is greater than -2 but less than $+2$. The autocorrelation function, $c(\tau)$, assumes its greatest value when $\tau=0$, which indicates that the two signals overlap perfectly, as in C.

Autocorrelation of $s(t)$ can be physically accomplished by processing the signal in a correlation receiver in which is stored $s(-t)$, the time-reversed replica (the reference) of the signal. The reference can either be an active signal, as indicated in G, or a static representation, such as a film transparency on which the time-reversed signal has been written. In either case, as $s(t)$ and $s(-t)$ pass each other, they are multiplied together and the product integrated by the receiver, whose output is the autocorrelation function of $s(t)$.



mit covertly, a broad-band signal can be made to resemble noise to a hostile receiver. However, at a correlation receiver equipped with appropriate signal references, all the components of the transmitted signal add up in phase and an output well above the background noise is obtained. Broad-band signal transmission has the added advantage of reduced susceptibility to jamming. The broader the signal's bandwidth, the less effective is jamming of a fixed bandwidth.

Another application of broad-band coded signals and correlation receivers is multi-receiver addressing. An orbiting satellite, for example, could continuously communicate meteorological data to land-based stations throughout the world. Each station would respond to signals containing a unique address code and would thus receive meteorological data pertinent only to a particular geographical area.

While many different coding schemes exist for conventional radar, they all suffer a common ultimate limitation. As the signal pulses are made increasingly complex to garner more bandwidth and energy, they may become so long as to make real-time conventional electronic processing impractical if not physically unrealizable. This is because the signal is operated upon sequentially as it arrives, which generally requires one channel per bit. Beyond some limiting number of bits, real-time processing becomes impossible. Although some types of processing systems avoid this limitation by recording the received pulses on tape or photographic film and then processing them in whatever time it takes, such techniques are unsuitable for real-time applications such as radar.

Opto-Acoustic Signal Processing

Real-time processing of long complex radar pulses is well suited for opto-acoustic devices, as they can handle pulse durations of up to about 1 ms as well as much shorter signals. The key to their efficiency is the replacement of all the electronic bit processing channels and related circuitry by a much simpler system based on the interaction of light and sound.

Like the conventional electronic correlation receiver, the output of an opto-acoustic correlator is the autocorrelation function of the returning signal pulses. As each returning pulse enters the correlator, it is first converted into an acoustic signal by a piezoelectric transducer at one end of a transparent delay line (Fig. 2). At the opposite end of a parallel delay line, a reference acoustic signal is simultaneously generated—the time-reversed replica of the original transmitted pulse. As the two signals approach, overlap, and pass each other in their respective delay lines, they modulate a transverse beam of collimated monochromatic light that is collected and focused onto a light-detecting diode. The

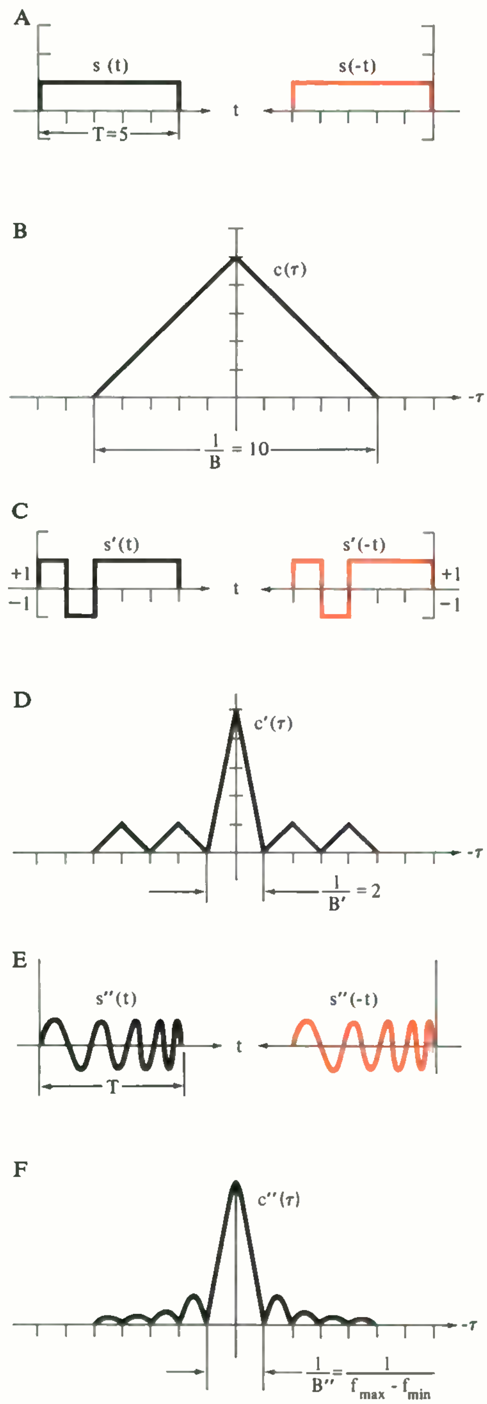
Signal Coding for Improvement of Range Resolution

The energy in a radar signal can be increased by increasing its pulse duration, but at the expense of reducing its bandwidth and thus reducing the range resolution (autocorrelation resolution) of the return pulses. The resolution can be restored by appropriately coding the signal pulses to increase their bandwidth.

A radar signal, $s(t)$ shown in A, is modulated into rectangular pulses $T=5$ units in duration with a bandwidth $B=1/(2T)=1/10$ (units)$^{-1}$. When a return pulse is processed with its time-reversed reference, $s(-t)$ shown in color, the resulting autocorrelation function, $c(\tau)$ shown in B, has a duration of $1/B=10$ units. The duration of the autocorrelation peak could be shortened and its resolution thereby improved by decreasing the signal pulse duration, T, but the signal would then contain less energy and therefore cover less range. A better technique is to maintain T but code the pulse—for example, into a 5-bit word of bit sequence +1, −1, +1, +1, +1, as shown in C.

The new autocorrelation function, $c'(\tau)$, is shown in D. While its total duration remains 10 units, the duration of its principal peak, $1/B'$, has been compressed to 2 units, or 1/5 that of $1/B$ shown in B. The reciprocal of 1/5 is the coded signal's *compression ratio*, which is given by its *time-bandwidth product*, $B'T=(1/2)(10)=5$. The compression ratio represents the factor of improvement in autocorrelation resolution gained by coding the signal pulses to increase the bandwidth from $B=1/10$ to $B'=1/2$.

Another scheme to increase signal bandwidth is frequency modulation (FM) coding. The carrier frequency within each pulse is continuously increased (or decreased) from beginning to end, as shown by $s''(t)$ in E. The bandwidth is increased from $B=1/(2T)$ to the difference between the highest and lowest frequencies, $B''=(f_{max}-f_{min})$. The effect of increased signal bandwidth by such FM coding is similar to that obtained by digital coding—the autocorrelation resolution is improved, as shown in F.



information contained in the modulated processing light corresponds to the integration of the product of the two acoustic signals. The light is converted by the diode into an electrical signal that, after suitable amplification and filtering, is displayed on an oscilloscope screen as the autocorrelation function (Fig. 3).

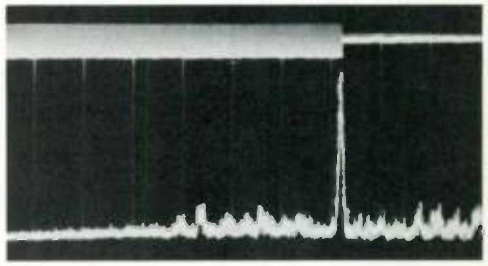
The acoustic signal generated by the return pulse need not necessarily be processed with an acoustic reference to produce its autocorrelation function. In place of the second delay line, for example, there can be a film transparency on which is written the time-reversed replica of the transmitted pulse. Autocorrelation is performed as before—the transverse processing light is modulated by the acoustic return signal sweeping past its reference signal, which in this case is the film transparency. Use of film references reduces overall system complexity.

Film references, however, are impractical whenever transmission signal coding is rapidly varied, as from pulse to pulse. The appropriate film references could not be positioned rapidly enough to be processed with corresponding acoustic return pulses. Instead, a local generator supplies electrical reference signals that are synchronized for conversion into acoustic references for processing with corresponding acoustic return pulses.

Delay Line Configurations

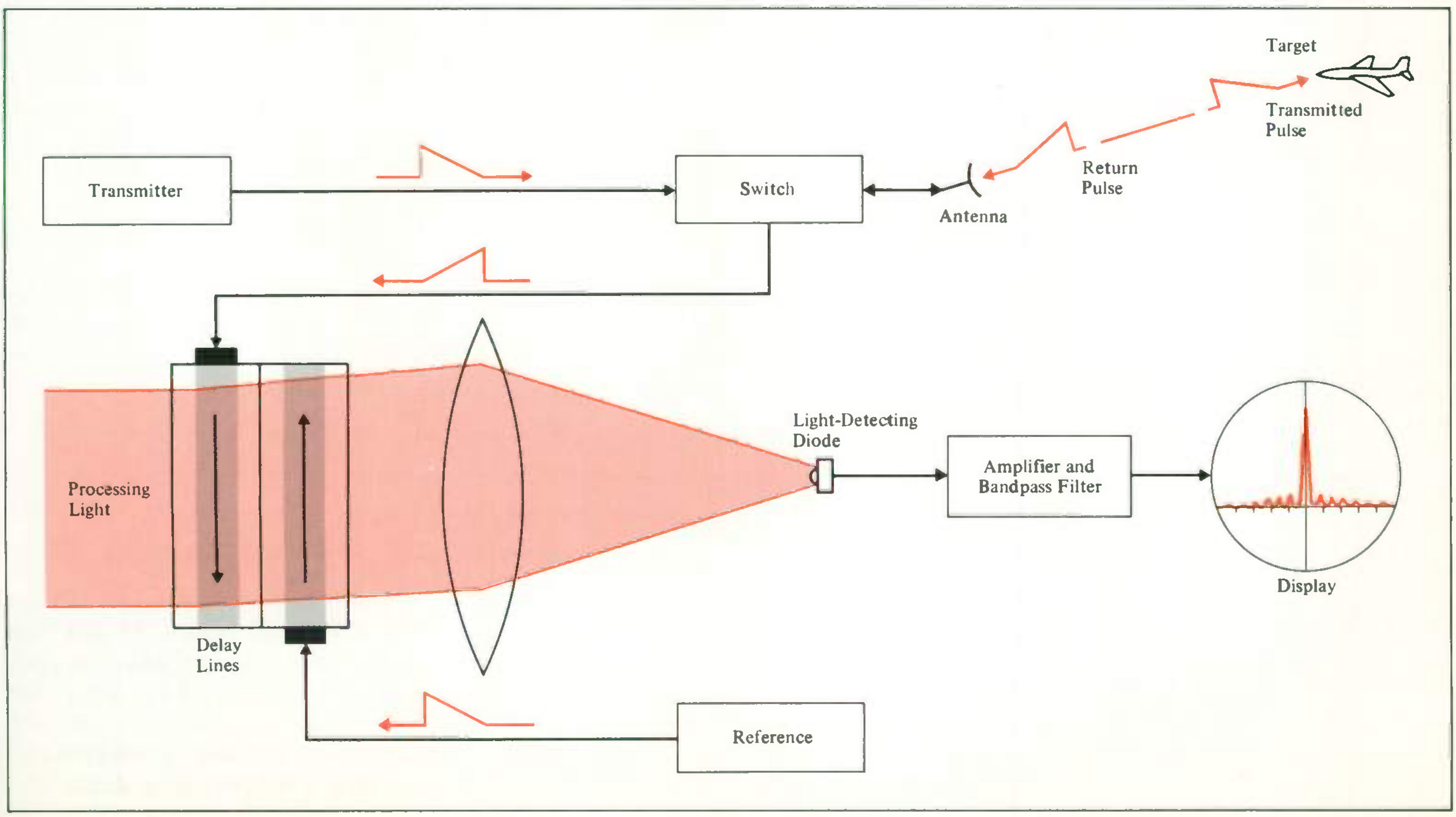
As discussed earlier, for good range and resolution, radar pulses must have large bandwidth as well as long duration. A figure of merit is the signal's time-bandwidth product, BT, which indicates the maximum number of bits of information that can be contained in a signal pulse of bandwidth B and duration T. To process a signal of a given BT, a correlation receiver must be capable of storing the pulse for time T and passing bandwidth B.

A major advantage of opto-acoustic correlators is their ability to process signals having BT's as great as 50,000 and pulse durations up to about 1 ms.[3] These upper limits are set chiefly by the acoustic properties of the delay line. It would be imprac-



3—A simulated radar pulse (top oscillograph) is shown with its opto-acoustically derived autocorrelation function. The pulse is a 30-bit digitally phase-coded signal.

2—In this simplified opto-acoustic radar processing system, a return pulse and its time-reversed reference (both shown symbolically) are converted into acoustic signals in parallel delay lines. The signals modulate the incident processing light, which is focused onto a light-detecting diode. The amplified and filtered output of the diode is displayed as the autocorrelation function of the return pulse.



tical, however, to obtain such long storage times by using straight-path delay lines in the processors, such as shown in the simplified system in Fig. 2. Straight-path delay lines would have to be several meters long, which would require components of exceptionally large optical aperture to project a collimated beam of processing light broad enough to illuminate the entire acoustic path.

The usual way of reducing the size of the optical aperture required is to increase the length of acoustic delay path illuminated by a given diameter light beam by folding the path so that the acoustic signals are reflected several times within the delay line. The rectangular delay line shown schematically in Fig. 4, for example, has its delay path folded along two orthogonal axes in a plane perpendicular to the optic axis (axis of the processing light). The acoustic return pulse and its time-reversed reference signal traverse parallel but offset paths within the structure.

Fabrication of this configuration is relatively simple since it is basically a rectangle with two 45-degree-angle edges on which the signal and reference transducers are bonded. (The material most commonly used in making delay lines is fused quartz because of its high optical uniformity and low acoustic attenuation.) A practical size delay line of this design has a storage time of about 250 μs.

While the rectangular delay line configuration in Fig. 4 enables a given diameter light beam to illuminate an acoustic path much longer than that in a straight-path line, some operational complications also arise. Since the acoustic signals propagate along two orthogonal axes inside that delay line, they diffract the processing light in two different directions. Thus, two light-detecting diodes are needed at the focal plane to receive the modulated light; their combined output represents the complete autocorrelation function.

Another complication, common to all folded-path delay lines, concerns the 180-degree phase reversals that the acoustic signals undergo upon each reflection within

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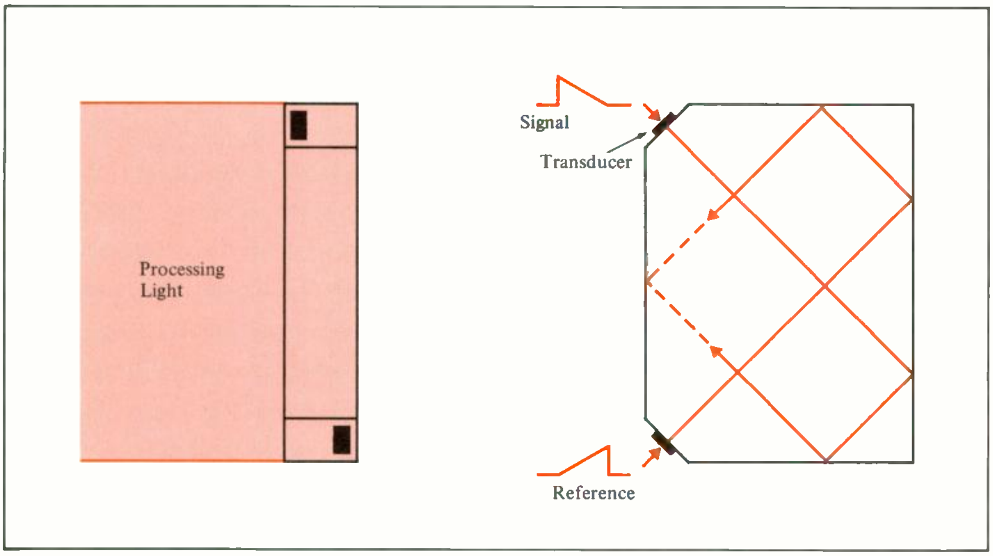

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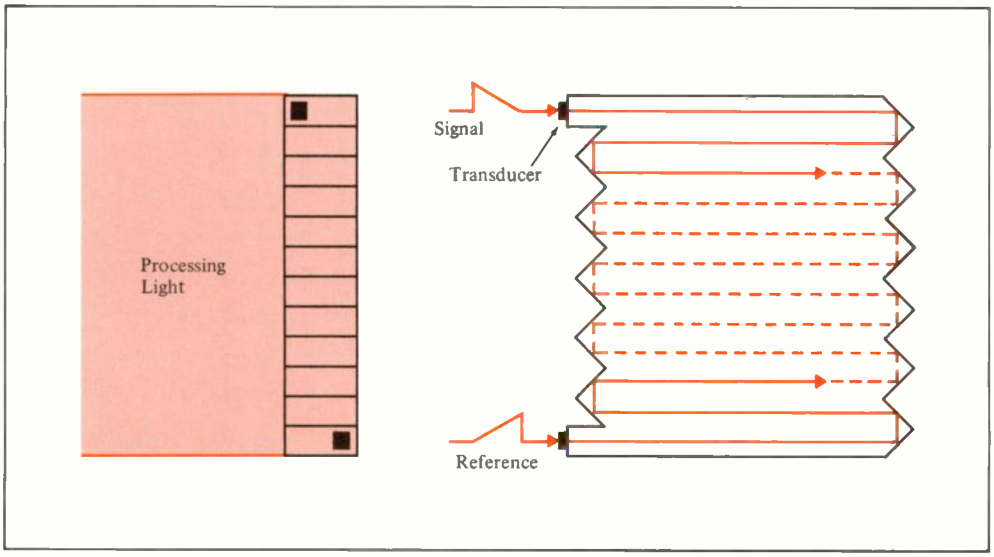

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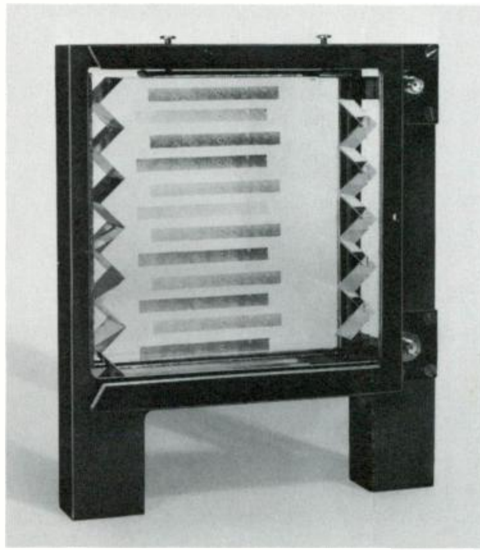


4—Two views of a rectangular delay line illustrate how internal reflection of acoustic signals increases the effective length of the acoustic path and thus increases the storage capacity of the delay line. Incident processing light illuminates the acoustic paths of a radar return signal and its reference.

5—Still greater length is provided by this 12-segment delay line. Moreover, signal and reference undergo phase reversals upon entering and leaving each corner section, so acoustic waves in the 12 major path segments are all of the same phase.

6—The 12-segment delay line can be operated with film references instead of an active acoustic reference, if desired. Film references for the 12 major signal segments are arranged on a glass plate positioned over the face of the delay line.

the structure. If left uncorrected, the modulated light collected by the diodes from the various path segments would be of two opposite phases, which could lead to intolerable output distortion, especially with digitally phase-coded signals. This condition can be corrected by phase compensating one of the diodes so that their outputs are of the same phase before being combined.

A more serious limitation of the rectangular delay line is the problem of the delay path making multiple crossings with itself, which makes it difficult to apply film references. Therefore, only active acoustic references can be practically applied with that delay line configuration.

To overcome those problems, folded-path delay lines of improved design have been developed at the Research Laboratories. They provide even greater path length for a given illuminated area than the rectangular scheme and have fewer complications and limitations. One type is shown schematically in Fig. 5. Its delay path is folded in a plane perpendicular to the optic axis, with the major portion of the path divided into 12 parallel segments. Since an acoustic signal undergoes phase reversals upon entering and leaving each corner section, the portions of signal in the 12 parallel major segments are all of the same phase. Thus, only one light-detecting diode is required at the focal plane to receive processing light modulated in those segments, which account for about 94 percent of the signal.

The relatively small portions of signal within the corner sections propagate along axes perpendicular to the 12 parallel major segments and are of opposite phase, so their modulated light is not received by the diode. That loss may not be significant, depending on the nature of the transmitted signal. If it is desirable to receive light modulated by the entire signal, the output of the diode must be combined with that of a phase-compensated diode receiving light modulated in the corner sections.

An important feature of this design is that the delay path makes no crossings with

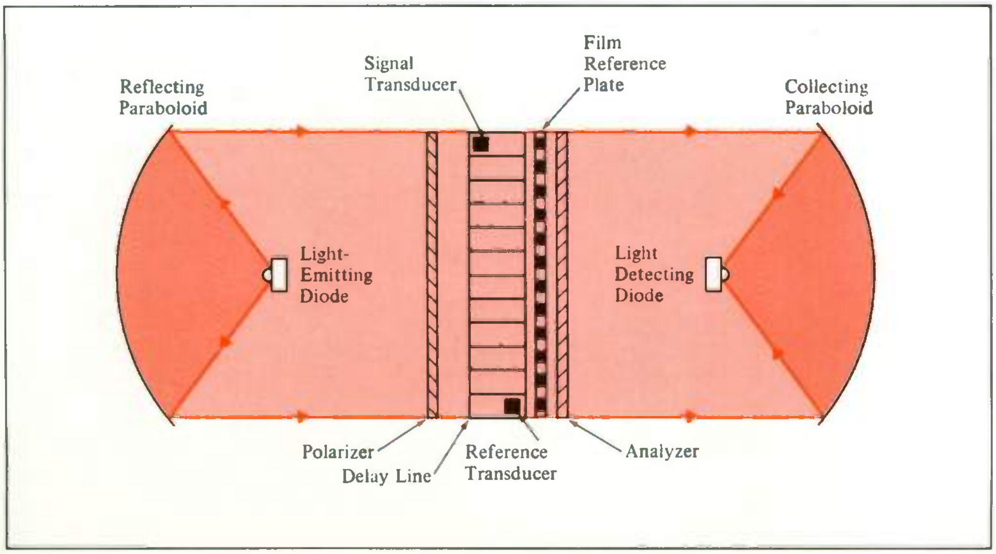
A Prototype Opto-Acoustic Correlation Receiver

The prototype unit illustrated in the photograph and diagram is suitable for actual field application as well as for demonstrating the principles of opto-acoustic signal processing in the laboratory. It is compact and rugged, has reasonably low power consumption, and can operate for long periods without maintenance or adjustment. The key element of the system is a 12-segment 350-μs delay line that operates at 30-MHz center frequency with 10-MHz bandwidth. The unit can accept either an active acoustic reference generated by a piezoelectric transducer or a film reference whose segments are arranged on a glass plate adjacent to the delay line. Processing light of sufficient optical coherence is obtained by polarizing the monochromatic beam of a 200-mW gallium arsenide light-emitting diode. The diode requires a 2-volt dc 1.5-ampere power supply.

The diode is located at the focus of a 6-inch-diameter paraboloid that collimates the emitted light (shown in color in the diagram) and reflects it through a polarizer onto the delay line. As the processing light traverses the delay line, the light is modulated by the input signal and its reference. The modulated light is collected by a matching paraboloid and focused onto the light-detecting diode. The output of that diode, after amplification and filtering, can be displayed on an oscilloscope screen as the autocorrelation function of the input signal.

In configurations where space permits, the light-detecting diode is positioned at the focal point of the diffracted first-order modulated light. However, the focal length of the collecting paraboloid is so short (only 2 inches to minimize overall size) that the focal point of first-order light cannot be adequately separated from that of zero-order light.

The required separation is achieved by polarization filtering. The polarizer orients incident processing light perpendicular to the direction of acoustic propagation. By using shear acoustic waves, the orientation of the diffracted first-order light is rotated 90 degrees with respect to the zero-order light, whose orientation remains unchanged. Another polarizer, called the analyzer, is oriented perpendicular to the first polarizer and therefore blocks the zero-order light but allows passage of the modulated first-order light onto the light-detecting diode.



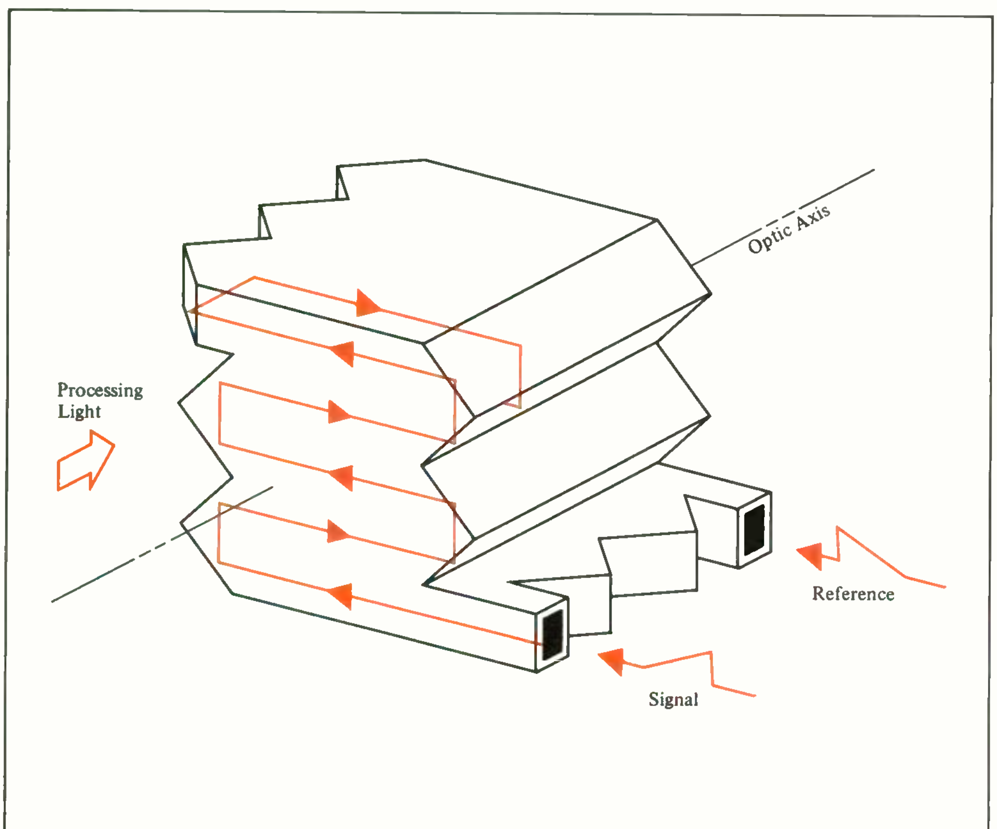
itself, which allows film references to be used easily instead of an acoustic reference if desired. The appropriate film references are arranged on a glass plate so that positioning the plate over the face of the delay line aligns each reference segment over its corresponding path segment (Fig. 6).

A prototype correlation receiver employing a 12-segment delay line is described on page 81. Its total path length is 128 cm, which corresponds to a storage time capability of 350 μs. The delay line requires a 6-inch-diameter beam for illumination. Other versions of this design have also been fabricated that have storage times of 125 and 250 μs.

A delay line scheme that enables illumination of an even greater length of delay path by a given diameter processing beam is the three-dimensionally folded configuration (Fig. 7). Five major parallel path segments are contained in each of six planes stacked perpendicular to the optic axis. All 30 major parallel path segments can be illuminated by a 4-inch-diameter processing beam. A device of this design fabricated at the Research Laboratories is shown on the back cover. Its total path length is 240 cm and its storage time is 650 μs. Delay lines based on this design can be fabricated with storage times up to about 1 ms.

It is difficult to use film references with this type of delay line because the processing light beam passes through more than one plane of delay segments. Each plane must be addressed by a single set of references without producing a cross signal (crosstalk) with references addressed to segments on adjacent planes. One technique is to use a complex optical system that projects a focused image of the appropriate reference set onto each corresponding delay plane. Crosstalk is minimal at each delay plane because reference images addressed to other planes are out of focus there.

7—Three-dimensionally folded delay lines enable a further increase in signal storage capacity. In this design, the acoustic path is folded into five major segments in each of six planes stacked perpendicularly along the optic axis (axis of the processing light). To minimize size and complexity, the signal and reference share the same acoustic path.



Addressing is simply and effectively achieved by the alternative technique that employs an active acoustic reference traversing a delay path physically coincident with the acoustic return signal. However, the problem of crosstalk between planes would remain if highly coherent processing light were used, such as that of a laser. The crosstalk is effectively suppressed by using less coherent light, such as from a high-power light-emitting diode, whose coherence length is less than the spacing between adjacent delay planes.

New delay lines of various sizes and configurations are continuously being developed and tested at the Research Laboratories. The optimum choice ultimately depends upon the processing requirements of the particular application.

Conclusion

As signal processing requirements of future generations of radar and communications systems grow beyond the capabilities of conventional devices, opto-acoustic processors may assume an important role. Much development work remains, however, to make these processors fully compatible with their intended applications and more cost effective than alternative technologies.

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Ground Fault Circuit Breaker Optimizes Protection of People and Equipment

John J. Misencik
G. B. Mason

Ground faults in electrical equipment pose a serious shock hazard because fault current can flow through a person who touches both the faulted equipment and a path to ground. A new circuit breaker maximizes protection of people by opening the circuit before fault current can reach a dangerous level; it also provides the usual protection against overload and short-circuit currents.

The traditional methods of protecting people and equipment from electrical line faults to ground have recently been supplemented by a more effective method—use of ground fault circuit interrupters. Those devices interrupt the electric circuit to the load when a fault current to ground exceeds a predetermined level that can be harmful even though it is less than the current required to operate the conventional overcurrent devices in the circuit.

The predetermined operating value depends on the purpose of the ground fault circuit interrupter, that is, whether it is to protect the system and connected equipment or to protect people. The latter type is classified by Underwriters' Laboratories as a Class A Group I device, a classification that specifies 5-mA sensitivity to ground fault currents.

A new device in that class is a combination ground-fault circuit interrupter and circuit breaker made by the Bryant Division (Fig. 1). Its dimensions and mounting arrangement are such that it is simply installed in a load center, replacing a standard 1-inch plug-on breaker. Use of the Bryant GFCB Ground Fault Circuit Breaker, as the device is called, thus gives the entire circuit three kinds of protection—protection from short circuits, protection from circuit overloads, and protection from ground faults. That last feature provides maximum protection for people against dangerous shock levels as well as protecting buildings and equipment against fires and damage that can be caused by arcs to ground. It is provided by a simple but effective sensor and hybrid circuit.

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Protection Methods

Before the advent of ground fault circuit interrupters, the main methods used for protecting people and equipment from ground faults were insulation, equipment grounding, and circuit breakers. Requirements for all of them are included in electrical codes. While all are necessary, none of them can be completely effective in all situations.

Insulation is subject to damage by impact, abrasion, environmental effects, and rodents. It can also be defeated by human error and neglect.

Equipment grounding consists of various means of connecting non-current-carrying metal parts of equipment, raceways, and other enclosures to the system's grounded conductor. It protects people from electrically "hot" enclosures by providing an alternate low-resistance electrical path to ground. It is effective if properly installed, used, and maintained, but, again, it can be defeated by human error and ignorance such as use of a two-wire plug in a three-wire receptacle. Moreover, breaks can occur unnoticed in the path to ground, or resistance can build up through such effects as corrosion at conduit joints.

Circuit breakers monitor the flow of current in circuits and open automatically on a predetermined overload current. Their purpose is to protect electrical wiring and devices from damage by overloads. However, an ordinary circuit breaker is not sensitive enough to detect small (but hazardous) ground faults. For example, a 20-ampere breaker may carry 22 amperes (at 25 degrees C) indefinitely without tripping (thus preventing nuisance trips). That 22 amperes could include a small ground fault current. Though small, it can cause fire or damage if it is arcing to ground. Even more important, it can be a lethal shock hazard if it passes through a person.

Electric Shock

The effects of electric shock on a healthy person depend mainly on current level, current duration, and the size of the person. In ascending order of seriousness, the effects include unpleasant shock sensation, inability to let go of the conductor, interference with breathing, and ventricular fibrillation (cessation of the normal rhythmic contractions of the heart muscle).[1] Fibrillation is often fatal. Even in healthy adults, milliampere currents are sufficient to cause fibrillation (Fig. 2).

To be listed by Underwriters' Laboratories, a Class A Group I ground fault circuit interrupter must meet the requirements of U. L. Standard 943, which requires the device to open its circuit on ground faults of 5 mA or higher. That sensitivity is great enough to protect human life, yet low enough to allow manufacture of the devices at reasonable prices and also to minimize unnecessary circuit interruptions. A Class A Group I device must operate at a speed determined by the equation $T=(20/I)^{1.43}$, where T is time in seconds and I is current in mA. Thus, on detection of a fault current of 250 mA for example, the device would open its circuit within 25 ms.

The National Electrical Code (NEC) requires ground fault protection for all 15- and 20-ampere outdoor residential recep-

1—Bryant GFCB circuit breaker combines the functions of an ordinary thermal-magnetic breaker and a ground fault circuit interrupter. Protection of people from dangerous levels of electric shock is the primary purpose of the ground fault circuit interruption feature.

tacles, receptacles located near outdoor and indoor swimming pools, and equipment used with storable swimming pools. It permits ground fault protection for marina receptacles and underwater lighting fixtures. After January 1, 1974, NEC will require ground fault protection for 15- and 20-ampere receptacles used on construction sites. Adherence to NEC is made mandatory by the Occupational Safety and Health Act (OSHA) of 1970.

Bryant GFCB Circuit Breaker

The GFCB breaker is the simplest and most economical ground fault circuit interrupter that meets NEC and Underwriters' Laboratories requirements. It operates in single-pole 120-volt circuits with or without a third-wire ground; however, a third-wire ground is recommended for maximum safety.

Ground fault protection permanently installed on branch circuits in the load center is more economical and convenient than the use of portable ground fault circuit interrupters that plug into electrical outlets. Moreover, decentralizing the protection by installing the devices on branch circuits in the load center is superior to use of one central device for all circuits for two reasons: first, it permits immediate identification of the circuit that has a ground fault; second, power for the entire building is not interrupted when a ground fault circuit interrupter operates or when it is tested periodically.

The economical method of adding such individual circuit protection at the load center is by use of the Bryant GFCB breaker, because it is interchangeable with existing Bryant circuit breakers and thereby saves the expense of a separate enclosure and additional wiring (Fig. 3). It is also physically interchangeable with circuit breakers made by several other major manufacturers. The device is plugged onto the stab in the load center to obtain the 120-volt power, and then it is connected to the branch circuit to be protected.

A test button provides for checking the operation of the GFCB breaker. Pressing the button electrically simulates a ground fault so that the entire device is tested—electrically and mechanically. Underwriters' Laboratories suggests that ground fault circuit interrupters be checked monthly. A test record card is included with every Bryant GFCB breaker for that purpose.

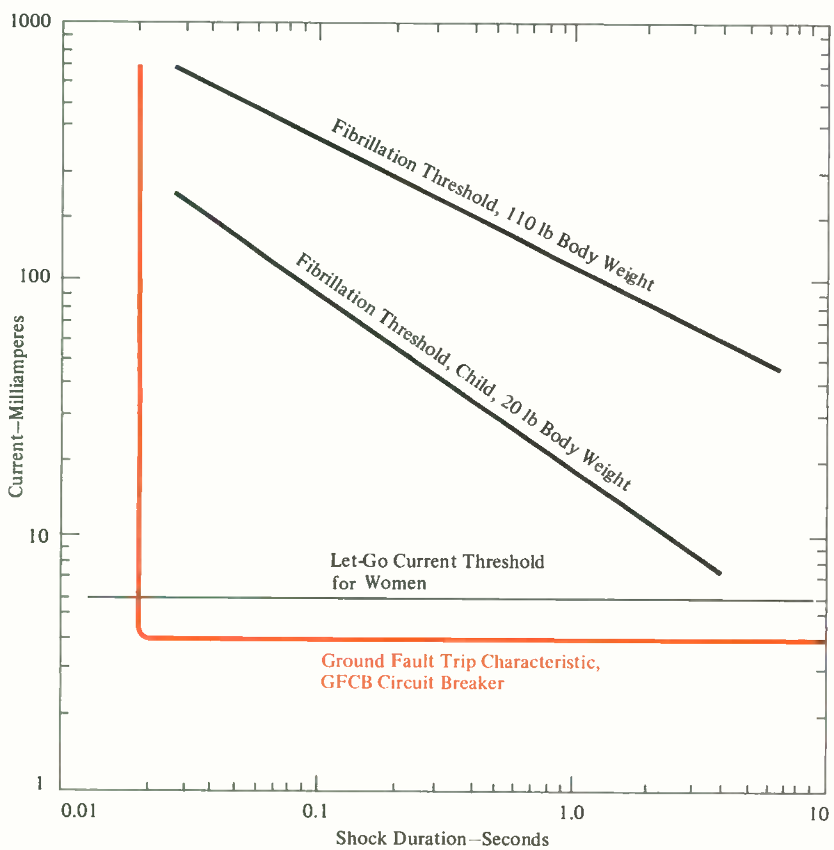
Present full-load ratings of the GFCB breaker are 15, 20, 25, and 30 amperes. The operating handles are color coded for fast and positive identification of each device's rating. Maximum interrupting capacity is 10,000 amperes, and operating temperature limits are −35 to +66 degrees C (−31 to +151 degrees F).

For industrial applications, a version of the GFCB breaker that fits panelboards and switchboards is supplied by the Low-Voltage Breaker Division. It requires no modification of existing mounting or wiring arrangements. Both bolt-on and plug-in versions are available.

Construction and Operation—The GFCB breaker has two main portions, the circuit breaker and the ground fault circuit interrupter. Those two portions are housed in separate chambers to help assure reliability by preventing any foreign matter in the breaker section from entering the electronic section. (Such foreign matter could be produced on the breaker's contacts from normal use and from the recommended monthly tests.)

The circuit breaker portion is a standard Bryant thermal-magnetic breaker. Its thermal element provides overload protection with an inverse time delay, and its magnetic element provides instantaneous short-circuit protection. The breaker has a quick-make quick-break over-center switching mechanism that cannot be held closed against short circuit current, overload current, or ground fault current.

The ground fault circuit interrupter portion consists basically of a sensor, a hybrid



2—Estimates of some effects of electric shock as functions of time are compared here with the ground fault trip characteristic of the GFCB breaker. The breaker interrupts fault current passing through a person before it reaches a dangerous level. "Let-go current" for a given person is the maximum current at which he can release a conductor by using muscles directly stimulated by that current; "fibrillation" is cessation of the rhythmic contractions of the heart.

circuit that includes an amplifier and a silicon controlled rectifier (SCR), and a solenoid mechanism to trip the breaker (Fig. 4). The sensor is a transformer core with secondary winding, commonly called a differential transformer. The load wires of the branch circuit both pass through the sensor. Normally, current flowing to the load at any instant is equal to current flowing from the load, so the magnetic fields generated by the currents in each wire cancel. The sensor detects no imbalance, and therefore no signal current is sent to the amplifier.

If a fault occurs between the "hot" load wire and ground, an alternate return path to ground appears and so the current in the hot wire exceeds that in the neutral wire. The resulting imbalance generates a voltage in the sensor's core, causing a signal current to flow to the amplifier. If the fault current exceeds 5 mA, the amplified sensor current fires the SCR to actuate the solenoid and trip the breaker. After the fault is cleared, the breaker is reset by means of its operating handle.

The hybrid circuit was developed with the help of the Westinghouse Research Laboratories, and it is the key component of the GFCB breaker. Its elements, which are formed or mounted on a durable ceramic substrate, include thick-film resistors that are cut to precise size.

The amplifier in the hybrid circuit is an integrated circuit that is internally temperature compensated and has high gain properties and low offset voltage input characteristics. It is an operational amplifier designed to be sensitive to the small signals from the sensor and yet to be insensitive to electrical noise. The SCR is a sensitive-gate device that has 400-volt withstand capability.

The hybrid circuit for every GFCB breaker is tested dynamically for 48 working hours to make sure it meets the requirements of U. L. Standard 943.

Advantages of the hybrid circuitry include the small physical size that it permits. Miniaturization makes it possible to fit the electronic portion of the GFCB device into a standard 1-inch breaker package and even to segregate the electronic and electromechanical portions within that package, as described earlier. Use of hybrid circuitry also reduces the number of connections required considerably below what would be required with discrete components, thus improving reliability.

Moreover, the technological level of hybrid thick-film circuit production is close to that of semiconductor production—the techniques are precise, well controlled, and repeatable. The ceramic substrate used is highly resistant to moisture, abuse, and dielectric currents. Conductor paths, resistor paths, and semiconductor chips are passivated, and the entire hybrid circuit is coated with a resin that conforms closely to it to make it immune to contamination.

All of those advantages enhance the reliability of the GFCB breaker. And reliability is especially important in a device intended primarily to safeguard human life.

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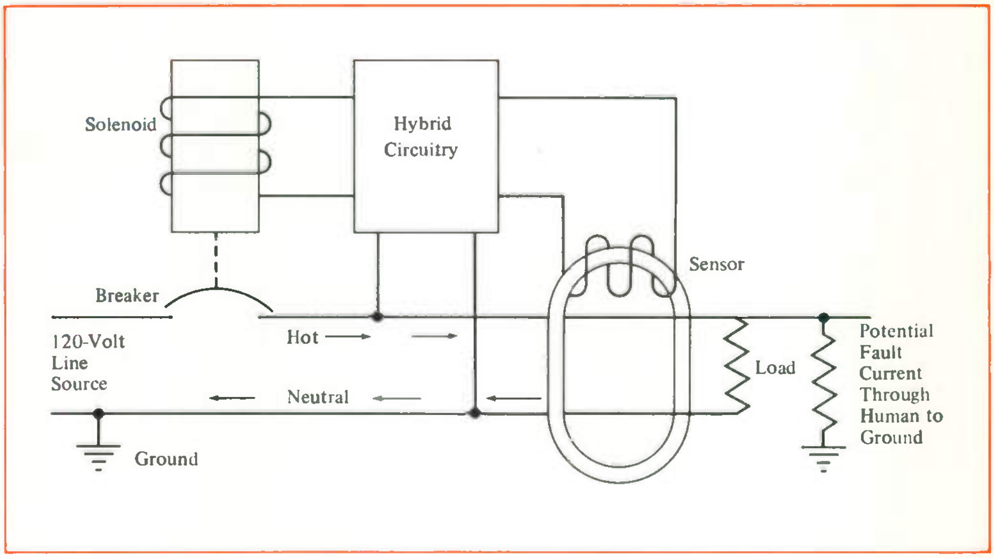
Westinghouse ENGINEER May 1973

3—The GFCB breaker is applied in place of a standard 1-inch-wide breaker in a load center, and it then provides ground fault protection for all the outlets on that circuit. It is the device on the left in this typical load center; the one on the right is an ordinary duplex breaker that protects two circuits against overload and short-circuit currents.



4—Both load wires of a circuit pass through a sensor in the GFCB breaker. If a ground fault occurs, it unbalances the current flow in the two wires; the sensor detects the imbalance and sends a signal to hybrid circuitry that amplifies the signal and uses it to trip the circuit breaker.

Wiring Devices Improved in Safety Features

Ronald J. Landisi

Better design, construction, materials, and standardization are enhancing the safety of people who use wiring devices. And that is just about everyone.

Improved wiring devices are among the important, if mundane, elements in today's growing concern for the safety of people where electrical power is used—in industrial plants, construction sites, homes, hospitals, or wherever. Since wiring devices are often the parts of an electrical system that people handle, good ones properly applied go far toward protecting people against shock and burn hazards. They also protect against fire hazard.

Wiring devices, as the term is used in this article, are devices used to control, connect, and disconnect electrical power at its point of use; examples are wall switches, receptacles, attachment plugs, and connectors. Improvements in wiring devices have been made steadily over the years, but the pace has quickened recently as a result of the general concern for safety on the part of industry and the public. That concern both stimulates, and is stimulated by, state and federal legislation regarding the manufacture of safe products and their use in safe ways.

Enactment of OSHA—the Occupational Safety and Health Act of 1970—was by far the most important legislation in the drive for product and workplace safety. The law required the immediate enforcement of recognized safety standards such as the National Electrical Code (NEC).

In the first full year of enforcement of OSHA, 29,505 industrial and commercial establishments were inspected. Some 75 percent of them were found to be in violation. The alleged violations resulted in proposed penalties totaling $2,291,147. Many of the citations were for electrical violations, and many of those could be related to use of improper wiring devices or improper use of acceptable wiring devices.

Citations for wiring device violations (as well as for other aspects of electrical equipment) derive from one or more of four basic OSHA requirements:

Grounding—Attachment plugs, connectors, receptacles, etc. for use on portable equipment (except double insulated equipment) must be of the grounding type, and the ground connection must be effective.

Rating—Attachment plugs and connectors must be rated to the size of the equipment and designed to prevent insertion of a plug into a receptacle or connector of a different rating.

Listing—Equipment and devices must be listed, labeled, accepted, or certified by Underwriters' Laboratories, Inc., Factory Mutual Engineering Corporation, or another recognized testing laboratory.

NEC Conformity—Every new electrical installation and all new utilization equipment installed after March 15, 1972, must be installed or made and maintained in accordance with the provisions of the 1971 NEC. So must every replacement, modification, repair, or rehabilitation of utilization equipment that was installed before March 15, 1972.

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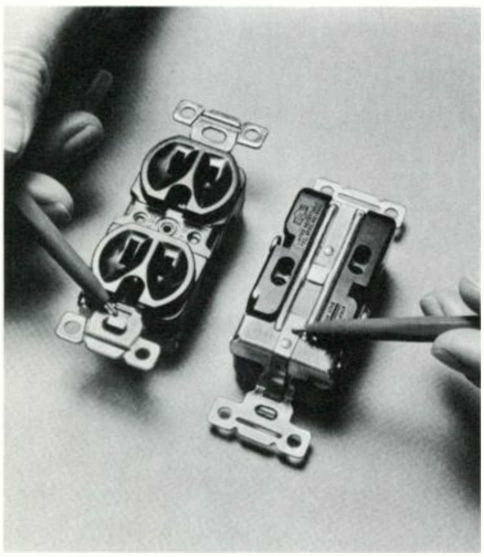
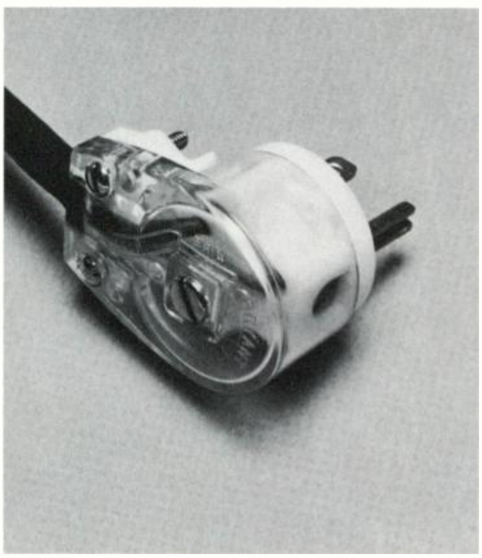
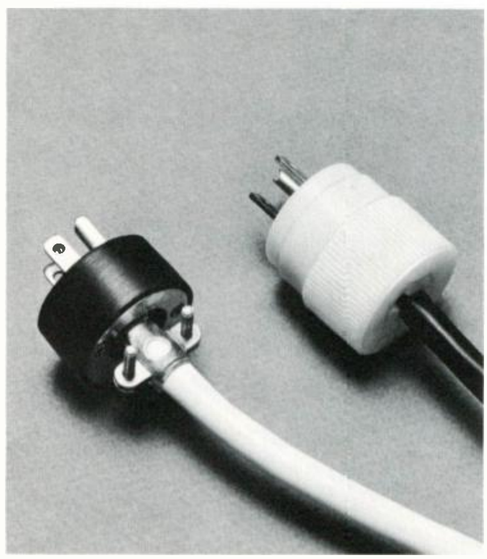


1—This receptacle is automatically grounded by a strap on the back that makes contact with the metal box when the receptacle is installed. There is no jumper to be attached to the box, or to come loose after installation.



2—Proper attachment of the grounding conductor in this three-wire plug can be verified visually because the back is transparent. Also, the right-angle cord attachment permits equipment to be placed against the plug without having to bend the cord sharply.



3—Cord grippers in the backs of plugs prevent strain on the conductors if the plugs are pulled out by the cords. The gripper in the new plug at right is made of nylon so that it will not conduct if it accidentally touches a live wire in the cord. (The plug body is also nylon.) The gripper on the old type plug is made of metal; besides the possible electrical hazard, that type takes more time to attach and has screws that can snag people's hands.

Safety Features

Wiring devices made by the Bryant Division conform to all of the OSHA requirements and go beyond the requirements in many ways. A few examples will illustrate the main areas in which design, construction, standardization, and material selection have been coordinated to produce devices that are inherently safe and give dependable service.

Grounding Design—If a user installs a grounding receptacle, but the ground circuit is not operative, he has not conformed to the requirements of OSHA. Therefore, Bryant has changed all its duplex grounding receptacles to incorporate a self-grounding feature (Fig. 1). (The Division is also in the process of incorporating self-grounding into single receptacles.) A heavy phosphor-bronze grounding strap insures that the receptacle is automatically grounded, provided, of course, that it is installed in a grounded metal box.

These grounding receptacles can be had in bright red color in addition to standard colors. Bright red is one of the means employed for identifying circuits that are energized by emergency generating equipment in the event of failure of the main power supply. A common application is in hospitals.

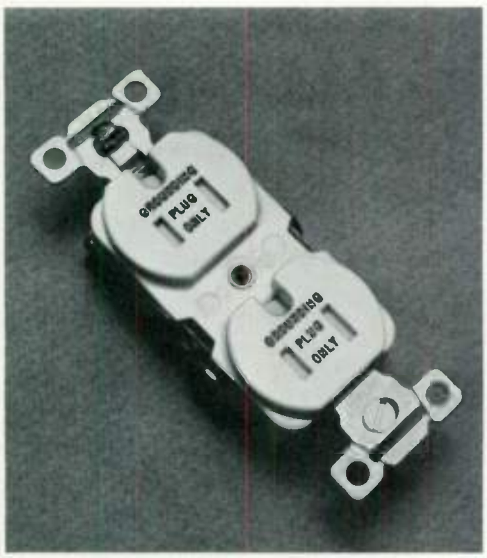
Even with a properly grounded receptacle, use of a three-wire grounding plug doesn't necessarily guarantee a ground circuit. For example, Sinai Hospital in Baltimore made a safety study of its electrical equipment that included x-raying the three-wire plugs. Almost half the plugs had open ground circuits because the ground conductor either had been broken or had never been attached to the grounding prong; neither condition could be detected by looking at the plugs. To prevent that hazard, a new type of Bryant plug features a transparent cover so the user can see that the ground conductor is securely connected (Fig. 2).

Another way Bryant prevents accidental opening of the ground circuit is by incorporating a nonmetallic cord gripper in its plugs and connectors (Fig. 3). The gripper prevents strain on the ground connection (as well as on the power connections) if someone pulls the plug out by the cord. Because the gripper is nonmetallic, it does not conduct if, through some accident, it touches a live wire in the cord.

Yet another way is by making the plug and connector housings of strong hard nylon to protect internal parts and connections from mechanical damage. Nylon construction is discussed more fully later in this article.

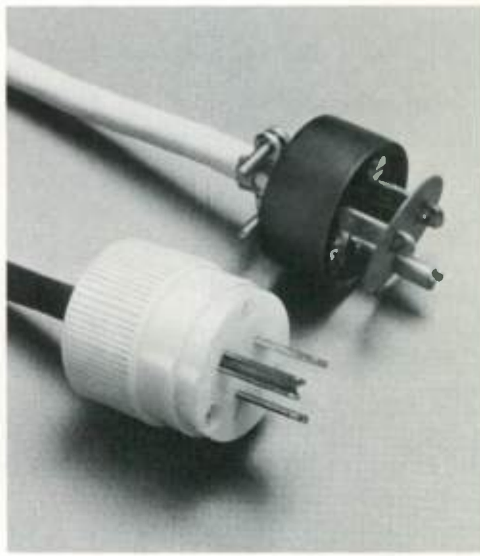
Moreover, there are special grounding receptacles and connectors that accept *only* a three-wire grounding plug (Fig. 4). As the grounding prong of the plug enters, it causes shutters to slide open to accept the power blades. A live electrical connection cannot be made until the ground connection is first established. These devices are especially useful in hospitals, nursery schools, day-care centers, and shock-hazardous areas such as construction sites and basements.

NEMA Rating Configurations—There is potential danger when wiring devices of



4—This receptacle accepts only grounding plugs. Inserting the grounding prong of a plug causes shutters to open so that the power blades can enter.

5—NEMA-configured devices include many types and ratings of plugs, connectors, and the flanged inlets and outlets that permit attachment of a power cord to electrical equipment. Devices of different ratings are physically incompatible so that a device of lower rating cannot be connected to a receptacle or connector of higher rating.



6—Dead-front construction, illustrated by the new nylon plug at left, seals off all electrical conductors. The fiber disk covering the front of the older type (right) can present an electrical hazard by coming loose or even getting lost.

different ratings are physically compatible so that a device of lower rating can be connected to a receptacle or connector of higher rating. To eliminate that danger, wiring device manufacturers, working together in NEMA, have developed standard configurations for all ratings of straight-blade and locking devices. The NEMA configurations can in no way overlap: for each, there is only one amperage and voltage. For example, a three-pole three-wire locking device in 15-ampere 125-volt rating does not fit a similar device in 20-ampere 250-volt rating. Another advantage of NEMA configurations is that they provide standard terminal identification by letter symbols and color coding.

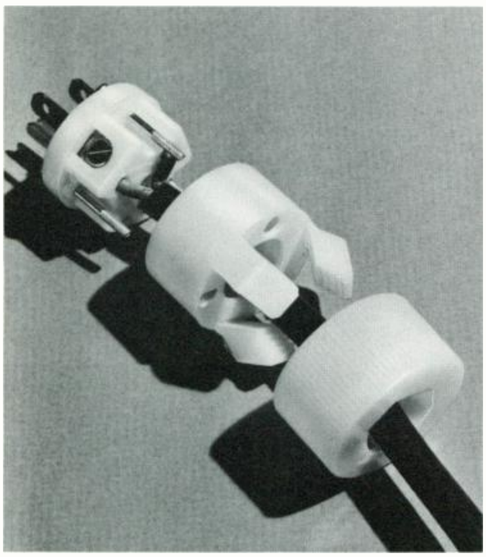
Bryant provides a wide selection of plugs, connectors, receptacles, and flanged inlets and outlets in NEMA configurations. They range from two-pole two-wire to four-pole five-wire, in both straight-blade and locking types (Fig. 5). To help users select the proper NEMA configurations, Bryant makes available a "Spec-eez" chart that gives NEMA line numbers, ratings, wiring diagrams, configuration drawings, and catalog numbers.

Other Safety Features—NEC requires that the front cover for wire terminals in plugs be mechanically secured or be an integral part of the plug. The latter, called dead-front construction, is the better choice and is used in all Bryant nylon plugs (Fig. 6). It eliminates the possibility of the common fiber disk cover coming off or allowing wire strands to protrude. It also prevents metal chips or other foreign matter from getting in because of loose or improper fit of the disk, and it prevents the conductors from contacting the metal wall plates sometimes used with receptacles. Isolated pockets are provided inside the body of the plug for each wire and its terminal (Fig. 7). This construction prevents arcing or contact between the conductors.

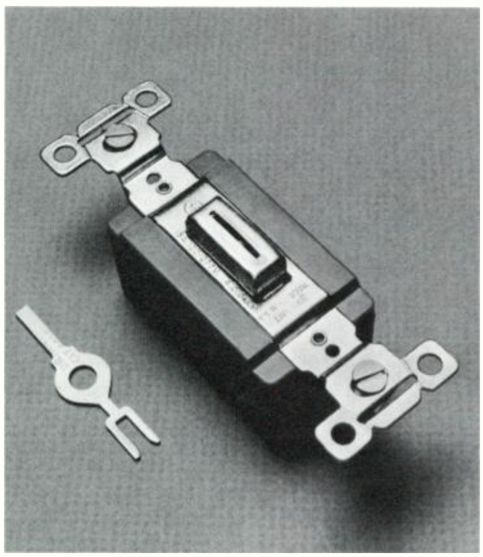
Lock switches, which are operated by a key, seem to challenge meddlers to insert such things as paper clips and pins in attempts to operate the switches. In some switches, such foreign objects can contact live conductors. The Bryant switch, however, has two internal steel rollers that prevent anything from reaching the conductors (Fig. 8).

Nylon Construction—The housings of many plugs, connectors, and flanged inlets and outlets in the Bryant line are made of nylon for maximum safety and durability. Besides being an excellent insulator, nylon is highly resistant to chemicals (Table I).

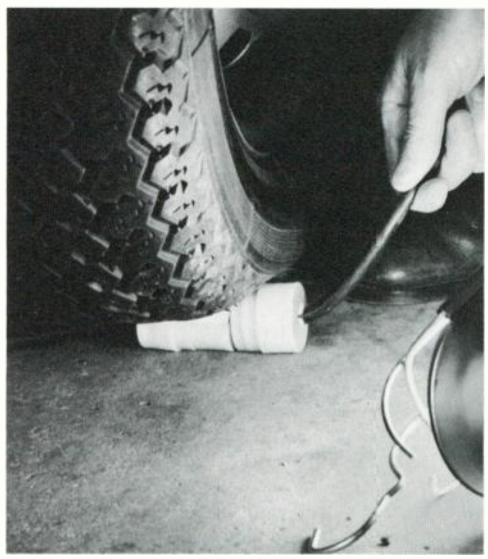
Moreover, nylon is resilient enough to resist shattering when dropped or struck, yet hard enough to retain its shape even under great pressure (Fig. 9). The latter quality is especially important where devices might be run over by lift trucks or other vehicles. When that happens, housings made of flexible material such as rubber and neoprene deform and permit internal damage that is concealed when the housing springs back into shape. In the unlikely event that a nylon device is damaged, the damage can be easily detected visually and the device replaced. Mechanical and electrical properties of nylon are compared with those of other common materials in Table II.



7—Disassembled view of the new nylon plug shows how the three conductors are isolated, each secured in its own pocket. Assembling the plug tightens the cord grip around the cord.



8—This wall switch is operated with a key to prevent unauthorized operation. Unlike some lock switches, it is so designed that such foreign objects as paper clips inserted into it cannot contact the switch's live conductors.



9—Plugs and connectors with nylon bodies are so strong that they can withstand such abuse as being run over by vehicles.

Table I—Chemical Resistance of Materials Commonly Used in Wiring Devices

Chemical	*Nylon*	*Mela-mine*	*Phenolic*	*Urea*	*Polyvinyl Chloride*	*Polycar-bonate*	*Rubber*
Acids	C	B	B	B	A	A	B
Alcohol	A	A	A	A	A	A	B
Caustic Bases	A	B	B	B	A	C	C
Gasoline	A	A	A	C	A	A	B
Grease	A	A	A	A	A	A	B
Kerosene	A	A	A	A	A	A	A
Oil	A	A	A	A	A	A	A
Solvents	A	A	A	A	C	C	C
Water	A	A	A	A	A	A	B

A—Completely resistant. Good to excellent, general use.
B—Resistant. Fair to good, limited service.
C—Slow attack. Not recommended for use.

Table II—Mechanical and Electrical Properties of Materials Commonly Used in Wiring Devices

	Nylon	*Melamine*	*Phenolic*	*Urea*	*Polyvinyl Chloride*	*Polycarbonate*
Tensile Strength (psi)	9000-12,000	7000-13,000	6500-10,000	5500-13,000	5000-9000	8000-9500
Elongation (percent)	60-300	0.6-0.9	0.4-0.8	0.5-1.0	2.0-4.0	60-100
Tensile Modulus (10^5 psi)	1.75-4.1	12-14	8-17	10-15	3.5-6	3.5
Compressive Strength (psi)	6700-12,500	25,000-45,000	22,000-36,000	25,000-45,000	8000-13,000	12,500
Flexural Strength (psi)	No break	10,000-16,000	8500-12,000	10,000-18,000	10,000-16,000	13,500
Impact Strength (ft-lb/in.)	1.0-2.0	0.24-0.35	0.24-0.60	0.25-0.40	0.4-20	12-16
Rockwell Hardness	R109-R118	M110-M125	M96-M120	M110-M120	70-90 shore	M70-R118
Continuous Temperature Resistance (°F)	180-300	210	350-360	170	150-175	250
Heat Distortion, 66 psi (°F)	360-365	*	*	*	179	285
Dielectric Strength (volts/mil)	385-470	300-400	200-400	300-400	425-1300	400
Arc Resistance (sec)	130-140	110-180	0-7	110-150	60-80	10-120
Burning Rate (in./min)	Self extinguishing	Self extinguishing	Very low	Self extinguishing	Self extinguishing	Self extinguishing

*Not applicable because these are thermosetting materials.

Besides the safety advantages, standardizing on nylon reduces inventory by eliminating the need for devices in several kinds of construction. In the past, phenolic resin was used for standard-duty devices while rubber and armored construction were used for devices subjected to rigorous use. The advent of nylon as a superior construction material enabled Bryant to standardize on that material for all applications. Standardizing has also greatly reduced the number of sizes required in the neoprene "boots" used to exclude water and other foreign material from the joints between mating wiring devices. Three boot sizes now fit all Bryant nylon devices, where formerly 27 different sizes were required.

Besides the nylon devices mentioned earlier, all Bryant flanged inlets and outlets now have nylon casings and receptacle faces. Applications include all kinds of portable and stationary electrical equipment where quick and safe disconnection of the power cord is required. The nonconductive nylon prevents accidental energizing of the casing and also absorbs impacts so well that it is virtually indestructible.

In addition to the standard white color, the nylon devices are made in high-visibility yellow for use in poorly lighted areas or where it is otherwise desirable to call attention to the presence of wiring devices. Versions of the nylon devices with special corrosion-resistance features are color coded in bright orange; they are for use in locations where corrosive vapors are present or anywhere else that corrosion could be a problem.

Conclusion

Industrial and commercial users are looking for safer versions of wiring devices, and government is also demanding that the devices be made and used with safety in mind. Bryant is supplying safe wiring devices and is continuing its development efforts to make them safer still.

Technology in Progress

AWACS Development Enters Preproduction Phase

Preproduction radar subsystems for the U. S. Air Force's Airborne Warning and Control System (AWACS) are now being designed by the Westinghouse Aerospace and Electronic Systems Division under contract to The Boeing Company. The contract also calls for building the subsystems. They will then be integrated with the other AWACS subsystems to produce three preproduction AWACS for use in a complete system demonstration and evaluation.

The radar uses the latest advances in solid-state and digital electronics, is simple and reliable, and has features for ease of maintenance. It was selected after recent demonstration flight tests, against a competing design, to evaluate detection and tracking performance.

AWACS, a high-flying long-range surveillance system, will substantially increase the effectiveness of the nation's air defense and tactical forces by detecting and tracking aircraft at all altitudes over both land and water. It can also serve in civilian emergencies such as loss of operation of conventional airport equipment by flooding or other natural disaster. In such an emergency it would provide surveillance and communications, including air traffic management, for direction of relief and rescue operations.

AWACS radar subsystem includes the antenna mounted in the structure on these test aircraft that were used to prove the engineering model.

Sodium Wear Test Rig Verifies FFTF Components

The frictional and wear behavior of materials are of special concern in sodium-cooled nuclear reactors because sodium has the ability to remove normal oxide layers and adsorbed impurities from metal surfaces. Those surface oxides and impurities frequently act as lubricants in conventional environments, so their removal, exposing clean metal surfaces, can markedly affect the friction and wear characteristics of surfaces sliding under sodium. Therefore, data on friction and wear in a sodium environment are required for design of almost every major component in the Fast Flux Test Facility (FFTF) that is now being built and in future liquid-metal fast breeder reactors.

Sodium Wear Test Rigs (SWEATERS) are providing reactor designers with the needed data for designing components and component interfaces that experience sliding or static contact. The tests conducted in the SWEATER facilities confirm or qualify bearing surface materials by determining friction coefficients, wear rates, and bearing surface load and motion capability.

Tests are run under conditions of load, motion, and surface configuration that are as typical as possible of prototype equipment. The sodium environment simulates that anticipated in the FFTF with respect to temperature, flow, purity control, and methods for measuring impurities. The SWEATERS were designed and built under contract to the USAEC, Division of Reactor Development and Technology, by the Westinghouse Advanced Reactors Division. They are in operation at the Division's Waltz Mill site in Pennsylvania.

The composition and configuration of a particular pair of interfacing components in a reactor are represented either by equivalent pin-and-plate specimens or by mock-

Top—*The sodium test chamber shown here is one of four planned for each of three SWEATER facilities. Each chamber contains about 5 pounds of sodium and each facility about 120 pounds. Operating temperatures of the sodium in the chambers can be varied from 400 to 1270 degrees F.*

Bottom—*Instrumentation for each SWEATER provides control and monitoring capability of test parameters such as specimen loads and displacements, sodium loop temperatures and flow rates, gas pressures, and the content of such impurities as oxygen, hydrogen, nitrogen, and carbon.*

up specimens of the actual surface configuration. The first type of specimens are tested inside a sodium chamber where two diametrically opposed pin specimens are mounted on horizontal rods on either side of a vertical reciprocating rod that holds mating plate specimens. Loads are applied by pneumatic cylinders connected to the horizontal rods. The motion of the vertical rod is adjusted to simulate the motion anticipated during the life of the actual component in terms of velocity, stroke amplitude, and total distance travelled. A sodium flow of up to 2.75 gal/min (velocity up to 2 ft/s) is directed past the specimen surfaces.

The plate and pin specimen rods are instrumented to provide continuous measurement of specimen temperature, frictional and static loads, and displacement. Friction coefficients are calculated as the ratio of frictional and static loads on the specimens. Wear is determined from changes in weight, length, and width of the pins and from quantitative analysis of wear scars on the plate by use of a surface profiling instrument. Additional information is obtained, with instruments such as a scanning electron microscope, on surface morphology, chemical composition, and metallurgical changes.

One example of how friction-coefficient data is applied is in determining the adequacy of sliding components in a reactor refueling machine. A component's friction coefficient can be plotted in terms of the total sliding distance over its expected life. If the plotted coefficient increases to an intolerable value, the designer can decrease the sliding travel distance required for each operation or change the material of the interfacing components.

The second type of specimens that can be tested are mock-ups of the actual reactor components. For example, frictional load and wear data were determined for the tube/tube-support assemblies of the FFTF dump heat exchangers. The data were then used as a basis for a stress analysis to confirm the adequacy of component material selection and design prior to fabrication. There had been concern that friction or self-welding between the tube and tube support plates might restrain thermally induced axial movements and result in excessive loads that could deform the tubes or tube headers. The self-weld part of the test was conducted in a separate sodium loop facility. In that loop, interface components are joined under static load for a given test period and the force required to free them is measured.

Warehouse Operations System Automates Information Processing

Computerized information and control systems have been helping large businesses for many years, and now they have been made sufficiently simple and inexpensive to be used by smaller businesses. One example is a computerized warehouse operations system developed for use by automotive parts wholesalers but applicable also to other warehousing businesses.

The system automates order processing, inventory control, purchasing, invoicing, accounting, and sales analysis, and it can be programmed to report management information at selected intervals. Use of the system has increased the productivity of warehouse work forces, increased turnover of inventory, and reduced the number of sales lost because items were not in stock.

The system was developed by the Westinghouse Tele-Computer Systems Corporation, which provides the central time-shared computers and programs required. That arrangement makes the service accessible even to relatively small businesses, since they do not have to buy a computer, develop the programs and subsystems, provide an environmentally controlled clean room, and employ, train, supervise, and pay computer personnel. The data terminals and procedures at users' locations are simple enough to be operated by their existing personnel.

When an order is received, a clerk enters it by typing in the customer's account number, requested part numbers, and quantities. All other information is stored or calculated by the system, which takes into account such factors as maximum credit allowances, inventory availability, obsolescence, and alternate and superseding num-

Warehouse operations system employs a keyboard, display monitor, and teleprinter to enable an operator to communicate with a remote computer. The new system produces shipping tickets and purchase orders, keeps track of inventory, produces accounting reports and statements, gives management operating reports, and provides a host of other information at selected intervals.

An order picker uses one of the shipping tickets produced by the system to assemble an order. The ticket tells in which zones and bins the parts will be found, and it lists them in the sequence that requires the least walking. Both photos show operations at Cleveland Ignition Company, Cleveland, Ohio.

bers. The system reserves inventory and in a few minutes prints shipping tickets at the user's location. Those tickets are used by the order picker (the person who puts the order together) and also are used as packing slips and for billing. The system also automatically prints an invoice ready for sending, produces credit memos, updates accounts receivable, and creates relevant sales statistics.

The system's inventory file is automatically updated by entry of orders and by receipts of merchandise. To maintain the best inventory level for each product, the system produces suggested purchase orders. The suggestions are based on such factors as projected sales demand, ranking of items in relation to their sales, current inventory, number of products already ordered or back ordered, economic order point, and up-to-date minimum and maximum product inventory levels.

The suggested purchase orders must be confirmed, changed, or cancelled by management, and then actual purchase orders are printed. Various status and activity reports also can be produced to aid inventory control.

All input to the user's accounting system is handled through the order-entry system with the exception of cash receipts and adjustments. Accounts receivable are updated frequently, and the system produces such outputs as a salesman account listing, salesman commission report, sales journal, and debit and credit memos.

Management reports giving information on the efficiency and activity of the warehouse also are produced by the system. They enable management to identify and correct delays and discrepancies in daily operations and to identify the nature and extent of product movement and status. Types of information that can be provided include reports on national account sales, daily operations, and sales ranking.

Gas Turbine-Generators Assembled in Specialized Facility

A standard line of gas turbine-generators is now in production in a manufacturing aisle devoted exclusively to assembly of that type of machine at the Westinghouse Large Rotating Apparatus Division in East Pittsburgh, Pennsylvania. The manufacturing arrangement permits increased specialization on the part of workmen, and production of a standard line of generators with interchangeable parts helps the Division meet production schedules.

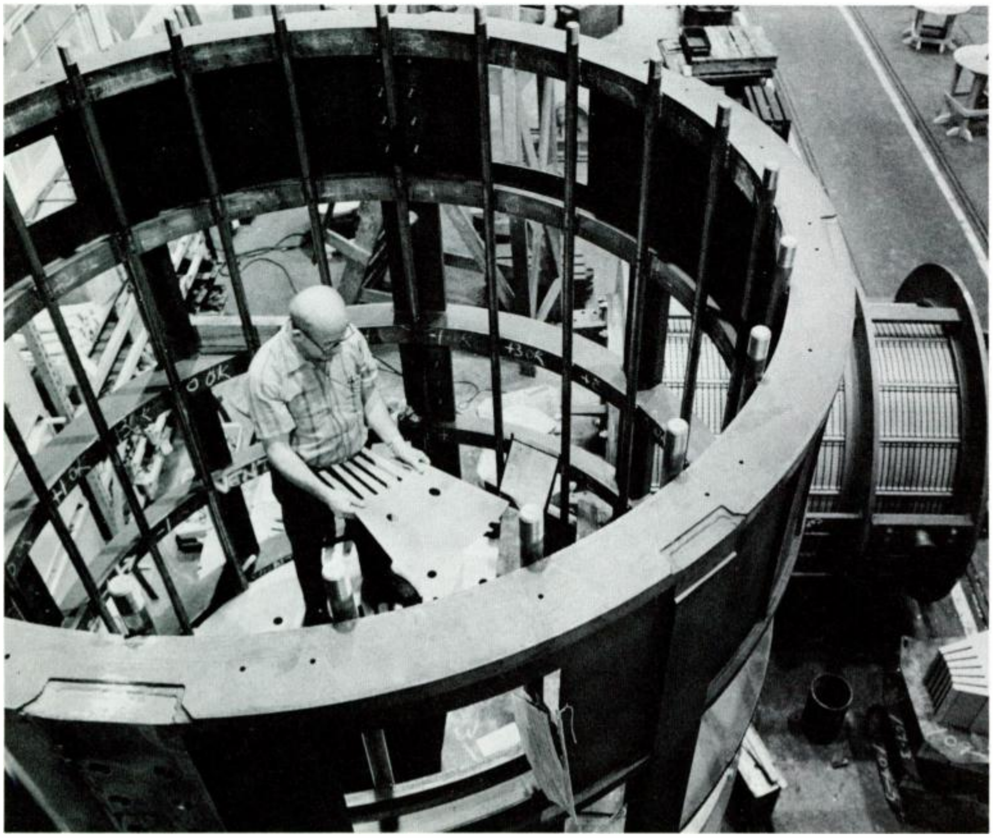
Hydrogen-cooled generators for PACE combined-cycle plants and air-cooled generators for W-251 and W-501 Econo-Pac peaking plants are being assembled in the renovated aisle. Assembled generators are mounted on skids and shipped on standard railroad cars.

The assembly aisle has five major manufacturing areas: prestaging and wiring of auxiliary generator components, outer frame and component machining, core building, winding, and final assembly. It includes a numerically controlled post mill that can machine outer frames up to 12 feet across and 36 feet long, in addition to machining smaller components such as inner frames and end boxes. An automatic core stacking facility is being installed.

Programmed "Light Sculpture" Adds to New York Skyline

Most of the programmable controllers made by the Westinghouse Industrial Systems Division operate machinery in industrial processes ranging from food processing to machining. Three of them, however, have made it big in New York show biz—putting a giant neon advertising sign through its paces.

Instead of the simple, and sometimes irritating, on-off sequence of most flashing signs, this one is programmed to be sophisticated and challenging to the viewer's imagination. The sign consists of three of the Westinghouse "circle W" trademarks, each of which has 12 controllable segments



Core laminations are being stacked here for an air-cooled generator that will go with a Westinghouse W-501AA gas turbine. Core stacking has been completed for the W-251 gas turbine-generator frame in the background.

This advertising sign has 36 lighted elements that are turned on and off by three programmed controllers. Because so many complex patterns of operation are possible, the sign adds an interesting and entertaining feature to the New York area. The Manhattan skyline forms the sign's backdrop.

for a total of 36 elements. That makes possible 36 factorial ways in which the lights can come on (36 times 35 times 34 and so on), each completing the assembly of the three trademarks. The segments are turned on and off in a series of intricate patterns that can vary from eight minutes to more than an hour without repeating.

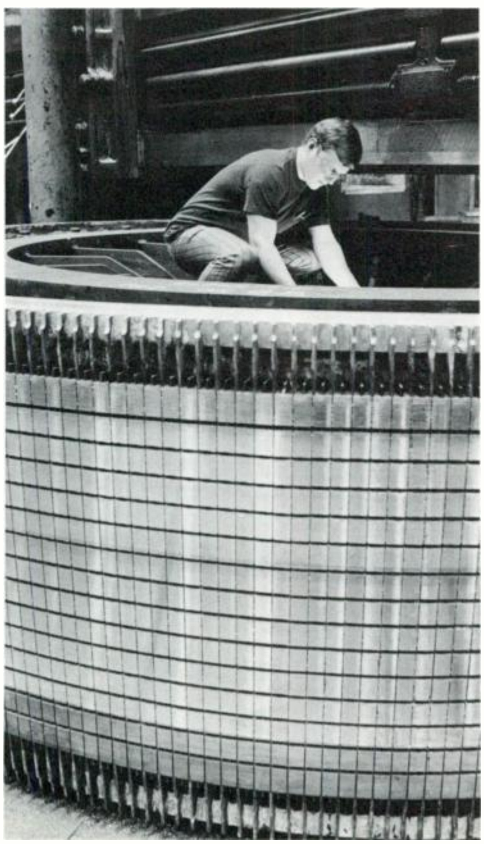
The light patterns were designed by artist John Roy, who approached the project as a form of public light sculpture that would enhance rather than detract from the New York Skyline. The sign is located in Long Island City, near the Long Island Expressway. It was built by ArtKraft Strauss Sign Corporation, and the program for it was implemented by the Industrial Systems Division's automatic manufacturing group. The Westinghouse Corporate Design Center coordinated the entire project.

The programmable controllers are solid-state units programmed to suit the particular application. For the sign, each controller operates one of the three trademarks. The program is stored in read-only memory and runs at a clock frequency of about ¼ second. The three memories each have 1024 words, 16 bits long. The first 12 bits of the word direct the sign segments to be on or off, the next three are a binary number that determines for how many clock pulses the sign is to retain its pattern, and the last bit determines if flashing is required.

A clock pulse is generated by the master controller and transmitted to the other two controllers to keep them in synchronism. The first clock pulse of the program causes the first word to be read from the memory of each of the three controllers. The word is processed by each controller, and the pattern is retained (and flashed if required) for the specified number of clock pulses. When the pattern is complete, the next word is read from memory and processed. The sequence is continued until the master unit transmits a reset pulse that causes all controllers to restart the program.

13,000-HP Motors Being Built for Diablo Canyon Nuclear Plant

Four 13,000-hp 240-r/min motors being built for Pacific Gas and Electric Company by the Westinghouse Large Rotating Apparatus Division are among the largest low-speed vertical squirrel-cage motors ever built. The motors will pump cooling water to grade level 85 feet above sea level for two 1060-MW nuclear steam-turbine generating units now under construction at Diablo Canyon (near San Luis Obispo), California. The first unit is scheduled for commercial operation in 1975 and the second in 1976.



The rotor being machined here weighs about 70,000 pounds. It is for a motor that will pump cooling water to the Diablo Canyon nuclear power plant.

Induction Heat Treating Lengthens Rail Life

Railroad rails tend to wear rapidly in tightly curved track sections where trains are frequent and freight tonnage is high (Fig. 1). The result is relatively short life—often less than a year. The trend toward increased speed and use of freight cars of higher capacity indicates that the condition could become even more severe in the future.

The reason for the wear problem is that most rails are not heat treated for extra hardness but instead are merely hot rolled from about 2350 degrees F and cooled in a controlled manner. They have a Brinell hardness of about 250 to 260.

To solve the problem, United States Steel Corporation has developed, with the Westinghouse Industrial Equipment Division, an electrical induction heat-treating system. The first line was put into operation at U. S. Steel's Gary, Indiana, plant; another was later installed there and two more at the Fairfield, Alabama, plant.

Induction heating followed by air quenching hardens both the sides and the top of the rail to a depth below that normally worn away under extended service (Fig. 2). The process produces Brinell hardness at the surface of about 360 while increasing the rail's yield strength and tensile strength more than 50 percent and 25 percent, respectively, over the controlled-cooled method. The precise heating control possible with electrical induction gives high quality and a high degree of uniformity from rail to rail, with a minimum of scaling and decarburization. To save on heating expense, the process hardens only the head of the rail.

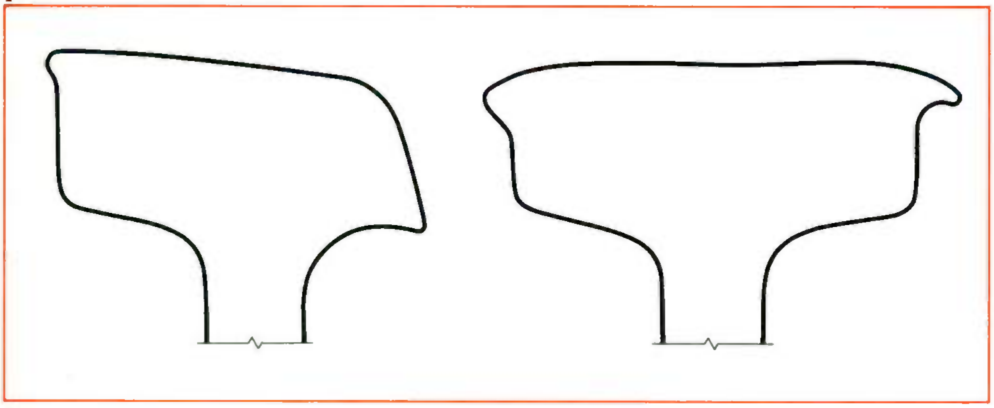
Rail life in many applications has been at least two and a half times that of regular rails at only a moderate increase in cost to the user, resulting in a substantially increased cost-to-life ratio. In one location, rail life was eight times that of regular rails.

The heat-treating process is applied to rails of standard 39-foot length, and each treating line handles two rails simultaneously. The induction-heating coils are powered by Westinghouse m-g sets rated at 350 kW, 1 kHz.

Before heating, the rails are prebent to offset stresses caused by the heat and thereby minimize the need for straightening after treatment. The rails are then heated under U-shaped induction coils to a surface temperature of about 1950 degrees F. The coils adjust automatically to maintain constant proximity to the rail surface, insuring uniform heating.

Air quenching lowers the surface temperature to 800 degrees F to produce the desired microstructure, depth, and hardness. The temperature of the air-quenched rail then climbs to about 1100 degrees, and self-tempering by residual heat occurs. Finally, a cold-water quench accelerates cooling of the rail to ambient temperature. The rails progress automatically by mechanical handling through the heating and quenching stations; the only labor required is loading and unloading, and that is done by crane.

1



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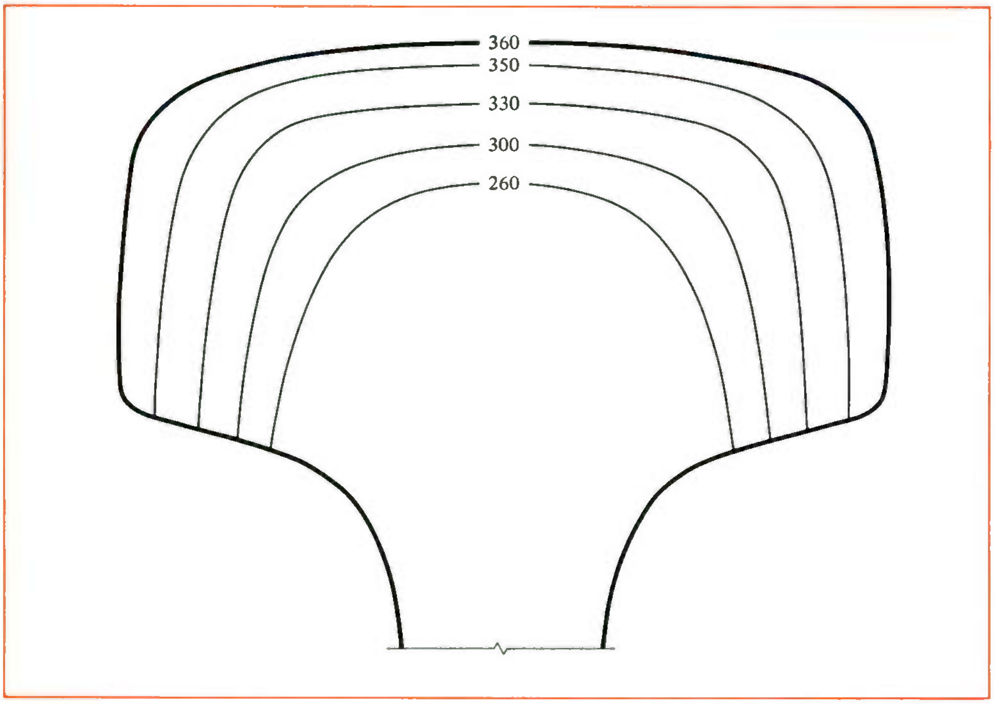


1—Typical wear on rails from a curve section of railroad track carrying frequent heavy loads shows why ordinary rails do not last long in such service. Car wheels abrade the inner corner of the high rail (left) *and "mash out" the low rail* (right).

2—Hardening the rail head by an induction heat-treating process greatly lengthens life. The numbers indicate Brinell hardness at the various depths. (In ordinary rails, hardness is only about 260 Brinell.)

Laser Drills and Welds Capsules for Reactor Tag Gases

A new use for laser technology has been developed in support of the U. S. Atomic Energy Commission's Fast Flux Test Facility (FFTF), which will be the major research site for the nation's Liquid Metal Fast Breeder Reactor Program. The task involved drilling the end caps of small stainless-steel capsules, pressurizing them with a "tag gas," and closing each capsule with a smooth weld.

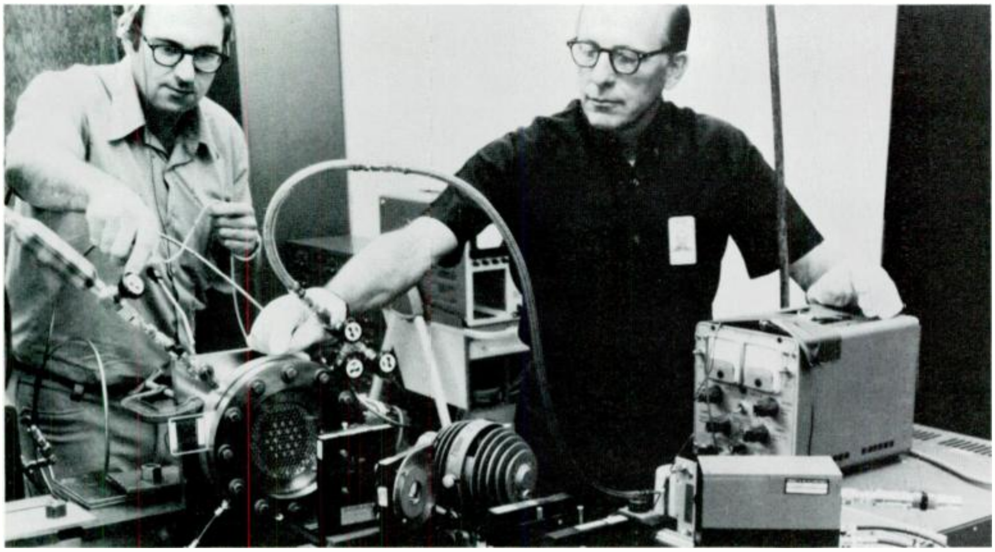
The FFTF reactor will have 73 fuel assemblies, each containing 217 fuel pins. Those pins are now being fabricated, with one of the gas capsules included inside each pin. The stainless-steel cladding of each pin is sealed, and then one end cap of the capsule is penetrated by an electromagnetically driven punch to release the tag gas into the fuel compartment. The tag gas for the capsules is a mixture, in various ratios, of xenon and krypton isotopes.

When the reactor is in operation, its cover gas will be constantly monitored. In the unlikely event of a failed fuel subassembly, the ratios of tag gas detected will permit rapid identification of the suspect fuel part. An estimated 40,000 gas capsules will be needed for the FFTF fuel program.

A neodymium-doped glass laser and a special atmospheric chamber were used in the project. The chamber held up to 500 capsules, permitting batch production of capsules containing identical mixes of tag gas. The laser was used to drill a hole (0.004-inch diameter) in the end of each capsule while the capsules were maintained under a helium pressure of half an atmosphere. The chamber was then evacuated and the appropriate isotope mixture was introduced at a pressure of two atmospheres. Finally, the holes were welded shut with the laser.

The overall process for fabricating and filling the capsules was developed by the Hanford Engineering Development Laboratory, which is operated for the Atomic Energy Commission by the Westinghouse Hanford Company. The laser drilling and welding procedures were developed by the Battelle Pacific Northwest Laboratory.

1



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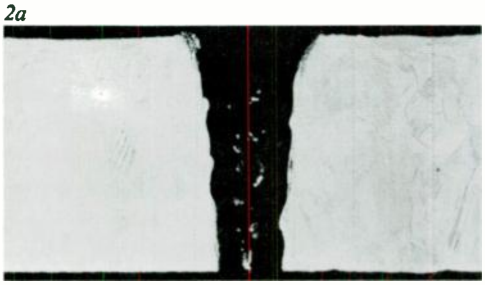

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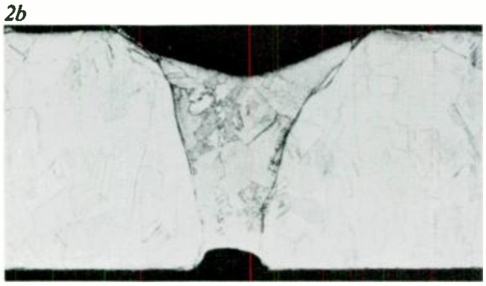


3

1—Gas capsules are held in the chamber at left and a hole is drilled through the cap of each with a laser. Then the capsules are filled with a tag gas and the holes are welded shut with the laser.

2—Typical holes (a) *and welds* (b) *are shown in section at 64 ×; the cap is about 0.020 inch thick.*

3—Each capsule measures 0.25 by 3 inches.

Environmental Management School Meets This Summer

The Fourth International School for Environmental Management will be conducted this year on the campus of Colorado State University, Fort Collins, July 15 to 28. Its purpose is to train personnel from electric utility companies, industrial companies, and governmental agencies in the technological and legal aspects of environmental management.

The curriculum will feature lectures, laboratory work, field trips, and problem solving in the general areas of site selection, environmental program planning, mathematical modeling concepts, environmental reports, and environmental regulations. Lecturers will include experts in the various technical disciplines, authorities from regulatory agencies, and environmental experts.

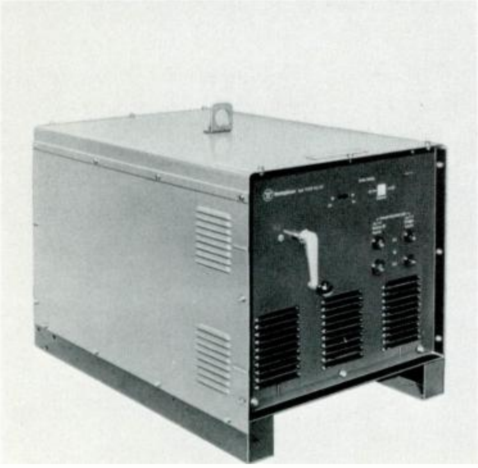
Work in the laboratories will familiarize the students with instrumentation and analysis techniques used in assessing environmental impact. The program will be divided into sessions on power plant siting, terrestrial ecology (including transmission line siting), air quality, nuclear radiation, aquatic ecology, and legal/regulatory considerations.

The school is conducted by the Environmental Systems Department, Westinghouse Power Systems, P.O. Box 355, Pittsburgh, Pennsylvania 15230 (telephone 412-256-7991 or 6279). Tuition is $2500, which includes room and board.

Products and Services

Type T920 thyristors have semiconductor elements of large diameter—2 inches (50.8 mm). The resulting high current capacities enable one of the devices to be used in place of several smaller devices, thus reducing complexity and cost of control circuitry and improving reliability. Their rms current ratings range up to 1570 amperes, and surge current ratings go to 16,000 amperes; dv/dt rating is 200 volts/microsecond. Production quantities are available with forward voltage ratings up to 2000 volts, and a 3000-volt rating is in pilot production. The devices have built-in amplification of the gate trigger current through use of the "di/namic gate" design, which simplifies or eliminates the drive circuitry used for firing and also provides fast turn-on (di/dt rating is 800 amperes/microsecond). The T920 thyristor comes in a flat ceramic package with single- or double-sided cooling. Devices are available in fully rated assemblies, including single- and three-phase full control bridges, doublers, center taps, and single- and three-phase ac switches. *Westinghouse Semiconductor Division, Youngwood, Pennsylvania 15697. (In Europe, Compagnie Westinghouse Electric, 41 Avenue George V, 75 Paris, 8e, France.)*

Type T920 Thyristors



Model TCHR Welder

Distribution substation transformer, in ratings from 750 to 5000 kVA, is designed for commercial and industrial applications outdoors, indoors, or in vaults. The rectangular coil is wound from aluminum conductor. The stacked core has legs joined to top and bottom yokes by step lapping to provide a superior flux path, and the interlocking laminations are uniformly and rigidly braced to prevent shifting during service. An externally operated tap changer provides positive-sequence line voltage changes under no-load conditions. *Small Power Transformer Division, Highway 58 West, South Boston, Virginia 24592.*

Model TCHR welder is a lightweight ac/dc transformer type made in ratings of 300, 400, and 500 amperes. Weight ranges from 500 pounds for the 300-ampere unit to 585 pounds for the 500-ampere unit. All are 23½ inches high, 23 inches wide, and 35½ inches deep, and they stack three high without frames or racks. The welder is rated at 60 percent duty cycle and operates from a 230/460-volt single-phase power supply. Features include wide single-range current control without taps, gaps, or switches; power factor correction capacitors; a rectifier assembly with a lifetime guarantee; and easy arc starting. Options include remote controls, other primary voltages, and accessory packages. *Westinghouse Industrial Equipment Division, P. O. Box 300, Sykesville, Maryland 21784.*

Computerized Lighting Cost Reduction Service for fluorescent installations gives the user substantial reduction in lamp replacement costs as well as improvements in illumination level and in the appearance of his installation. It is a logical approach to lighting maintenance through group relamping and cleaning of fixtures, ceilings, and walls at scheduled intervals. The service is designed primarily for installations that have large numbers of fluorescent lamps. It employs a computer that processes input information about a particular installation, including data on lumen maintenance, burning cycle, dirt accumulation, labor rates, and fixture types. The computer prints two curves, one of total lighting costs versus time between relampings and the other of light level versus time between relampings. The customer can then use the curves to choose the relamping interval that he prefers. *Westinghouse Fluorescent and Vapor Lamp Division, 1 Westinghouse Plaza, Bloomfield, New Jersey 07003.*

"OSHA Requirements for Wiring Devices" is a brochure that summarizes the most important requirements of the Occupational Safety and Health Act relating to electrical wiring devices. It also lists common violations of the safety requirements and tells how to correct the violations. *Westinghouse Bryant Division, Bridgeport, Connecticut 06602.*

Economics Correspondence Course teaches engineers the concepts and methods required to make an economic evaluation of alternative project proposals. Topics covered include accounting and financial terminology, financial mathematics, revenue requirements, cost of capital, depreciation, income taxes, effects of retirement characteristics on a project's lifetime costs, and economic replacement. The course employs a set of lesson guides developed by Westinghouse and the text *Profitability and Economic Choice* by P. H. Jeynes. *Systems Analysis, Westinghouse Advanced Systems Technology, 700 Braddock Avenue, East Pittsburgh, Pennsylvania 15112 (telephone 412-256-2780).*

About the Authors

Paul E. Jacobs graduated with a BS degree in electrical engineering from the University of Missouri in 1947. He joined Westinghouse in the former Motor and Gearing Division and worked on motor design until 1956, when he moved to the Industrial Systems Division. There he served as a development engineer for control systems and as a systems analyst and programmer. Along the way, he earned both an MS degree in electrical engineering and an MBA in business administration from the University of Buffalo.

Jacobs' background and his interest in systems analysis and computer applications led him to his present post in the Industrial Systems Division's Management Systems Section. Among the innovations he has contributed to are a bill-of-material and cost program that uses engineering parameters as input, a wire list program for controlling wire marking machines, and the Datadraft system described in his article. Off the job, Jacobs applies his systems expertise to growing wine grapes on his New York farm.

Joseph L. Mueller attended the University of Missouri at Rolla, graduating in 1968 with a BS degree in electrical engineering. He joined Westinghouse on the graduate student training program and went to work at the Industrial Systems Division. He is a systems analyst and programmer in the Management Systems Section, responsible for development and support of engineering programs used in the design, development, and manufacture of control equipment.

Mueller assisted in designing the Datadraft system and developing the software for its midicomputer. He had the chief responsibility for design and production of the Datadraft programs for the IBM 360 computer and for all additions and corrections to the software for the midicomputer. He also developed a program to help users prepare test instructions for the Division's automated test facility.

T. C. Giras joined Westinghouse in 1961 at the former Computer Systems Division, where he worked on the early development of noninteracting boiler control and electrohydraulic control for extraction steam turbine systems. In early 1963, he was made responsible for development of the first all digital automatic dispatching system for electric utilities. He then worked on the application of concepts developed for the small extraction steam turbines to an analog electrohydraulic package for large steam turbines, and he later extended the concepts to the development of Digital Electro-Hydraulic (DEH) control. He has basic patents in all those areas.

Giras has also been responsible for the application of similar concepts to gas turbine controls and more recently to the PACE control system. He holds degrees in electronic engineering and in electrical and instrumentation engineering. He has published extensively in the area of total energy management for electric utilities, turbine controls, and boiler control applying both analog and digital technology. He is presently Manager, Gas Turbine Controls Product Line, at the Computer and Instrumentation Division.

P. N. Papas earned his BS, MS, and PhD degrees in electrical engineering at Illinois Institute of Technology in 1955, 1957, and 1962 respectively. He also worked at IIT part of that time as a laboratory assistant, graduate teaching assistant, and instructor.

Dr. Papas came to Westinghouse in 1962 as an engineer in the former Analytical Department at East Pittsburgh. In 1967, he joined the newly formed Information Systems Laboratory, an organization that later gave birth to the Westinghouse Tele-Computer Systems Corporation. He progressed through a series of engineering and management positions in simulation and engineering services and is now Manager, Electrical Systems, in the Software and Corporate Systems Department. He is responsible for implementing software, control, and simulation for electrical systems.

Dr. Papas has written extensively, mainly on system simulation and modeling. He is a member of IEEE and is presently secretary of the Pittsburgh Section. Other IEEE responsibilities he has had include the chairmanship of the Modeling Conference in 1969 and the membership chair of IEEE's Systems Men in Cybernetics group in 1970 and 1971.

Milton Gottlieb graduated from City College of New York in 1954 with a BS degree in physics. He received his MS and PhD in physics from the University of Pennsylvania in 1956 and 1959, respectively. His early professional experience included service as a research associate at General Atomic.

Dr. Gottlieb joined Westinghouse in 1959 at the Research Laboratories to do development work on thermionic energy conversion. He is currently a Fellow Scientist in the Optical Physics Department where his responsibilities include investigating advanced techniques and applications of optical information processing and thin-film optical waveguides. Dr. Gottlieb holds five patents for contributions in his field. He has coauthored the books *Energy Does Matter*, *Seven States of Matter*, and *The Binding Force* (all published by Walker and Company, New York) and a chapter of *Physical Acoustics*, Volume VII (Academic Press, New York).

J. J. Misencik graduated from the University of Bridgeport in 1964 with a BS degree in electrical engineering. He joined the Bryant Division's engineering department, where he worked first on solid-state circuitry for such applications as light dimmers, photoelectric controls, and remote-control switching systems. He has been awarded patents in all of those areas, as well as in ground fault protection.

The latter work has occupied much of his attention for the past five years, and it resulted in developing the ground fault circuit breaker described in this issue. Misencik is presently a Senior Design Engineer in the Circuit Protective Devices Section.

G. B. Mason graduated from Stanford University with a BA degree in electrical engineering in 1935, and he went on to get his MBA degree there in 1937. He joined Columbia Steel and served in sales positions in San Francisco and Seattle. During World War II, he served in the U. S. Navy as an instructor and installation officer for harbor defense and underwater detection equipment. He holds the rank of captain in the Naval Reserve.

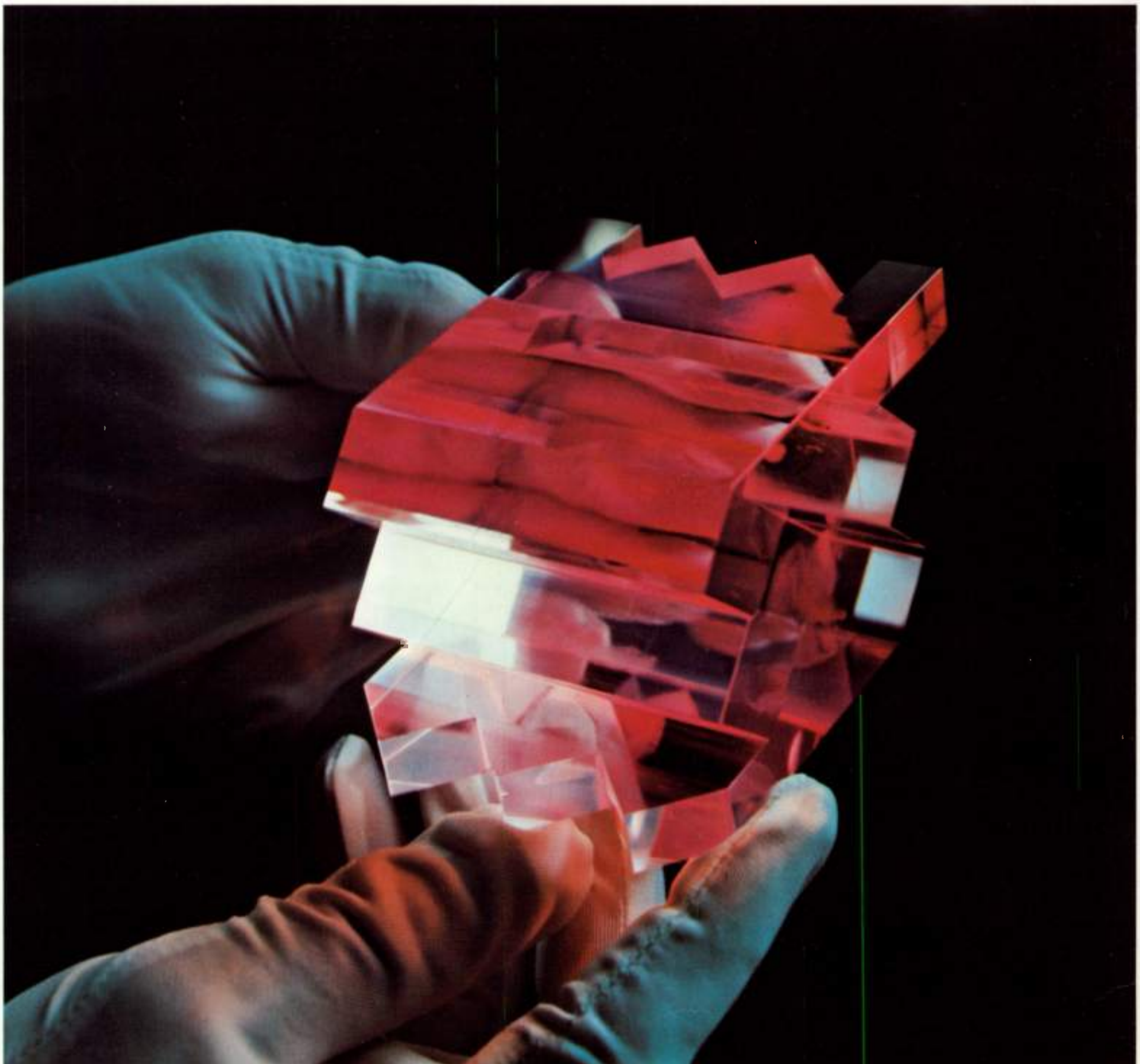
Mason joined Westinghouse in 1946 in the San Francisco sales office. He held various sales and management positions there and in the Los Angeles office. He transferred to the Bryant Division in 1965 and since then has been Product Manager, Circuit Protective Devices.

Ronald J. Landisi graduated from Fordham University in 1954 with a BS degree in marketing, and he joined Westinghouse on the graduate student training program. He then went into the Army, where he planned and scheduled training programs.

Landisi returned to Westinghouse in 1957. After marketing training, he joined the Bryant Division as a market analyst. He has progressed through a number of management positions in marketing and is now Product Manager for both wiring devices and lighting products.

Landisi has been an active spokesman for safety in the electrical industry. He has had safety articles published in trade journals and *Best's Safety Directory*, and he was guest speaker last year at 15 Safety Seminars throughout the country. He also helped organize more than 100 other seminars, reaching a total audience of more than 15,000.

Westinghouse Electric Corporation
Westinghouse Building
Gateway Center
Pittsburgh, Pennsylvania 15222



The basic element of an opto-acoustic signal processor is its delay line (see page 76). This three-dimensionally folded delay line has a signal storage time capability of 650 microseconds.