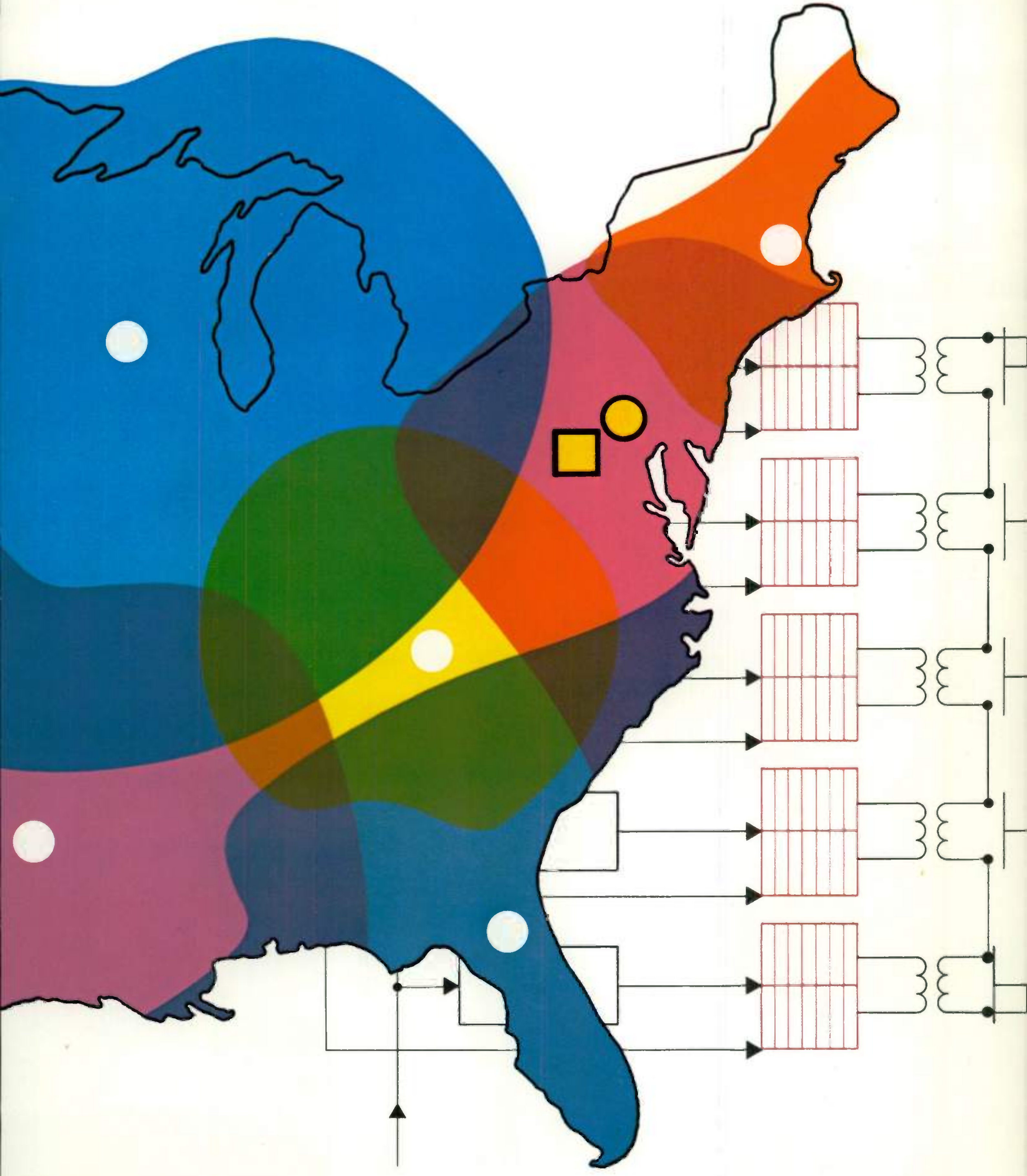
Westinghouse ENGINEER January 1975



Axial Fans Have Adjustable Blades for Efficiency at Various Air Flows

A new line of axial fans has been brought out by the Westinghouse Sturtevant Division for boilers in electric generating plants and for industrial processes. They are a joint development of that Division and the Westinghouse Product Transition Laboratory, with assistance from the Fluid Dynamics Laboratory of the Westinghouse Research Laboratories. A prototype fan has been under test at the Sturtevant Division for the past year.

The axial fans have blades whose pitch can be changed, while the fans are rotating at constant speed, to enable them to operate efficiently at various air flows. Centrifugal fans, which the Sturtevant Division also produces, are highly developed, but peak efficiency can be obtained economically with them only at one or two specified air flows; present methods of varying their air flow, such as use of dampers, variable-speed fluid drives, magnetic couplings, and turbine drives, cause energy losses that impair efficiency.

The axial fans are expected to be used primarily for boilers that furnish steam in swing-loaded electric generating plants, in which electrical output can fluctuate substantially to meet changing demands. Uses also are foreseen in some industrial applications where the flow of air or other process gas needs to be varied.

The rotor is supported by two sleeve bearings and a thrust bearing. Sleeve bearings have longer operating life than antifriction bearings in this application because there is no metal-to-metal contact, since the fan shaft rides on oil films.

Lever arms connect each blade to a hydraulically actuated piston in the fan hub. (See photograph at lower left.) When hydraulic pressure is varied, the pitch of the blades changes. The hydraulic blade adjustment is practically free of hysteresis, an important feature for stable boiler regulation. Blade position remains unchanged if the hydraulic system fails, permitting the generating unit to continue operating until it is convenient to service the fan.

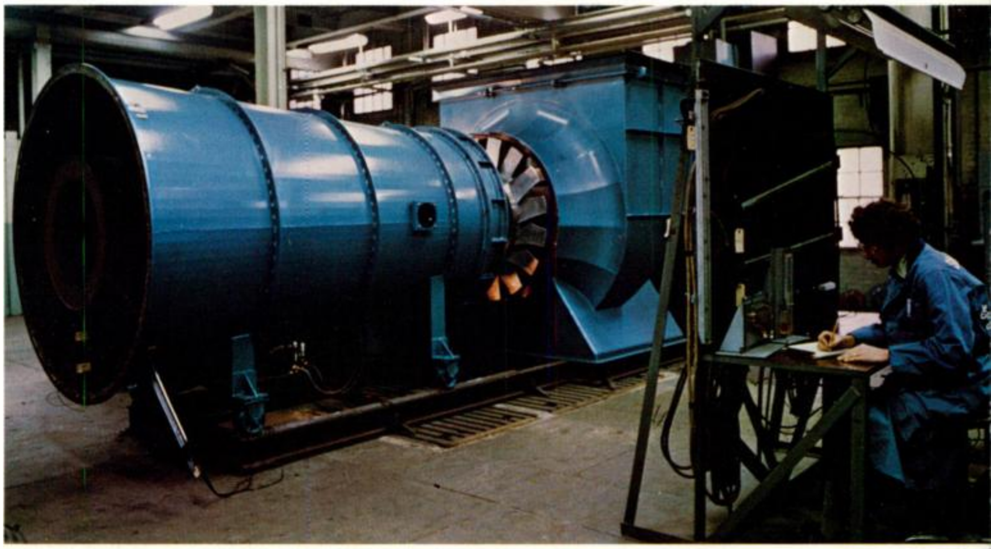
The axial fans are being made initially as single-stage forced-draft units with air-moving capacities ranging from 200,000 to 2,000,000 cubic feet per minute at gauge pressure of 30 inches of water. Rotors measure 45 to 200 inches in diameter, and the drive motors needed range from 250 to 15,000 horsepower. The Sturtevant Division expects to complete development of the product line later this year by introducing a single-stage induced-draft fan and two-stage forced- and induced-draft fans. The complete line will handle mechanical draft requirements for fossil-fuel generating units with electrical outputs up to 1200 MW and more.

The two-stage fans will have two wheels mounted in series on the same shaft and within the same casing. The required pressure rise is divided between the two wheels, so tip speeds are lower than with a single-stage fan. Two-stage fans will be applied when high pressures are needed and when low tip speeds will reduce the rate of blade erosion caused by particulates in the gas stream.

Besides the advantage of higher efficiency at changing air flows, axial fans are lighter than centrifugal fans. They generally require simpler ductwork, so erection costs are usually lower. Axial fans run at higher speed than centrifugal fans, so they use higher-speed motors that usually cost less than low-speed motors of comparable horsepower rating. Moreover, an axial fan's lower rotor inertia shortens the duration of inrush current during starting.

The axial fan also should be easier to repair and maintain. Main bearings and blades can be serviced through access openings, and all blades can be replaced within a few hours. If major overhaul of wheel parts is required, the housing can be separated to make the wheel completely accessible as shown in the photographs.

The hydraulic blade-pitch mechanism with its rotating seal has been subjected to severe life-cycle tests. Wheel stresses are being calculated by a computer program utilizing the latest analytical methods, and the program will be verified by strain-gauge tests. Critical and resonant speeds are also calculated by computer.



Westinghouse ENGINEER
January 1975
Volume 35, Number 1

Subscriptions: United States and possessions, $2.50 per year; all other countries, $3.00 per year.

Mailing address: Westinghouse ENGINEER
Westinghouse Building, Gateway Center
Pittsburgh, Pennsylvania 15222.

Published quarterly (January, April, July, October) by the Westinghouse Electric Corporation, Pittsburgh, Pennsylvania. Printed in the United States. Reproductions of the magazine by years are available on positive microfilm from University Microfilms, Inc., 300 North Zeeb Road, Ann Arbor, Michigan 48106.

Front Cover: Recent developments in technology have made possible an automated radio transmitting facility for the Decision Information Distribution System (DIDS). The developments include a reliable minicomputer to provide control, monitoring, and alarm functions and a solid-state low-frequency transmitter. A portion of the DIDS network that includes the prototype installation discussed in this issue and a symbolic representation of the solid-state transmitter were used by artist Tom Ruddy for this month's cover design.

An Automated Transmitting Facility for a National Warning Network

Nelson B. Tharp

An automated high-power low-frequency radio transmitting facility for the Decision Information Distribution System has been developed under sponsorship of the Defense Civil Preparedness Agency. All-solid-state modular design of the transmitter provides the required reliability for unattended computer-controlled operation in this crucial warning system. The facility is probably the first such high-power communication installation to be implemented for unattended operation, and its economic advantages promise to make such installations an accepted practice in the near future.

The purpose of the Decision Information Distribution System (DIDS) is to warn federal, military, and civilian authorities, state officials, and the civilian population of natural disasters or other extreme emergencies. The system was designed by the Defense Civil Preparedness Agency of the U.S. Department of Defense to augment and improve the present system on which the nation now depends for warning of enemy attack. It will provide a much more versatile communications network for disseminating all forms of emergency information.

When completed, DIDS will have ten regional transmit facilities to provide coverage to the 48 contiguous states (Fig. 1). Additional coverage to Hawaii and Alaska is planned for the future.

Warning information will be inserted into the DIDS transmitting network from one of three alternate National Warning Centers located in Colorado, Texas, and near Washington, D.C. The warning signal from a National Warning Center is carried by Autovon and private dedicated lines to the regional transmitters, where it is rebroadcast on low-frequency radio. Low frequency (163 to 197 kHz) was chosen for the DIDS network because the groundwave type of propagation in that frequency range provides very consistent signals over a large area and is relatively unaffected by time of day or ionospheric disturbances, both of which degrade radio broadcast signals of higher frequency.

Construction on the first element of the DIDS network began in the spring of 1972. This prototype installation, now completed, consists of a control equipment at the National Warning Center at Olney, Maryland (near Washington, D.C.), and a regional transmit facility near Edgewood, Maryland (Fig. 2).

Acceptance tests for both the control and transmit facilities have recently been completed successfully. The entire system could be completed by 1978.

The prototype system was designed and built by the Command and Control Division, Westinghouse Electric Corporation.

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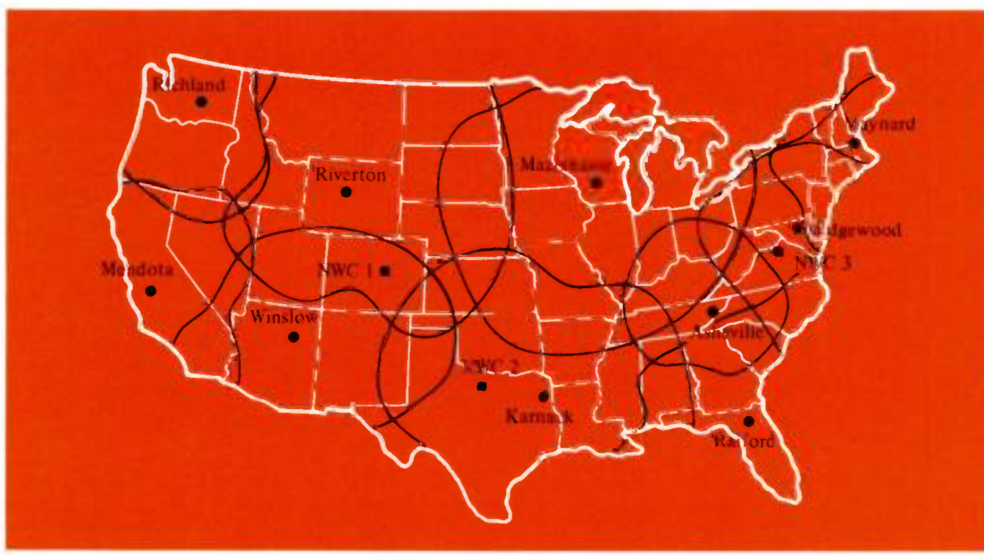


1—(Above) *The DIDS network will cover the contiguous United States with ten regional transmit facilities, identified here by black dots. The regional transmit facilities will use ten frequencies ranging from 163 to 197 kHz. They will be controlled from three National Warning Centers, identified by black squares.*

2—(Left) *This prototype regional transmit facility is located near Edgewood, Maryland. Its equipment building is semiburied to protect it from overpressure and other environmental disturbances.*

3—(Right) *Major components and functions of the prototype regional transmit facility are illustrated by this functional diagram.*

Regional Transmit Facility

The regional transmit facilities will be constructed to survive very severe environmental conditions, as demonstrated by the prototype regional transmit facility at Edgewood (Fig. 3). The equipment building is partially below ground and constructed of heavily reinforced concrete to withstand overpressure, tornado-level winds, and severe air and ground shocks. The heavily guyed antenna tower, the strongest of its type in the northern hemisphere, is designed to survive 150-knot winds even when covered with a heavy layer of ice.

The wire lines for carrying command and message signals from the National Warning Centers will eventually be paralleled with VLF radio links to increase reliability. Wire lines also connect the transmit facility to monitoring equipment at a remote maintenance center and to alarm indicators at area police and fire stations.

The facility is capable of operating without personnel or any outside resources for two weeks. The only outside inputs required are the command and message signals from one of the National Warning Centers.

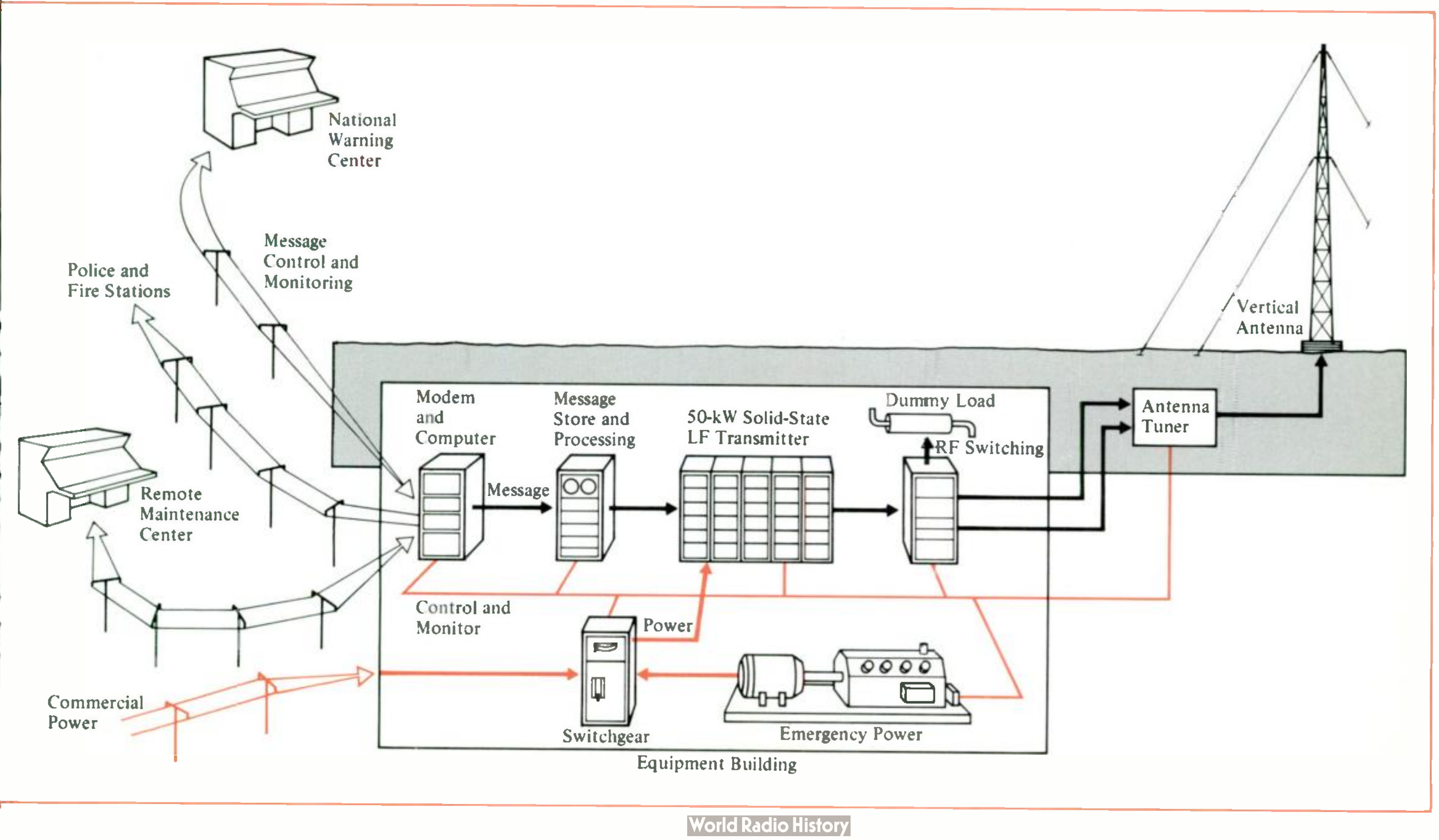
Remote monitoring allows maintenance and engineering service to the facility to be done by a central maintenance group that can also service other government communications systems in the area. This provides for maximum use of the regional maintenance resources.

The amplitude-modulated transmitter provides 55 kW to a vertical 700-foot top-loaded antenna. Dual transmission lines run between the transmitter and the antenna tuner at the base of the antenna tower. The low-frequency transmitter provides highly reliable transmission to voice, teletype, and siren-activation receivers over a 400-mile radius from the regional transmit facility.

The facility normally operates on commercial power but is switched to an internal emergency engine-generator, which is automatically started if commercial power is lost or whenever a general alert transmission is made. This procedure is followed to assure transmitter power in the event of commercial power failure, which could occur during catastrophic environmental situations. The control equipment and transmitter installed at the Edgewood prototype site are shown in Fig. 4. The shock-mounted emergency engine-generator sets are shown in Fig. 5.

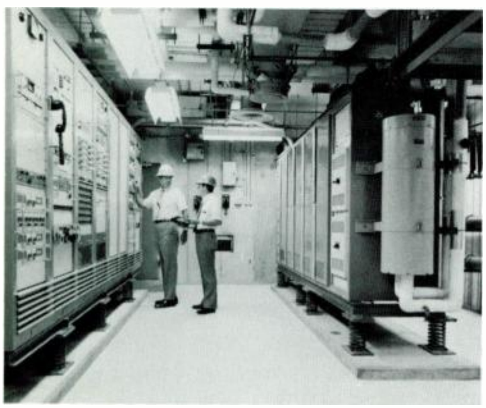
Design Approach to Automation

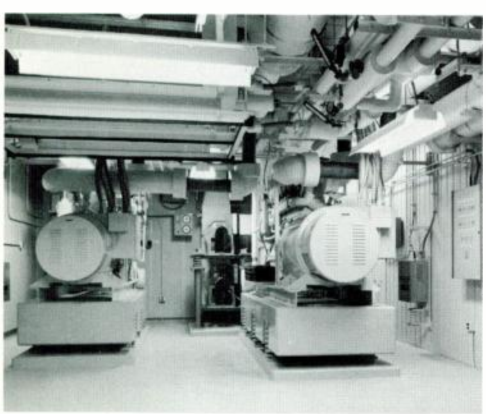
The benefits to be gained from automating a radio transmitting facility have been apparent for some time. However, several difficulties have impeded its feasibility until recent developments in technology provided practical solutions to the problems. First, unattended operation of a major transmitting facility essentially requires a computer to provide all the memory, evaluation, decision, and enabling functions necessary to direct the complex control, monitoring, test, and administrative operations required. The recent availability of a reliable minicomputer at a reasonable cost has made the use of a



computer practical in this application.

The DIDS facility design combines such a computer with appropriate hard-wired logic to provide rapid and accurate, yet flexible, automatic station control. The computer used is a Westinghouse Type CP-1138 Millicomputer with an 8192-word magnetic core memory (Fig. 6). This





4—(Top) *Transmitter and control equipment at the regional transmit facility are spring mounted to protect them from ground shock. The 55-kW transmitter and dummy (tune-up) load are housed in the cabinets on the right; the station computer, control equipment, and tape-storage equipment are in the cabinets on the left.*

5—(Bottom) *Two 150-kW engine-generator sets at the regional transmit facility provide a backup power source.*

computer was originally developed for use with the U. S. Navy's Harpoon missile and would also be used with the Navy's Condor missile system. Since the Millicomputer was originally designed to meet the rigorous requirements of a military airborne application, it is well suited to the DIDS application where the requirement for reliable operation is paramount.

Another basic requirement for successful unattended operation, particularly for a high-power installation, is equipment reliability. This requirement is met in the DIDS transmitter design by employing solid-state active devices, which are inherently reliable components, and by utilizing modular redundancy with automatic standby switching. The control computer is programmed to continually evaluate equipment status and implement switching to select the optimum modular configuration for the existing set of operating (or failure) conditions. Computer control provides almost instantaneous selection and is not subject to the panic errors that sometimes occur with manual operation. Rapid and accurate reconfiguration of redundant modules is a major contributor to realizing the extremely high reliability required.

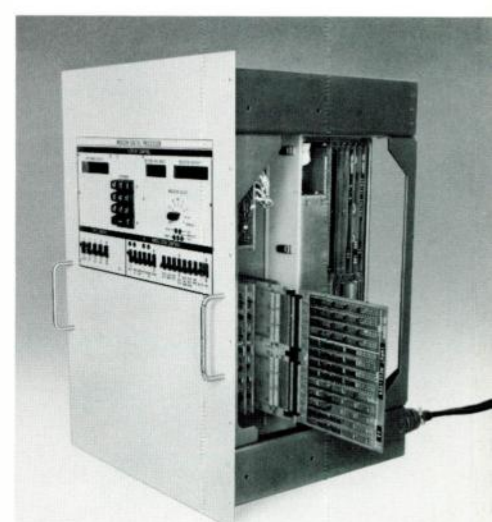
Solid-State High-Power Transmitter

The use of all-solid-state design in the 55-kW DIDS transmitter is particularly effective in producing high reliability because power transistors do not have the fragility and wear-out problems associated with vacuum tubes. Reliable operation is enhanced by modularizing the power amplifier into four 14-kW amplifier modules plus a switchable spare. The switching arrangement is shown in Fig. 7. Substitution takes place automatically upon failure of a power-amplifier module and is completed within 2 seconds. This approach of switched redundancy was developed by Westinghouse in the design of the Air Force 487-L Transmitter.[1]

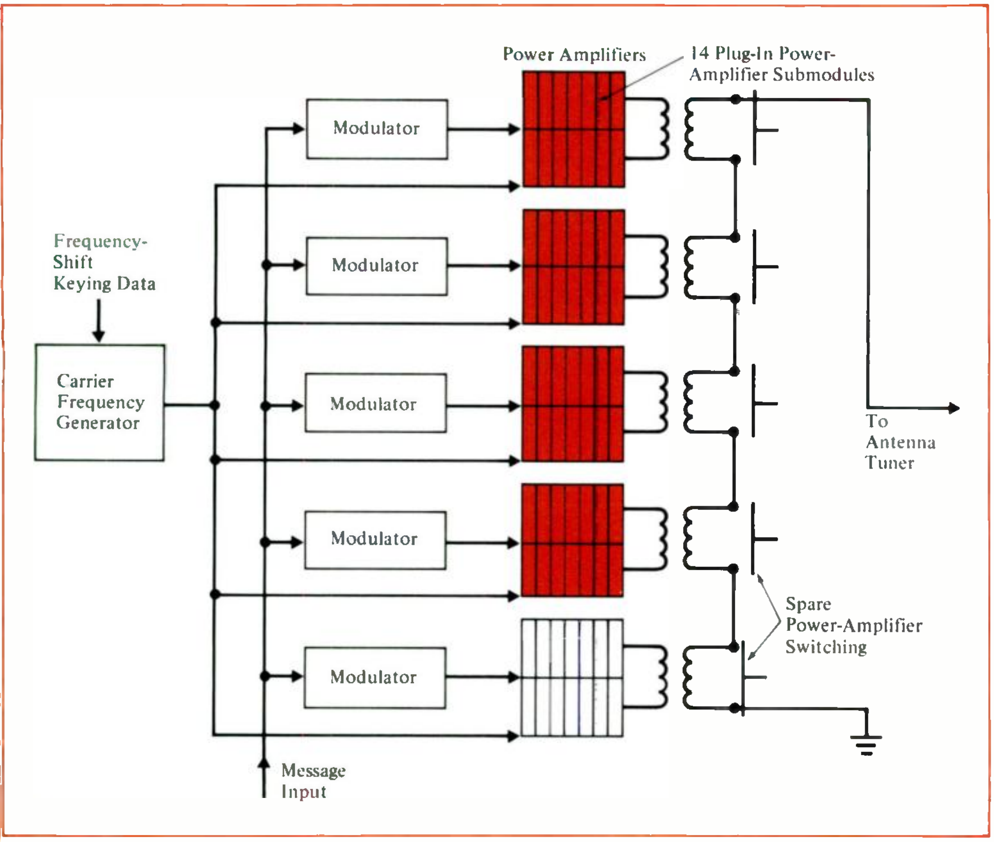
The modular configuration of one of the five 14-kW power-amplifier units is shown in Fig. 8. Each amplifier unit includes a driver, seven modulator trays, and 14 amplifier trays containing a total of 1120 power transistors, which provides a 20-percent built-in redundancy of transistors. Each power-amplifier tray contains 64 power transistors and is capable of generating a kilowatt of radio-frequency power.

Use of multiple transistors in parallel, arranged to be fail-safe, essentially eliminates the transistor as a cause of transmitter failure. A malfunctioning transistor is removed from the output bus by a series fuse. Transistor redundancy combined with the switchable spare power-amplifier module has provided a transmitter mean time between failures of more than 2500 hours.

The power transistors (2N 3902) are operated in a switching (saturated) mode to provide very high efficiency. The power amplifier runs at more than 90 percent efficiency rf/dc (ratio of radio-frequency power into the antenna to dc power input to the final amplifier). The overall transmitter has an rf/ac efficiency of approximately 80 percent. The high efficiency of the solid-state transmitter is a vital factor in minimizing the amount of power required, which in turn minimizes the amount of engine-generator fuel that must be stored.

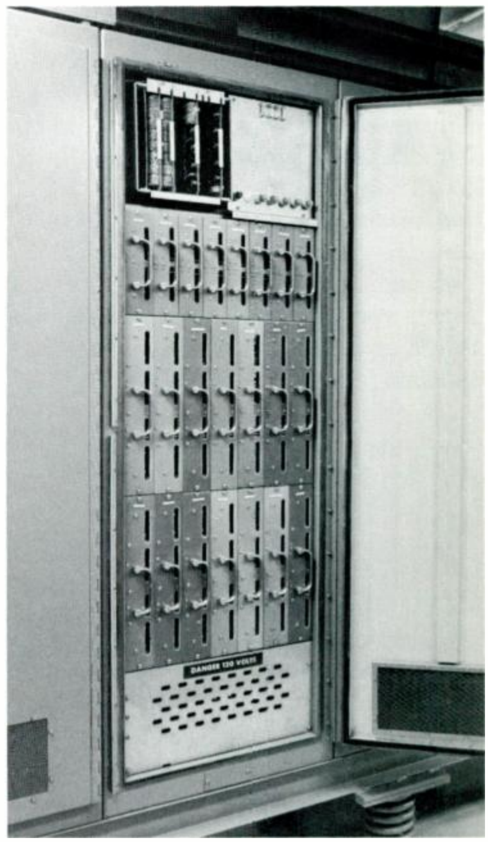


6—*A Westinghouse CP-1138 Millicomputer supervises station operation so that the regional transmit facility can operate unattended.*



7—(Left) *The 55-kW solid-state transmitter is of modular design, with four 14-kW power-amplifier modules operating (color) and a fifth held in reserve as a spare.*

8—(Below) *Each 14-kW power-amplifier module consists of a driver, seven modulator trays, and 14 amplifier trays.*



in the underground building.

Another major benefit of high conversion efficiency in the transmitter is the reduced requirement for heat loss dissipation. Transmitter losses raise the temperature of the cooling air, and an air-to-water heat exchanger is used to transfer this heat to cooling water drawn from wells. After passing through the heat exchanger, the water is cooled and discharged into the nearby river.

To illustrate the savings in fuel and cooling water, the difference in heat dissipation required for the solid-state 55-kW transmitter and a conventional tube transmitter of the same output is approximately 60 kW, which would require an additional 5.2 gallons of fuel and 2450 gallons of cooling water per hour.

Sensors at the transmitter site constantly measure critical operating parameters of the equipment and transmit them by a 100-word-per-minute teletype circuit to the remote maintenance center where they are printed out for record. When the measured quantities are out of tolerance, or other abnormal conditions are sensed at the unattended transmit site, an alarm is sounded and displayed on the console at the remote maintenance center (Fig. 9).

Automatic Control

The control equipment in the regional transmit facility includes teletype and digital signaling terminals for receiving computer commands from the National Warning Center, a minicomputer used as the station processor, storage and control for tape-recorded teletype and voice messages, and a transmitter control and monitor. A simplified diagram of the computer control of major transmit station elements is shown in Fig. 10.

Primary operating commands originate at the National Warning Center and are implemented by transmitting teletype signaling codes over lines to the computer at the regional transmit facility. To eliminate the possibility of broadcasting alert messages containing ambiguities or inaccuracies, standard procedure is to carefully word the warning messages and prerecord them on cassette tapes, which are stored in the control unit at the transmit site. However, in the event that no prerecorded message is appropriate, live voice and teletype messages can also be transmitted to the regional transmit facility for broadcasting.

Confirmation of the messages received from the National Warning Center and the response and status of the equipment at the regional transmit facility are returned to the National Warning Centers over the wire lines by digital signals. Operational data and alarms monitored at the regional transmit facility are transmitted to the remote maintenance center by teletype signals over wire lines.

Commands from the National Warning Center contain an address-selection code to operate transmitters at all or selected transmit sites. Also, the command message contains instructions for selecting the address format of the broadcasts. The digital address format is transmitted by digitized audio tones. The address format of the broadcast operates all or only selected groups of receivers within the area covered by the activated transmitters.

User groups can be structured into organizational, political, or geographical categories, giving a wide flexibility of uses for the DIDS network. For example, an address format might activate receivers at state police facilities, or at civil defense agencies along a coast in the path of a hurricane, or at local authorities located along a river valley subject to flooding. More than 2000 discrete addresses are available for programming desired user groupings.

Computer Functions

The operating functions performed by the computer at the regional transmit facility can be grouped into three major categories: control, monitoring, and alarms.

Control—Upon command from a National Warning Center, the computer sets up the transmitter to operate. For an alert message, it starts the two engine-generator sets and selects the first to stabilize. For routine and test operations, the facility is operated on commercial power but, if commercial power fails, the engine-generator set can be quickly started automatically.

The computer selects the antenna or dummy load as directed by the National Warning Center; if the dummy load is selected, it also starts the flow of cooling water. The dummy load is a water-cooled device that simulates the antenna and is used for tune-up and test of the transmitter without radiating a signal. If signal radiation is desired, the computer ungrounds the antenna and selects the better of the two rf transmission lines (minimum-voltage standing-wave ratio). If a transmission line fails, the computer switches to the alternate line. At the end of a broadcast, the computer shuts down the transmitter and ancillaries and grounds the antenna.

Message control performed by the computer includes the selection of alert or general user coverage or specific addressees from computer storage as instructed by the National Warning Center. Then a prerecorded voice or teletype message (or both) is selected from the tape storage for transmission, or the transmitter is set up to retransmit live or taped voice and/or teletype messages from the Center.

When the computer has recognized a command received from the National Warning Center, it causes a confirmation to be returned to the Center by digital signals. Upon completion of the broadcast, a confirmation and status report is returned to the National Warning Center, again by digital signals.

The transmitter facilities are periodically exercised by the National Warning Center to assure maximum system availability. Upon receipt of an exercise command, the computer sets up the transmitter to operate into the dummy load (or antenna), selects the test message, runs the message through the transmitter, monitors the test, and reports pertinent test results to the Center and the maintenance center.

Monitoring—The computer monitors transmitter frequency and keeps a log of operating periods, transmitter configuration, and dummy load current. It monitors specific operational measurements including transistor collector voltage and saturation level for the transmitter power amplifier and modulator. Radiation system monitoring includes transmission line forward current, reflected current, and voltage standing-wave ratio; the antenna is monitored for current and output power.

The commercial power source is monitored by the computer for line voltage and frequency, and the engine-generator supply is monitored for voltage, frequency, water temperature, oil pressure, battery charge, and fuel level.

Alarms—As it monitors, the computer also determines if any of the key operational indicators are out of allowable tolerance. Some of the quantities that can operate alarms are: transmitter output power, digital modem and computer malfunction, rf transmission-line pressure, carrier oscillator output level and frequency, and engine failure. Any out-of-tolerance quantities cause an alarm to be displayed at the remote maintenance center. The computer also supervises building overtemperature (fire) and illegal-entry detectors and, if activated, relays these alarms to local fire and police stations as well as to the central maintenance center.

Additional memory modules can be added to the computer to extend its control and processing functions. Examples of other functions that could be added in the future include station diagnostics (e.g., cause of abnormal operation other than those related to alarm monitor) and error

9—(Above) *The monitor and alarm console at the remote maintenance center receives and displays warnings of any out-of-tolerance quantities at the regional transmit facility.*

10—(Right) *The station processor provides the memory evaluation, decision, and enabling functions necessary to operate the regional transmit facility.*

detection and correction coding for improving accuracy of transmission from the National Warning Centers to the regional transmit facilities.

Economic Advantages

While many of the control functions described have been done in the past by means of hard-wire logic, the computer becomes the economic choice when the required functions are sufficiently complex as in the case of the DIDS facility. Further, the computer provides a much more economical way of accommodating changes, as reprogramming is less costly than making major modifications to hard-wire logic and control equipment.

In addition to operational benefits, an unmanned transmit facility provides a significant advantage in operational cost savings. A high-power radio transmitter of this type would normally require three 8-hour shifts of at least two skilled operators, seven days a week. The DIDS regional transmit facility has been designed to permit safe and efficient operation of the facility without any site-based operating personnel. It is not anticipated that maintenance visits will be required more than once a week, and probably much less often as operating experience is accumulated. Although the initial cost of procuring an automatic facility is somewhat higher than for a conventional design, the overall reduction in operating cost makes automation very economic over a 20-year period, which is generally the equipment life objective designed into a major communication facility. There is little doubt that unattended operation of major electronic facilities will become of increasing interest to both military and industrial system planners. In fact, the economics involved will probably make that approach almost mandatory in many situations.

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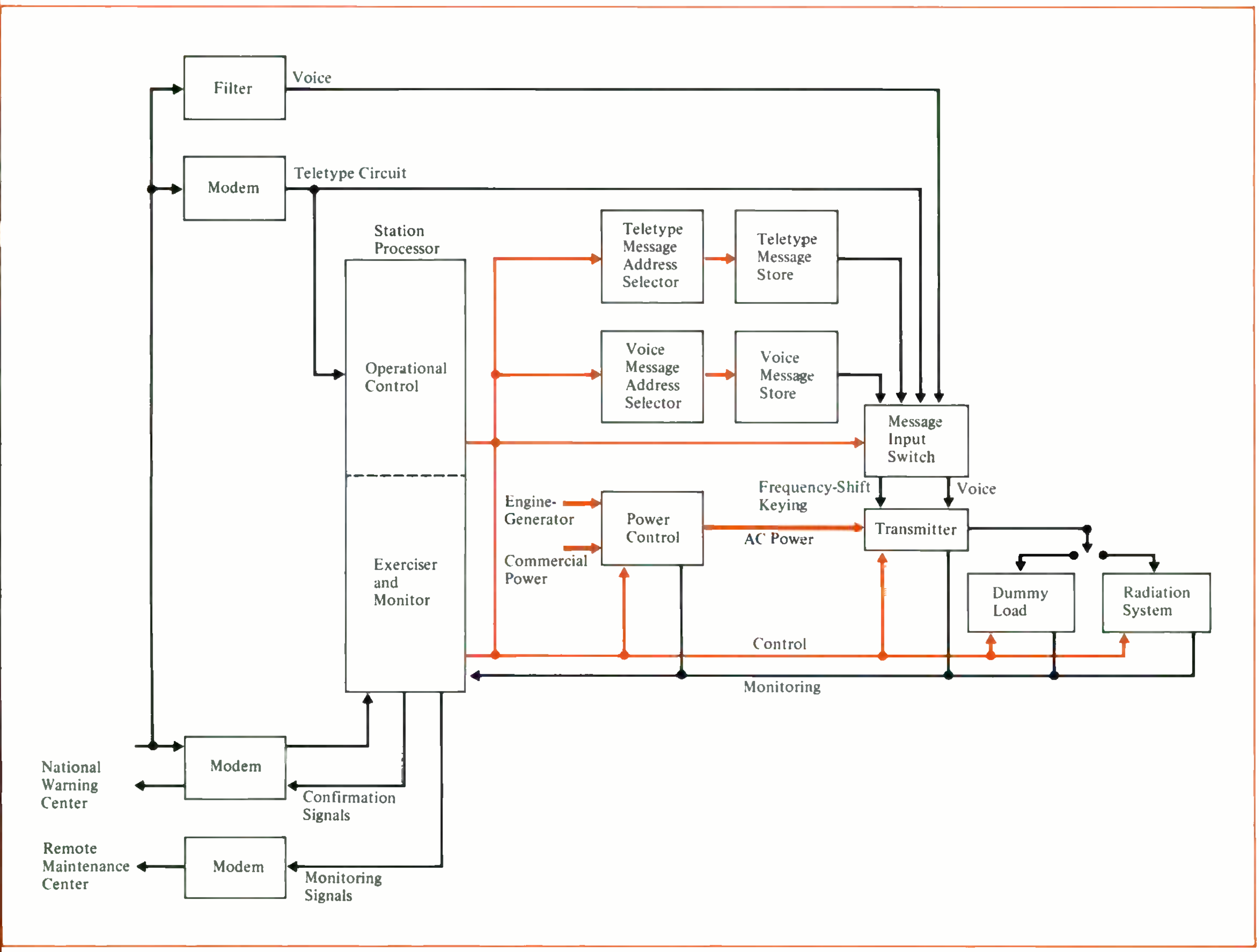
[1]N. B. Tharp, M. L. Jones, J. R. Colgan, and G. R. Brainerd, "New Concepts in VLF/LF Communications," *Westinghouse ENGINEER*, September 1967, pp. 130-41.
[2]Robert Martin, "Decision Information Distribution System," *Proceedings, National Telecommunications Conference*, 1973.



Motors for High-Speed Aerators and Cooling Modules

L. J. Taylor

High-speed direct-drive aerators and cooling modules are efficient devices for aerating or cooling bodies of water. Their electric motors are carefully designed and built to withstand the rigorous environments in which the devices must operate.

The bacteria that break down organic materials in wastewater frequently require more oxygen for sufficiently rapid action than is available naturally. Consequently, biological oxidation is often aided by various water treatments. One of the most effective and most frequently used is the activated-sludge process, in which wastewater and sediment are agitated and aerated by mechanical aerators to increase the rate of oxygen uptake.

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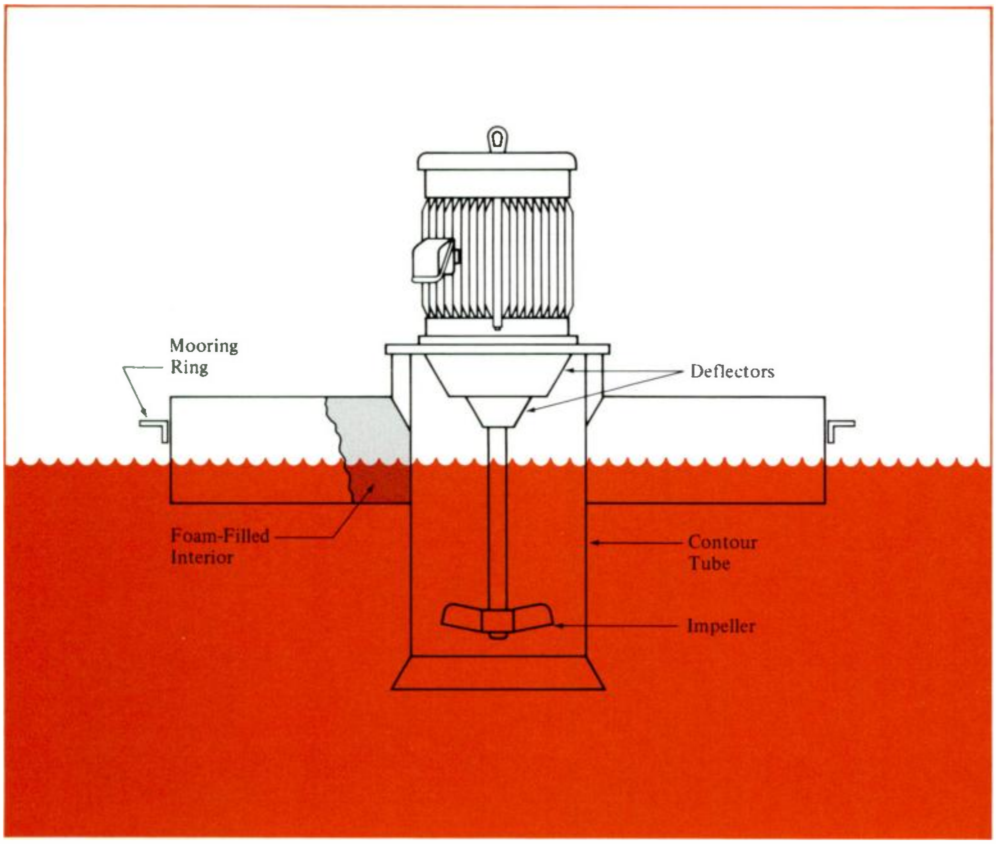
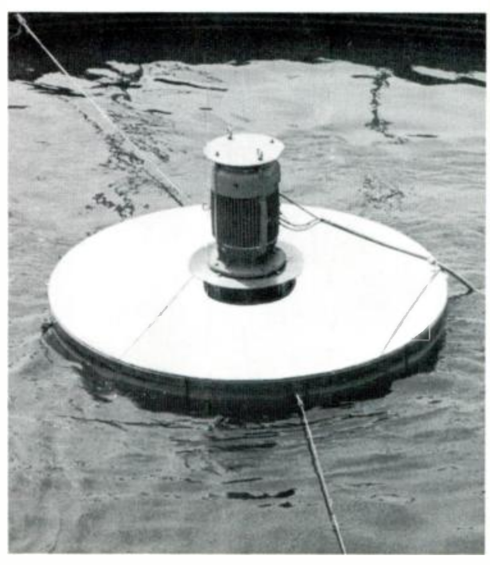
A popular type of aerator is the high-speed surface-entrainment type, in which an electric motor directly drives a propeller-type impeller at motor shaft speed. Impeller and motor are mounted on a flotation module, which maintains the impeller at an optimum depth regardless of variations in the water level in the aeration basin (Fig. 1). The unit functions as a high-volume axial-flow pump producing flow rates of 3000 to 30,000 gal/min with oxygen input capacities up to 4 lb/hp-hr. It is well suited to aeration because it effectively translates the theory of oxygen transfer into practice. (See *Mechanisms of Oxygen Transfer and Heat Transfer*, facing page.)

Besides oxygen transfer, spraying and mixing cause a certain amount of heat transfer from water to air and consequent cooling of the water. The spray can be optimized for maximum heat transfer by modifying the impeller and nozzle (Fig. 2). The resulting device looks much like an aerator but is called a cooling module. It provides an economical alternative to cooling towers for reducing the temperature of water used for cooling in electric-utility generating stations. Besides being lower in cost, the device has the advantage of localizing fogging and drift because water droplets are introduced into the air at low altitude in contrast to the high-altitude plume from a wet cooling tower.

Motor Design

Westinghouse motors for these applications are three-phase squirrel-cage machines of the totally enclosed fan-cooled type, built for vertical P-flange mounting (Fig. 3).





1—A high-speed aerator consists of a motor mounted on a float and coupled directly to an impeller as shown in the partial section view. The aerator in the photographs has a 30-hp motor; its approximate spray diameter is 24 feet and its flow rate 11,000 gal/min. These photographs and Fig. 2 show an aerator and a cooling module made by Richards of Rockford, Inc., Rockford, Illinois.

They range in size from 5 to 100 hp; shaft speeds are 1800 r/min through 40 hp and 1200 r/min for 50 hp and larger. Design considerations are similar for both applications because, in both, the motors are exposed to windblown spray. In the cooling application, the spray frequently has considerable salt content. Special features enable the motors to withstand their difficult environment.

Aerator Motors—All exposed parts on motors for high-speed aerators are corrosion resistant. Frame, end brackets, fan hood, and conduit box are of heavy-walled cast iron, and only noncorrosive plated hardware is used. The drip cover is of sheet steel on motors through 30 horsepower and, on larger ratings, of a fiberglass composition that is unaffected by chemicals in the water. The cooling fan also is of fiberglass. All external surfaces are protected by a full-gloss epoxy enamel applied over a chromated red oxide primer that is rich in zinc.

Deep register fits between the motor frame and the end brackets help minimize the entrance of moisture into the motor enclosure (Fig. 4). An external neoprene shaft flinger protects the lower bearing against water impinging against the base of the motor, and the upper bearing is protected by the cooling fan. A premium moisture-resistant grease is used in the bearings to inhibit corrosion even if moisture finds its way into the bearing cavities. Potting of the motor leads where they pass through the frame excludes moisture at that point. The conduit box has a gasket between its cover and base and between its base and the motor frame. In addition, a stainless-steel one-way pressure condensate drain is included at the lowest point.

In spite of these efforts, some moisture gets into the motor in service because the motor "breathes." Aerators and cooling units are usually operated only as required rather than continuously; consequently, the motor draws in moist air when it is turned off and the winding is cooling, and then drives the moisture off when it is turned on and the winding gets warm.

Mechanisms of Oxygen Transfer and Heat Transfer

Oxygen Transfer—The process occurs in three distinct phases. Oxygen molecules are first brought in contact with the liquid surface, saturating the interface. During the second phase, the oxygen molecules pass through the liquid interface by molecular diffusion. In the final phase, oxygen is mixed in the body of liquid by diffusion and convection. The following equation describes the process:

$$\frac{dC}{dt} = K_L a\,(C_s - C_t),$$

where C is oxygen concentration per unit volume, t is time, dC and dt are differentials of those two parameters, and K_La is the overall oxygen transfer coefficient for the unit process. The process rate is a function of the difference between the oxygen saturation concentration, C_s, and the initial oxygen concentration, C_t. K_L is the oxygen diffusion coefficient at the air/water interface, and $a = A/V$ where A is the exposed air/water interface and V is the aerated liquid volume.

The equation applies to clean water conditions at 20 degrees C and 1 atmosphere pressure. Additional parameters can be integrated into the equation for evaluation of aerator performance for various wastewater conditions.

The nature of the process, then, dictates the performance features of a properly designed aerator:

1) The largest practicable interfacial area should be generated between the water and the air. Mechanical aerators produce a water spray consisting of discrete droplets, maximizing the interfacial area.

2) The air/water interface should be continually broken down to keep the transfer coefficient high. Turbulence generated by the pumping and mixing action of mechanical aerators, as well as by impingement of the droplets on the water surface, keeps the surface film disrupted.

3) The highest possible oxygen concentration differential should be maintained. It is achieved by the strong mixing action produced in the parent body of liquid by mechanical aerators.

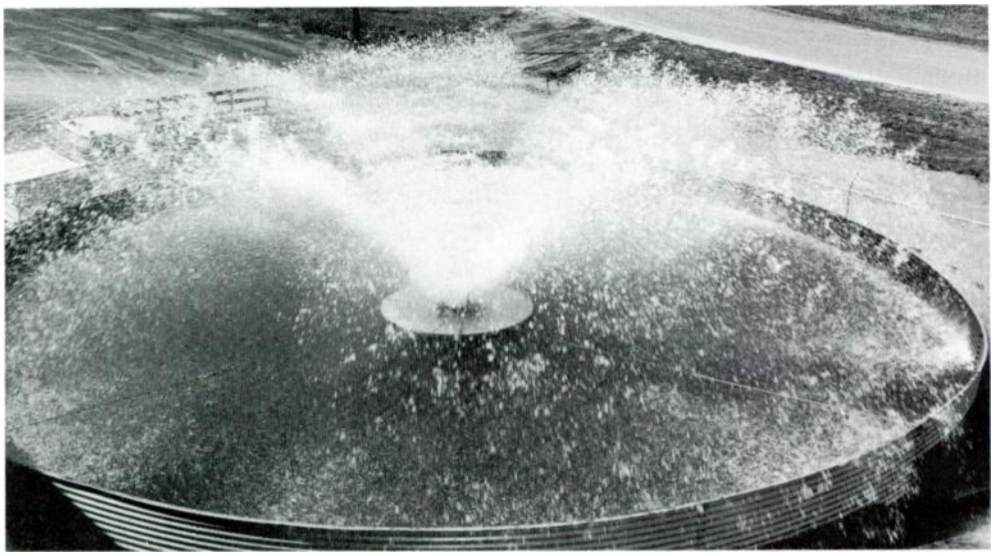
Aerator units are designed to produce a spray pattern of low profile (1 to 2 feet), perpendicular to the shaft axis and nearly parallel to the water surface. That pattern provides maximum impingement and air-water interface, minimizes blowoff, and helps prevent ice formation on the unit during winter operation.

Heat Transfer—Spray cooling is essentially a vaporization process involving simultaneous heat and mass transfer, and it is controlled by the temperature and moisture content of the contacting air. The minimum theoretically attainable water temperature is the wet-bulb temperature of the air, the temperature at which water can be evaporated into the air to bring it into saturation at the same temperature. It can be thought of as the equilibrium temperature at the air/water interface existing when the convective heat transfer rate to the interface equals the mass transfer rate away from it. Performance is optimized by producing as small a droplet size as possible at as high a rate as possible.

Practical considerations limit the extent to which droplet size and formation rate can be optimized. Horsepower requirements for droplet production increase as the mean droplet size becomes smaller; therefore, minimizing droplet size for a given input horsepower would leave little capacity for developing a sufficient flow rate. In addition, the finer the droplet size, the more severe the fogging and the associated drift and ice accumulation.

A practical solution in terms of temperatures, mass flow, and pumping cost is achieved with a vertical axial-flow propeller pump discharging through a slot nozzle. It is characteristically a high-volume low-head device. Mean droplet size produced is 3/8 to 1/2 inch, and the height of the spray is approximately 15 feet. The time constants for cooling are in the neighborhood of the descent time for that spray height. Thermal efficiency is acceptable, and fogging and drift are minimized.

System performance is also affected by the degree of mixing provided with the parent body of water. Locating the pump intake several feet below the water surface eliminates the possibility of respraying cooled water. A complete cooling installation consists of a large number of spray modules appropriately arranged in a cooling pond to minimize shadowing and to utilize the prevailing winds. Ideally, the pond is long, narrow, and oriented perpendicular to the prevailing summer winds.



2—A cooling module is similar to an aerator except that its spray pattern is optimized for heat transfer instead of oxygen transfer. This one has a 75-hp motor, and its spray cone is about 15 feet high.

Therefore, the stator bore, end turns, and die-cast aluminum rotor are coated with a premium moisture-resistant (PMR) corrosion-inhibiting epoxy insulation system. Accumulation of water within the motor is prevented by a stainless-steel one-way pressure condensate drain located at the low point of the bottom bracket. Optional moisture protection includes sealing of bracket-to-frame fits and addition of a flinger above the upper bearing.

Carbon-steel shafts with extensions suitable for coupling to impeller shafts are standard, but longer shafts can be provided for direct mounting of the impeller. Stainless-steel shafts are supplied when necessary.

The motor bearings have to carry the impeller thrust, static weight of the rotating parts, and shock loads that might be caused by debris striking the impeller. That is one of the major differences between high-speed aerators and low-speed (geared) aerators, in which the gear unit is the design challenge.*

*In low-speed aerators, the loads are all restrained within the gear unit; the motor is coupled to the input shaft of the gear unit and sees no significant mechanical load other than torque.[1] Also, drive motors for low-speed aerators are less susceptible to water spray problems because they are mounted above the gear unit, which is generally on a fixed platform that prevents water from coming directly in contact with the drive. Near-standard motors are used.

Double-shielded regreasable ball bearings made of vacuum-degassed steel are used in the high-speed aerator motors. The lower bearing is so constructed as to permit the motor to handle up or down thrust continuously. Bearing load ratings are based on a one-year minimum B-10 life (the life that 90 percent of a group of identically loaded bearings will achieve before the first evidence of fatigue appears), which is five years average life. If expected loads exceed these standard bearing capabilities, or if longer life is desired, a double-row angular-contact thrust bearing is used.

Cooling-Module Motors—Utility companies impose special requirements for equipment reliability and long life. In addition, the spray cone of a cooling module is much higher than that of an aerator, resulting in the motor getting much wetter. Consequently, the motors have additional features.

Bracket-to-frame fits are sealed with a silicone cement, as are bearing cap bolts and mating surfaces of the conduit box. The castings are those normally used in explosion-proof motors; their wall thicknesses exceed those required for fan-cooled motors. The lower thrust bearing is a high-capacity single-row angular-contact ball bearing, and both bearings are protected by stainless-steel revolving seals of labyrinth type. Waterproof grease applied between the lower bracket and seal protects against admission of water and provides additional corrosion protection for the machined surface of the bracket.

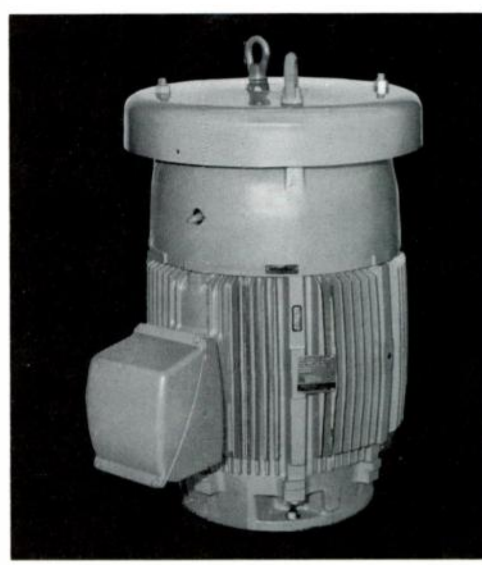
No condensate drains are provided in the conduit box. Instead, the box is filled by the user with a potting compound after the power connections are made, encapsulating the connections to make them impervious to moisture.

A long stainless-steel shaft is provided for direct mounting of the impeller.

Application Analysis

The motors and impellers for a particular application undergo a complete mechanical analysis by computer simulation to insure their adequacy for that application. In addition to a review of the thrust-bearing capability, a resonance-frequency study is performed for both the rotating and the stationary parts.

The resonance frequency for a rotating system is that at which a natural frequency of the system coincides with the frequency of an exciting force. The latter is determined by rotational speed and the number of blades in the impeller, so all rotor and shaft

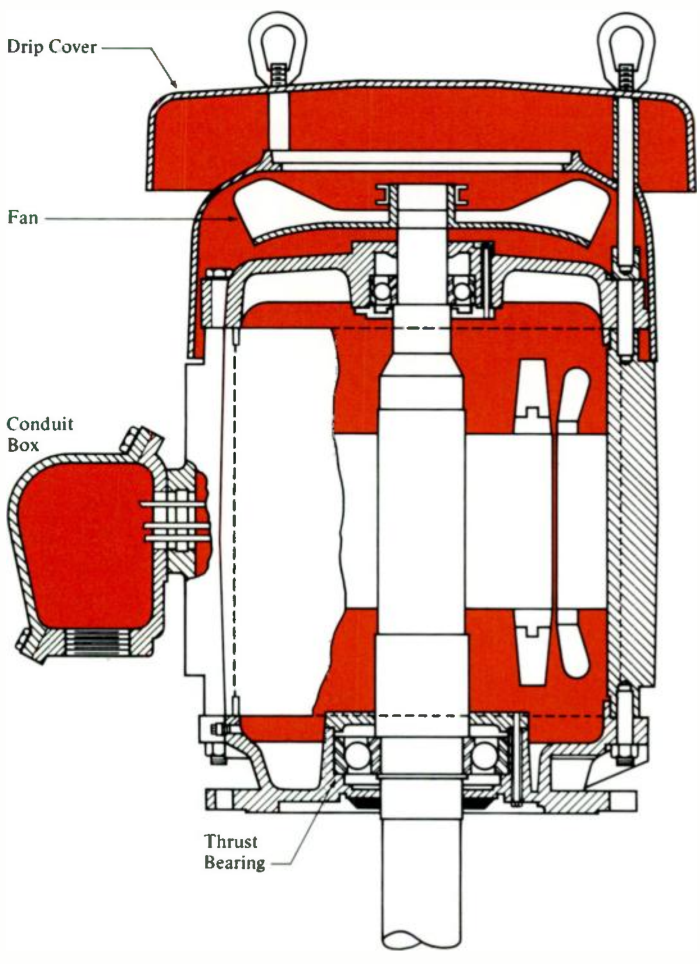


3—(Above) *Drive motors are totally enclosed fan-cooled types with special features that enable them to withstand the wet environment in which they operate. The one shown is a 100-hp aerator motor with a short shaft extension for coupling to the impeller shaft.*

4—(Right) *The main elements of an aerator motor are seen in this section view.*

assemblies are checked to make sure that their natural frequencies are far enough removed from the operating speed of the motor to prevent resonance. The stationary motor parts (frame, stator, brackets, etc.) are also characterized by a resonance frequency; with a vertical flange-mounted motor, this vibration response is called reed resonance because the motor tends to vibrate much like a reed on its mounting base.

Operation of the aerator or cooling unit at a speed too near (within 25 percent) any of these resonance frequencies would result in undesirable amplification of any inherent imbalance in the system. Therefore, the lowest resonance frequency is made greater than the operating frequency so that the system does not have to pass through any resonance points in accelerating to operating speed. The natural frequency of a component is increased, when necessary, by stiffening the component; increasing the diameter of the motor shaft, for example, can prevent resonance of the rotor and shaft assembly.



Space Heating

If a motor winding becomes moist with condensation from moisture-laden air breathed in during shutdown, the insulation may break down when the winding is reenergized. To increase motor reliability and service life, some form of space heating is strongly recommended. Heating maintains the motor winding approximately 5 to 10 degrees C higher than ambient temperature, thus preventing condensation of moisture on the winding. The two most common methods are use of space heaters and low-voltage heating.

A space heater consists of a resistance element embedded in silicone rubber. It is wrapped around (and laced to) the stator coil extensions when the motor is manufactured; the winding is then dipped in thermosetting varnish and baked, making the space heater an integral part of the winding. Two leads are provided for applying single-phase power.

Low-voltage heating requires no auxiliary devices within the motor. When the motor is not running, single-phase power is connected across two of the three phases of the motor through suitable control. Applied voltage is 7 to 9 percent of the motor's normal operating voltage. The torque produced is insufficient to cause motor rotation, but the electrical losses heat the winding enough to keep it dry.

Conclusion

High-speed aerators and cooling modules require a special breed of motor for reliability and long life. Careful design and construction are necessary, followed by analysis to make sure that the aerator or cooling module will not operate at a resonance frequency.

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Developing a Communication System for Automated Distribution

R. F. Cook
R. V. Adams
I. A. Whyte

Automation of feeder and residential functions in electrical distribution systems depends on capable and economical communications in both directions. Distribution-line carrier is the best type of communication link, and the required equipment and techniques are now being developed.

For several years, electric utilities have expressed interest in automated systems that would monitor and control the supply of electricity to various points on their distribution circuits. The cost of providing these automated services has been greater than their worth so far, but the present trends of rising labor and fuel costs and the need to maintain acceptable service reliability at higher distribution voltages are improving the economic attractiveness of automated distribution systems. In response to this narrowing gap between cost and worth, the Westinghouse Meter Division, Research Laboratories, and Headquarters Distribution Systems Department have been working to develop a communication system for use in automated distribution.

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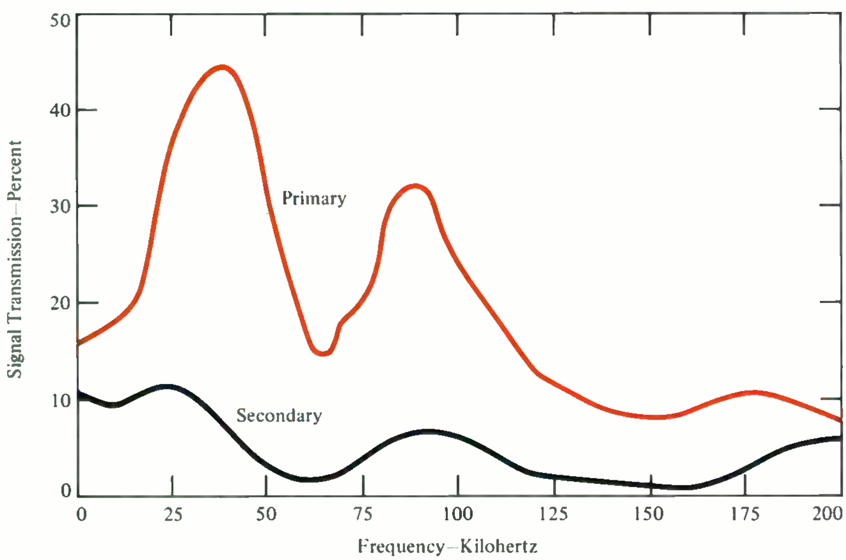
The major automated distribution services can be classified in two categories: residential automation and feeder automation. Residential automation includes functions performed at the home, such as automatic meter reading, selective load control for system peak load reduction, voltage continuity monitoring, and remote service connect/disconnect. Feeder automation includes functions performed on the high-voltage part of a distribution circuit, such as remote monitoring and control of circuit breakers, switches, reclosers, fuses, line sectionalizers, and shunt capacitors. Those functions can be used to reduce outage times in the event of a line fault and to provide information that can be used to perform switching operations to balance the loading on feeder circuits. In addition, auxiliary services such as industrial demand metering and distribution-transformer load/temperature monitoring are also foreseeable.



1—The amount of carrier-signal transmission varies with the frequency of the carrier signal. These curves are drawn from values measured on one mile of a representative active overhead distribution line, with the measurements made at the primary and secondary of a distribution transformer.

Communication Links

Several alternative communication links have been considered for providing the above services. They are commercial telephone, radio, pilot wire, coaxial cable, and distribution-line carrier.

Field trials conducted by AT&T in Chicago and Houston have demonstrated the technical feasibility of commercial telephone as a communication link for automatic meter reading. However, it has several drawbacks. First, administrative cooperation between the electric utility and the telephone company would be necessary. Second, AT&T and its subsidiaries have not quoted tariffs for the use of their lines for residential automation services. (However, tariffs have been established by some subsidiaries of AT&T for feeder automation, and several utilities are using telephone for such services.) Third, the mass-addressing capability necessary for the highly desirable home service of selective load control is lacking.

Radio communication links have also been shown to be technically feasible and could be completely administered by an electric utility. Radio systems are presently being used in limited applications for selective load control, but bidirectional applications of radio for automatic meter reading and service restoration appear uneconomical.

Pilot wire and coaxial cable are also technically feasible, but they lack the necessary system coverage to be attractive communication links for large-scale use. The cost of retroactively installing large amounts of pilot wire or coaxial cable appears prohibitively high for most automated distribution functions.

Due to the limitations of the above communication links, Westinghouse has undertaken a major program to develop the necessary technology for a distribution-line carrier (DLC) communication system. The advantages of using DLC are: it has the potential to provide all the functions of automated distribution, each function can be performed by use of existing electrical networks, expansion to provide additional automated distribution functions should be relatively simple and inexpensive, and the entire communication system would be owned and maintained by the electric utility.

Although *transmission* lines have been used for decades as a communication medium, the use of *distribution* lines for communication purposes has not been very successful in the past. New equipment and new system concepts are required.

Suitability of Distribution Network as Communication Medium

To determine how to use the distribution network as a communication medium and to choose a frequency for communication, designers have had to consider such basic factors as signal attenuation caused by the power lines that form the distribution network, signal attenuation caused by distribution equipment, and noise and interference present on the distribution system. It was assumed initially that some information on the communication capability of distribution lines could be obtained from information about transmission-line carrier ripple-control systems. However, little data is available on either system that is pertinent to distribution-line carrier, so the first part of the development program consisted of field measurements to obtain the required basic information.

2—This prototype home transmitter/receiver for distribution-line carrier communications, shown here installed on the residence of a Carolina Power & Light Company customer, is part of the equipment used for field trials. It performs such functions as automatic meter reading, selective load control, voltage continuity monitoring, and remote service connect/disconnect.

Attenuation by Lines—Signal attenuation between points on an electrical distribution system depends mainly on frequency and load (Fig. 1). Although the exact shape of the transmission characteristic varies according to load conditions and line configuration, some interesting generalizations can be made. In the frequency band from 10 to 30 kHz, attenuation is often quite low. At frequencies between 50 and 100 kHz, it appears to increase in proportion to frequency. There is often a "dead band" between 100 and 200 kHz in which signal attenuation is very high and in which it would be difficult to communicate. At frequencies above 200 kHz, attenuation is too high for long-distance communication. However, 200 to 300 kHz appears suitable for short- and medium-distance communication.

Attenuation by Distribution Equipment—The distribution transformers and shunt capacitor banks of a distribution network are major sources of attenuation. At frequencies above 10 kHz, the effect of shunt capacitors is to short-circuit the communication signal. To overcome that effect, it is necessary to install a distribution carrier trap, typically a parallel tuned LC circuit, at the capacitor bank. The required inductance is in the range of a few hundred microhenries. That inductance, when tuned to the communication frequency, provides a suitably high impedance while otherwise not altering the performance of the capacitor bank.

Distribution transformers are a problem because of the large numbers and wide variety of types installed in a typical distribution network. Although it is difficult to characterize the high-frequency parameters of distribution transformers, some generalizations can be made. Input impedance measured at the primary at high frequencies is usually capacitive, and the magnitude of the input impedance may be in the range of 50 ohms to several hundred ohms. Signal voltage attenuation between primary and secondary varies with frequency and is in the range of 10 to 70 dB in the 30- to 100-kHz band. Signal voltage attenuation from secondary to primary is less than in the opposite direction, with a reasonable value of approximately 30 dB at frequencies of interest.

At frequencies above 50 kHz, neither the primary nor the secondary input impedance is particularly sensitive to load changes. However, at frequencies below 20 kHz, load changes can result in significant changes in impedance. The secondary input impedance of transformers can be in the

3—A prototype transmitter/receiver for use in feeder automation is also installed on the Carolina Power & Light Company system. It performs much the same functions as the home unit, but it performs them on the high-voltage part of the distribution system.

range of five ohms to several hundred ohms depending on frequency and load. Signal attenuation caused by distribution transformers causes no major problem for the primary-to-primary communication required for feeder automation. On the other hand, residential automation requires communication from primary to secondary and, in some cases, return communication from secondary to primary. Due to the wide ranges of impedance presented by distribution transformers, it was necessary to develop a means of coupling the carrier signal around the transformers.

Noise and Interference—Noise and interference from local radio stations, transmission-line communications, and low-frequency radio navigation aids present problems. The signal levels due to radio stations can be of several volts amplitude, whereas those from other sources rarely exceed a few hundred millivolts. Noise and 60-Hz harmonic interference vary roughly as $1/f$ and $1/f^2$ respectively, where f is frequency. Typical values lie between 300 and 400 μV rms noise per kilohertz at 100 kHz, and between 1.0 and 20 mV rms noise per kilohertz at 20 kHz.

Considering the effects of noise, unwanted signals, and signal attenuation, three bands—20 to 30 kHz, 50 to 100 kHz, and 200 to 300 kHz—appear most suitable for DLC communications.

Modulation and Bandwidth

Two modulation methods are particularly suitable for power-line communications: frequency-shift keying (FSK) and two-tone frequency modulation (FM). The former has the advantage of making maximum use of available signal power. However, it requires relatively complicated circuitry, is prone to interference from continuous adjacent signals, and frequency drift at either the transmitter or receiver can result in a change of the level of the detected signal.

Two-tone FM is less efficient in use of signal power, but the receiver requirements for frequency drift are less stringent and the receiver can be made less prone to interference from continuous adjacent signals. Both FSK and two-tone FM have certain advantages, and each is susceptible to performance and cost compromises. Practical considerations indicate that both systems have a signal-to-noise ratio of about 15 dB to provide an error rate of slightly better than one part in 10^5.

FSK has been used in most of the field tests. Typically, the frequency shift has been 2 kHz and the receiver bandwidth approximately 5 kHz. Thus, several channels could be accommodated in the selected frequency bands of 20 to 30 kHz, 50 to 100 kHz, and 200 to 300 kHz.

Equipment Development

In addition to the field measurement programs, prototype equipment has been developed. The equipment has been installed and tested at Consumers Power Company, Carolina Power & Light Company, and West Penn Power Company. The installations include substation transmitter/receivers, repeaters, distribution carrier traps, home transmitter/receivers, and feeder-automation remote transmitter/receivers.

The substation transmitter/receiver is capacitively coupled onto a substation bus, and it communicates with the remote equipment for either feeder automation or residential automation. It is linked to a central control station by conventional communication links such as radio or telephone.

A repeater unit is required at points on the distribution network where line or equipment attenuation makes signal amplification necessary. For example, a step-down autotransformer bank on the West Penn Power System severely attenuated the DLC signal. To solve the problem, a repeater was used to bypass the autotransformer bank and provide an amplified DLC signal for remote equipment farther down the line.

Two versions of a distribution carrier trap have been developed. One is an air-core unit (presently under test on the Carolina Power & Light Company system) and one a combination air-core/iron-core unit. Both appear as a short circuit at 60 Hz and as a high impedance at DLC frequencies. A 14-ampere distribution carrier trap has been used at a 150-kVAR 12-kV capacitor bank on the West Penn Power System, and traps ranging up to 150 amperes in rating are being designed.

Prototype home transmitter/receiver units have been demonstrated (Fig. 2). They contain the necessary logic circuitry for the various residential automation functions.

A remote transmitter/receiver unit for use in feeder automation is shown in Fig. 3. It is connected to the high-voltage part of a distribution circuit to monitor and control devices such as circuit breakers, sectionalizers, and capacitors. This unit performs basically the same function as the home transmitter/receiver, although the logic requirements are greater.

Conclusions

Feeder automation can be implemented immediately by conventional communication methods such as radio and telephone. However, distribution-line carrier will be needed to make widespread use of complete automated distribution practical. The necessary equipment is being developed.

Experimental equipment using narrow-band FSK modulation has been built. The results of initial test programs show that DLC communications at satisfactory error rates can be achieved with low-cost low-power equipment.

Reliable Oxygen Measurement Reduces Process Costs

Edmond D. Neuberger

Combustion and many other industrial processes requiring controlled atmospheres need a good means for measuring the content of free oxygen in a gas stream. A probe-type Oxygen Analyzer now provides that capability so rapidly, accurately, and reliably that the signal is used as a primary control value, with dramatic savings in fuel and reductions in air pollution.

Effective automated process control depends on rapid, accurate, and reliable primary measuring instruments that report what is happening in the process. Such instruments for measuring oxygen content of gases have been lacking, preventing full automation of combustion and other processes that require controlled atmospheres. Now, however, the required instrument is available in the Hagan probe-type Oxygen Analyzer. It effectively closes the control loop in the combustion process and other gas processes.

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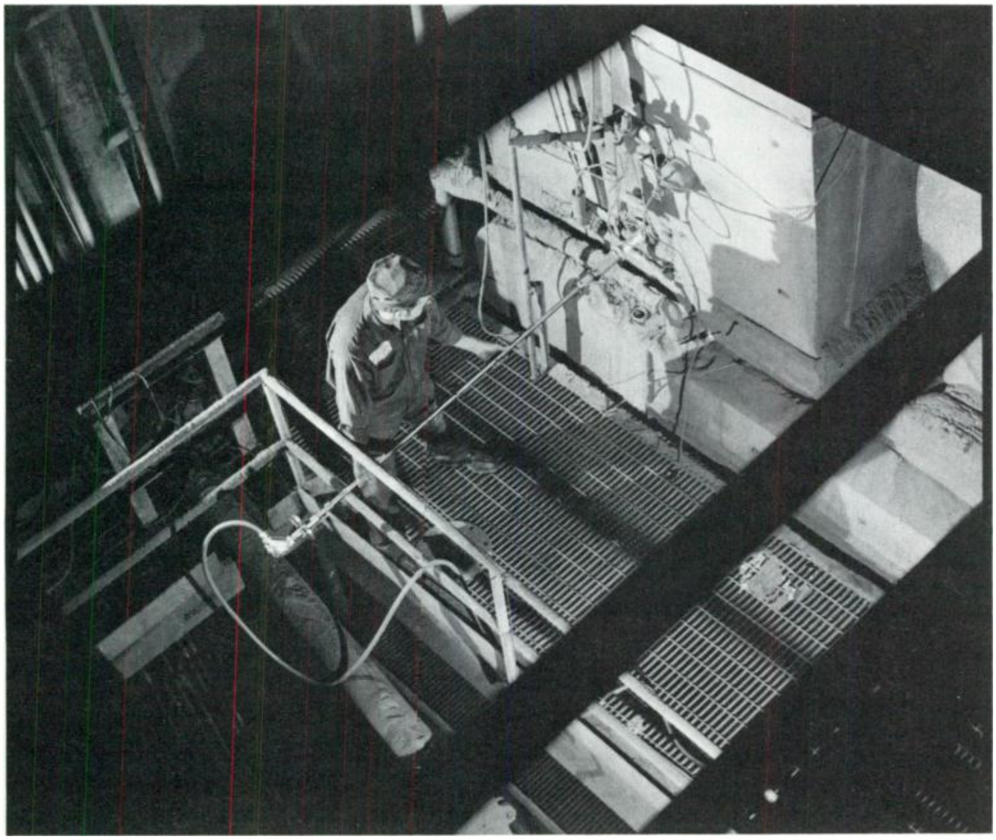
For brevity, this article discusses application of the Oxygen Analyzer in the combustion process. However, the basic principles of its operation and application apply to many processes involving mixtures of oxygen with other gases.

To optimize the combustion process, fuels must be mixed with the proper amount of air. Too much air wastes fuel in the form of heat up the stack, and too little wastes fuel in the form of unburned combustibles up the stack. The key to determination of the proper fuel/air ratio is the content of available oxygen in the stack gases.

Earlier equipment for oxygen analysis has major drawbacks. It is costly to install and maintain, it is slow because it requires removal of a sample of process gas that often must be cooled, dried, cleaned, and analyzed chemically, and it analyzes an artificial dry sample rather than the actual gas flow with its variable content of water vapor formed by combustion. Moreover, the sampling systems require much maintenance and are not very reliable; an estimated 90 percent of the maintenance problems with sampling-type oxygen analyzers occur in the sampling systems.[1]

The Hagan probe-type Oxygen Analyzer is inserted right in the flue (Fig. 1). It needs no sampling system, costs only about a tenth as much to install as a sampling-type analyzer, is accurate, indicates virtually instantaneously, can be used with any fuel, and is so reliable that it is used extensively for closed-loop control. It measures the free oxygen in the total gas stream (including water vapor) that is available for combination with combustibles. It can analyze even the dirtiest flue gases, such as those in boilers fired with pulverized coal, without frequent maintenance. It is suitable for process temperatures up to 760 degrees C. It has all-solid-state electronics, and continuous operation for two years is common. In large flues, several probes are often used in parallel and their signals averaged.

Typically, the instrument's signal is used as a feedback signal to optimize the fuel/air ratio in the combustion process. It can also be displayed on an indicator, recorder, data logger, or computer.



1—The Oxygen Analyzer measures oxygen content of a process gas without requiring a sampling system. It is inserted right in the gas and stays there, providing its measurement signal continuously. Here it is shown being inserted in the flue of a large utility boiler. Its output can be used as a feedback signal in a closed-loop combustion control system and also to show oxygen content on a recorder or indicator.

Oxygen Analyzer

This completely new approach to oxygen measurement came out of basic research with fuel cells at the Westinghouse Research Laboratories. It was found that when gases bearing different amounts of oxygen are separated by a barrier of zirconium oxide, oxygen ions migrate through the barrier and leave an electron imbalance across it. Coating the two sides of the zirconium barrier with a lattice of platinum forms two electrodes, and a voltage is produced across the electrodes. Such a cell is used for measuring oxygen content in gases by providing a reference gas of known oxygen content on one side and the process gas to be measured on the other.

The cell's output in volts is given by the Nernst equation:

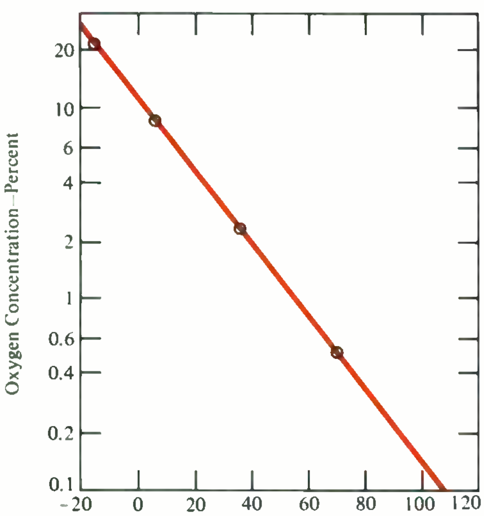
$$V = RT/4F \times ln\left[P_1(O_2)/P_2(O_2)\right] + C,$$

where R is the gas constant, T is absolute temperature of the cell, F is Faraday's constant, $P_1(O_2)$ is partial pressure of oxygen in the reference gas, $P_2(O_2)$ is partial pressure of oxygen in the process gas, and C is the cell constant (which is determined at the time of manufacture and remains constant throughout the cell's life). Cell temperature is held constant at about 843 degrees C, which eliminates temperature as a variable. Thus, the voltage developed across the cell is due solely to the ratio of the partial pressures of oxygen across the cell. Ambient air is used as the reference gas because its oxygen content is constant. Clean, dry, instrument-quality air is all that is required.

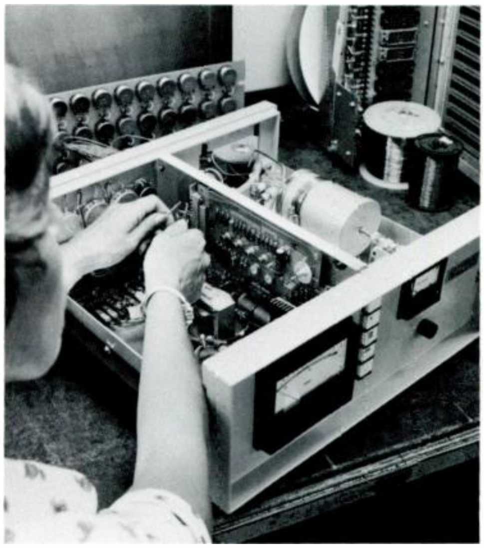
The remaining term in the equation, the variable $P_2(O_2)$, is in the denominator of the *ln* expression in the Nernst equation, so the voltage signal is an inverse logarithmic function of it. As a result, the sensitivity and voltage output of the cell actually increase as the oxygen concentration decreases (Fig. 2). That characteristic is important for combustion control, where the amount of oxygen being measured is small —around 2 percent.

The area of the cell does not appear in the equation because it does not affect the cell's operation. Therefore, the instrument's functioning is not impaired even if part of the cell surface becomes covered with foreign material.

The first commercial instrument employing the zirconium-oxide cell was the Hagan Model 209 Oxygen Monitor (Fig. 3). It is an extremely accurate and sensitive laboratory instrument of industrial quality, and it is used to detect oxygen levels in inert gas mixtures from less than a part per million to 100 percent. Typical applications include certification analysis of oxygen mixtures in nitrogen, argon, or helium; control of inert-gas blankets in food processing and semiconductor production; and control of the inert atmosphere above welding processes. However, the Model 209 Oxygen Monitor is not appropriate for measuring



2—The output of the Oxygen Analyzer is a voltage signal that is an inverse logarithmic function of the oxygen concentration in the gas mixture being analyzed. The instrument thus is most sensitive at low oxygen concentrations, a characteristic that suits it for flue-gas analysis and many other industrial processes.



3—(Top) *A forerunner of the Oxygen Analyzer is this Oxygen Monitor. Although it is an accurate and sensitive instrument, it requires a sampling system and therefore is not appropriate for measuring oxygen in flue gases or for other process applications.*

4—(Bottom) *The heart of the Oxygen Analyzer is a zirconium-oxide cell that produces a voltage when gases with different oxygen concentrations are applied to its two sides. Here a cell is being placed in a holder, which is then attached to the end of a probe that will be inserted into the gas to be analyzed.*

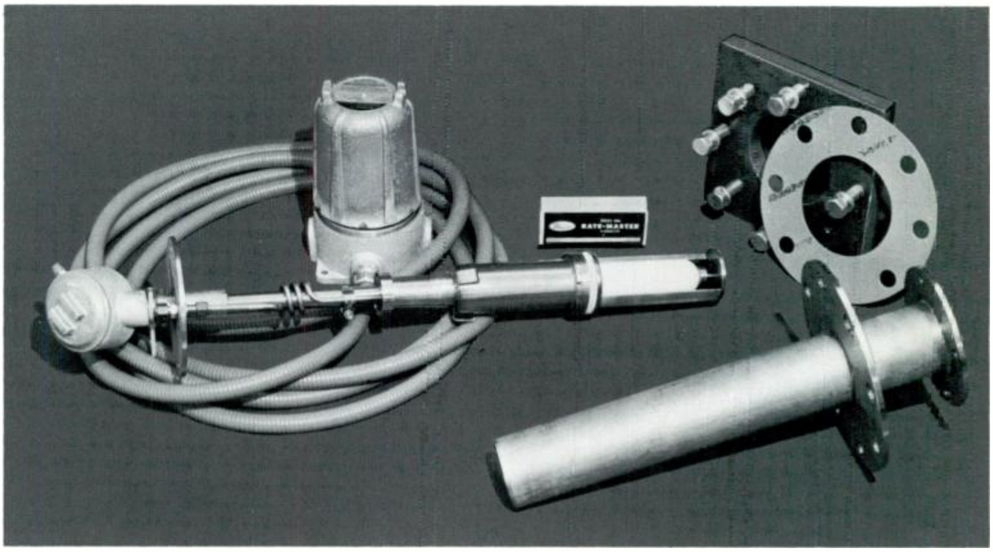
oxygen in flue gases and similar process applications because it requires a sampling system.

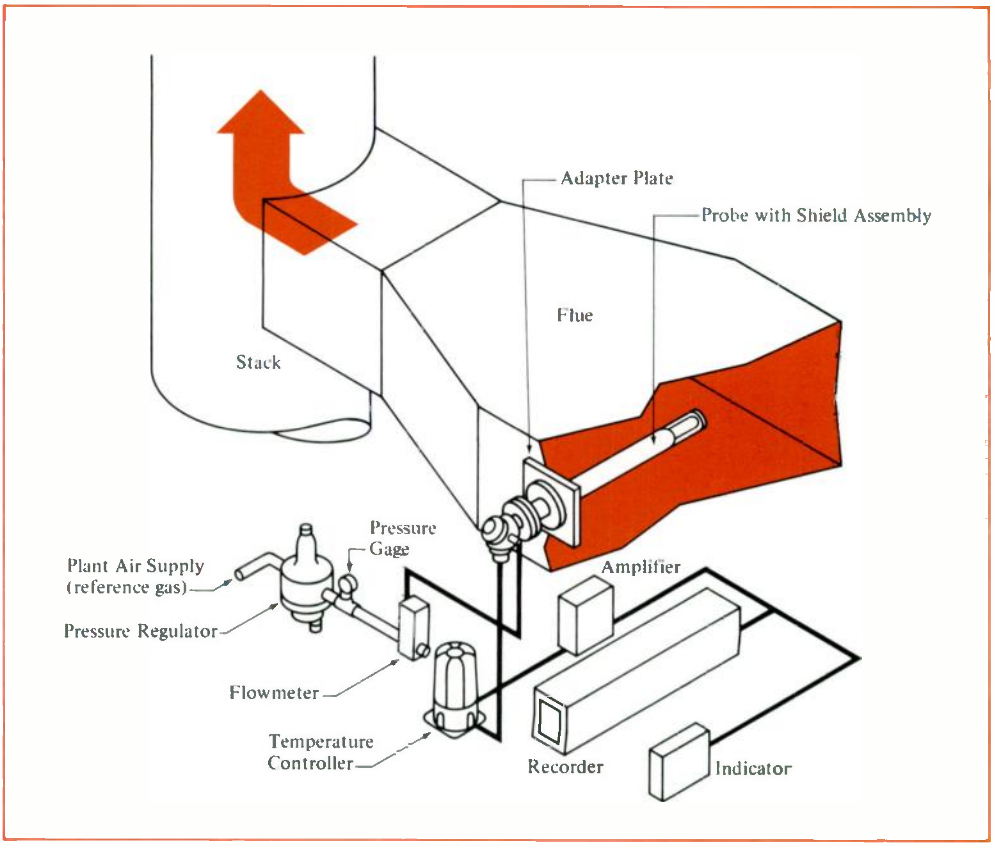
That problem is solved in the probe-type Oxygen Analyzer by putting the cell in direct contact with the process gas stream, eliminating the need for a sampling system.

The cell is about the size of a nickel (Fig. 4). It is secured near the end of a probe that is inserted into the gas stream (Fig. 5). The cell's temperature is kept constant by an electrical heater and thermocouple. A 5-micron filter at the end of the probe keeps the probe's internal components clean. A V-shaped deflector upstream from the filter directs flue gases and particulates tangentially past the filter, keeping the sides of the filter clean and yet virtually free from erosion.

Standard probe lengths are 18 inches, 3 feet, and 6 feet. Electrical connections are made in the temperature controller, which is located at the end of a 20-foot length of factory-wired flexible armored cable.

The instrument is extremely stable, typically operating for months without recalibration. It and the associated electronics are calibrated at the factory. However, that is a static calibration, so an optional provision is made for checking calibration in place—that is, without removing the instrument from the process. A tube is provided, running from a fitting on the flange of the probe to the measurement side of the cell; certified gases can be injected through the fitting directly to the cell to verify the calibration virtually instantaneously (Fig. 6). The procedure is more accurate than static calibration because it takes into account such factors as velocity of the process gas, process temperatures, and pressure. The tube can also be used for withdrawing samples of flue gas for laboratory analysis.





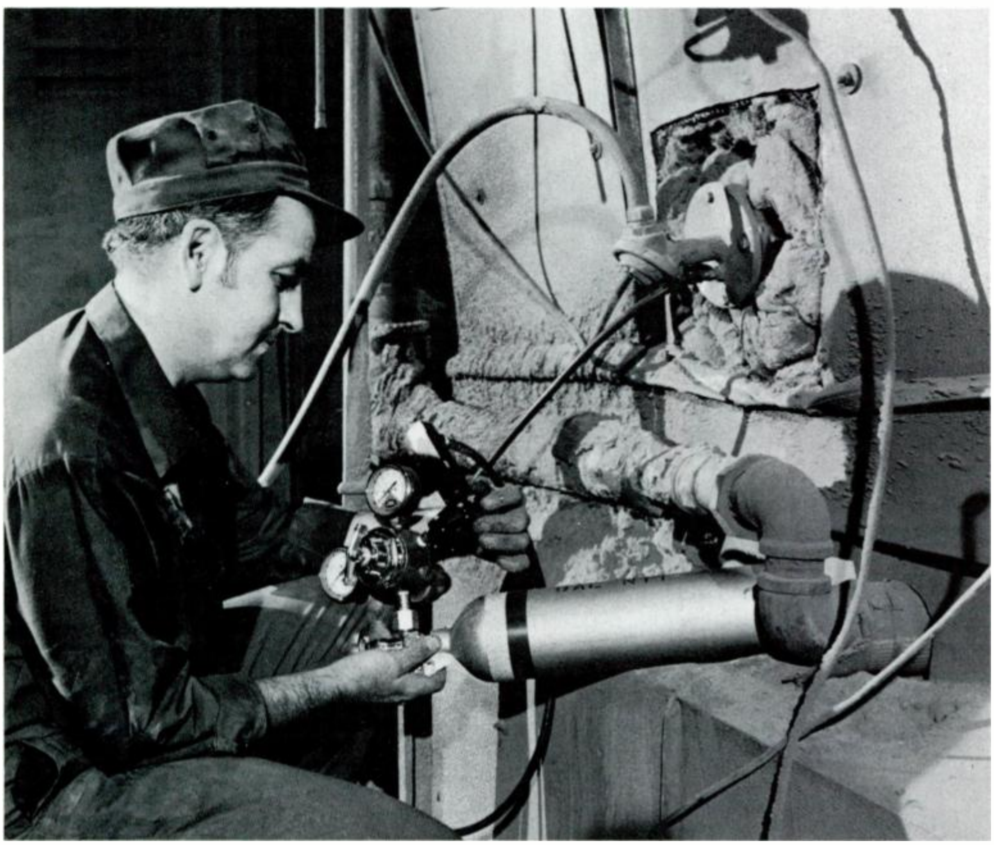
5—The complete Oxygen Analyzer (top) *consists of the assembled probe, a cable connecting the probe to a temperature controller that keeps the cell at the right temperature, a probe shield that supports the probe, an adapter plate for connecting the instrument to the flue, and accessories for controlling the flow of reference air to the cell. The cell is just behind the white filter at the end of the probe. In a typical installation* (bottom), *an opening is made in the flue and the adapter plate is attached there. The shield is bolted to the adapter plate, and the probe is inserted in and bolted to the shield.*

Another device supplied for recalibration is a calibration chamber, which is simply a cylindrical tank in which the probe is placed and supplied with a gas mixture of known composition. The indication from the Oxygen Analyzer is compared with the oxygen content of the calibration mixture.

The standard measurement range is 0.1 to 10.0 percent, but any logarithmic range or any two-decade linear range can be supplied. The choice depends on the process. Most installations for determining excess oxygen in the combustion process are best served by the standard range. Windboxes with oxygen enrichment need 0.3 to 30 percent linear range or 20 to 25 percent logarithmic range, while analysis of an inert-gas blanket needs a parts-per-million range.

Accuracy of the Oxygen Analyzer is ± 5 percent of the actual reading—for example, ± 0.1 percent at 2-percent oxygen concentration. The analyzer can operate in any gas having a temperature up to 760 degrees C.

Because of the direct contact of the cell with the process gas, the cell responds in less than 200 milliseconds. The time constant of the entire system, including the filter, is about 3 seconds. Thus, the control signal is based on what conditions in the process are, not on what they were some time ago.



6—The Oxygen Analyzer can be supplied with provisions for recalibrating it without removing it. A gas mixture with a known percentage of oxygen is passed through a tube to the cell, and the resulting output is compared with the known oxygen percentage in the mixture.

Combustion Optimizing

Combustion efficiency can be significantly improved by optimizing the fuel/air ratio. The best known index for optimizing that ratio is the amount of oxygen in the flue gas available for combination with combustibles. The amount of this oxygen in the flue gas can be determined with the probe-type Oxygen Analyzer far faster than it can with analyzers that employ sampling techniques and far more accurately than by inferential techniques such as measuring air flow. The Oxygen Analyzer continuously reports the amount of available oxygen regardless of what other changes occur.

In the higher ranges of excess oxygen, say 5 percent, a 1-percent reduction in oxygen concentration yields a 1-percent gain in combustion efficiency. In the lower ranges (1 to 2 percent), a 2-percent reduction in oxygen concentration yields a 1-percent gain in combustion efficiency.

Improved combustion efficiency reduces fuel costs. For example, if a boiler operates at 80 percent efficiency rather than 79 percent, and if it is used 48 weeks a year, generates an average of 100,000 pounds of steam per hour, and burns fuel costing $1.76 per million Btu, a genuine saving of $17,695 is realized in fuel costs. Such a saving returns the investment in an Oxygen Analyzer in just a few months. With energy costs rising, oxygen trim control for the fuel/air ratio is increasingly important.

Oxygen trim control is a closed-loop control method that employs the Oxygen Analyzer to introduce an automatic response to changed conditions for the purpose of keeping the fuel/air ratio at an optimum value. It is especially valuable in applications in which frequent control adjustments are made necessary by changes in air humidity, load, and type and quality of fuel. Examples of such applications are

7—A typical boiler control system is diagrammed in simplified form to illustrate how the Oxygen Analyzer provides a feedback signal for closed-loop trim control of the ratio of fuel to air supplied to the boiler. Any change in conditions that results in a change in the amount of oxygen in the combustion gas is sensed by the Oxygen Analyzer, and the resulting signal is used to control the fuel/air ratio at an optimum value.

multifueled utility boilers and refinery boilers fired by waste gas supplemented by natural gas and oil.

A typical oxygen trim control system has the Oxygen Analyzer located in the economizer inlet, where process time lags are at a minimum (Fig. 7).[2] The system maintains the net free oxygen content in the flue gas by automatically trimming the fuel/air ratio as the oxygen concentration deviates from the setpoint. The fast response of the Oxygen Analyzer permits automatic trimming on the basis of what conditions are, not what they were.

The rapid return on investment in an Oxygen Analyzer is augmented by savings in maintenance. An Oxygen Analyzer requires much less maintenance than do instruments that require sampling, typically running maintenance-free for from six months to a year.

Reduction of NO_X emissions is another benefit realized by reducing excess oxygen to an optimum value.

Applications

Applications to date are extremely diverse. They include control of combustion in conventional power boilers, refinery process heaters, boilers fired by blast-furnace gas, chemical recovery boilers, windboxes for NO_X control from exhaust stacks, kilns (lime, phosphate, cement), marine boilers, incinerators, catalytic crackers, bark boilers in the pulp and paper industry, and oxygen enrichment systems.

Conclusion

The Oxygen Analyzer combines high reliability, low maintenance requirements, and high accuracy. In combustion processes, it is an effective means of optimizing fuel use because it provides a reliable input for closed-loop control of the fuel/air ratio.

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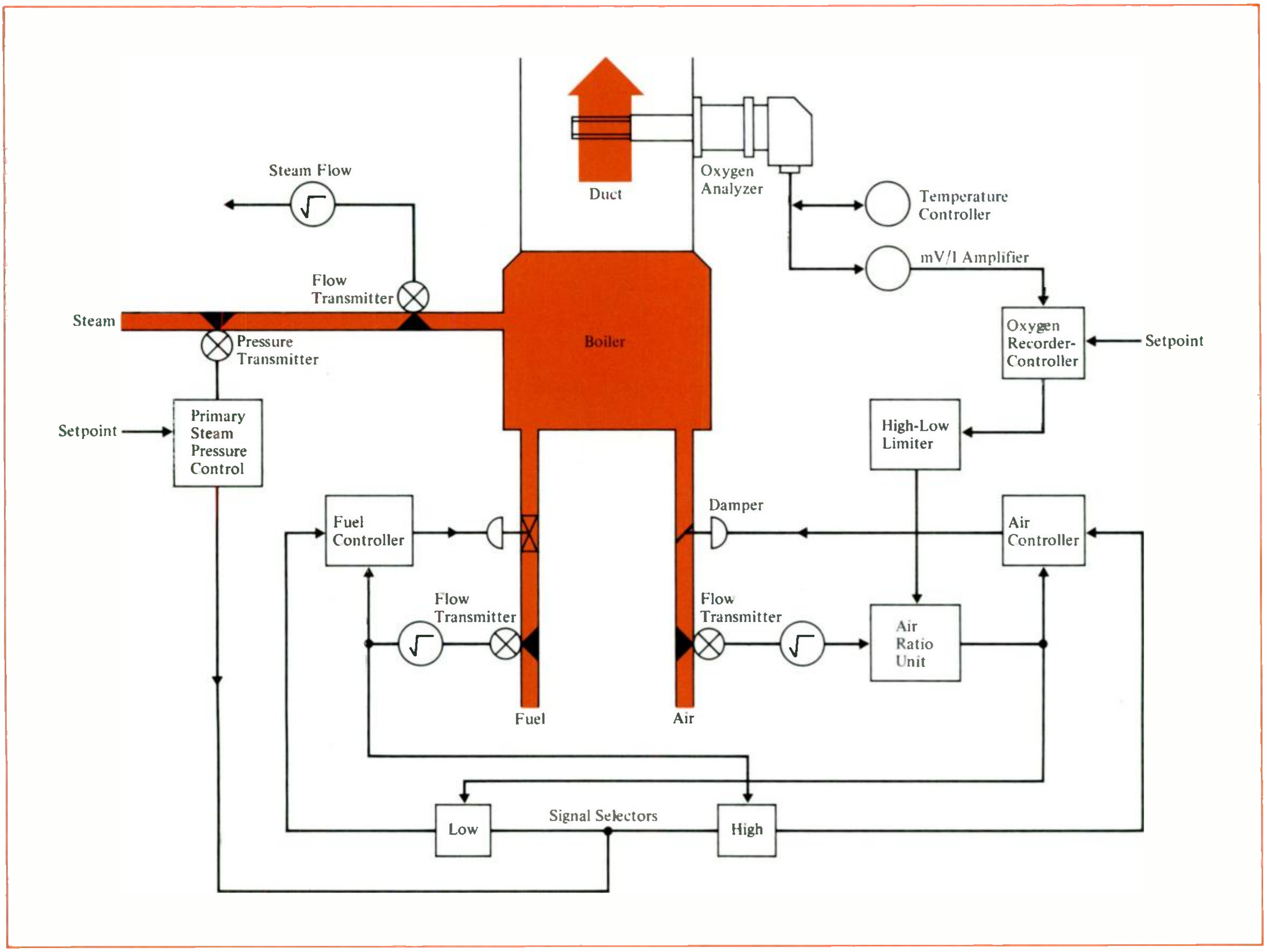

Light Sources—the Types Available and the Factors in Choosing

C. F. Jensen
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As new lamps are developed and older ones improved, more and more factors must be weighed in choosing a type for a given application. However, the greater number of choices available increases the opportunities for effective and economical lighting.

Three general types of electrical light sources are in use today: incandescent, fluorescent, and high-intensity-discharge (HID) lamps. Moreover, HID lamps encompass several subtypes. Both they and the fluorescent lamps are available with "white" light outputs of different colors, that is, different mixes of wavelengths that are perceived as white light but have different color-rendering ability.

The various lamp types also differ considerably in efficiency (more properly called "efficacy" in lighting parlance: the amount of light output for a given amount of electrical power input). The result is considerable difference in the amount of heat output for a given light output, which is an important consideration in designing a building's cooling, heating, and ventilating systems. Efficacy also is increasingly important on its own merits in this day of rising energy costs.

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The inherent linear nature of fluorescent lamps suits them well for many industrial lighting applications. In this TRW Equipment plant in Euclid, Ohio, the lighting provides 100 to 125 footcandles at the working level.

Until fairly recently, HID lamps were in limited use except for industrial and outdoor applications because of their relatively poor color. However, such great improvements have been made in their color that they now compete with the other types for many indoor applications where color rendition is important.

Thus, a wide choice of lamps is now available, and that makes choosing more difficult than it was a few years ago. On the positive side, however, it increases the opportunities available for users to improve the color-rendering ability of their lighting, increase the light level for a given energy expenditure, and/or reduce energy expenditure (and heat output) for a given light level.

Characteristics of the basic lamp types are summarized in the following sections and in Table 1.

Different light sources are often used in combination to obtain the advantages of each, as when fluorescent fixtures are used for the main area lighting in a building and incandescent or HID lamps for decorative effect or to increase the light level in selected areas. An example is the Learning Resources Center at Benedict College, Columbia, South Carolina.

Incandescent Lamps

For many years, improvements in incandescent lamps consisted mainly of steady increases in efficacy made by improving the configuration of the filament. Recent improvements, however, are due primarily to changes in the atmosphere inside the glass bulb that encloses the filament.

Lamps were first made with evacuated bulbs to keep the filament from burning up. Later, it was discovered that pressure exerted on the filament by an inert gas introduced into the bulb retarded evaporation of the filament, thus making it possible to design lamps for higher filament temperatures and therefore higher efficacies. Consequently, nearly all incandescent lamps used for area lighting are gas filled, with the most common fill being a mixture of argon and nitrogen. Krypton is used in some lamps. Because it has a higher atomic weight than argon and nitrogen, krypton slows heat loss from the filament by conduction and convection; the result is a lamp with greater efficacy and/or longer life.

Light Output vs. Life—The life of a lamp and its efficacy are generally interdependent and are determined mainly by filament temperature: the higher the temperature, the greater the efficacy and the shorter the life. A lamp can be designed for long life at the expense of efficacy or for high efficacy at the expense of life. In practice, the life for which a lamp is designed is an economic balance between the two factors, determined by the purpose of the lamp.

Thus, the quality or value of a lamp cannot be judged by its life alone. Lamp life may be as long as 12,000 hours for street lighting, where the high cost of replacing amps justifies lower efficacy. For general-service lamps, where efficacy is more important than long life because replacement s comparatively easy, a life of approximately 1000 hours has become accepted as a practical compromise. (Published data on lamp life refer to the *average* life of a group of lamps under specified test conditions and are not intended as a guarantee of the performance of any individual lamp.)

As a general rule, incandescent lamps should be burned at rated voltage. Overvoltage operation results in higher efficacy but shorter life and higher power consumption; undervoltage operation has the opposite effects.

Lumen Maintenance—An ordinary incandescent lamp's filament gradually sublimes in service, causing a slow but continuous reduction in light output until the filament breaks or burns through at its thinnest spot. Light output is reduced by absorption of light by the sublimed tungsten that collects as a black deposit on the inner surface of the bulb.

In the relatively new tungsten halogen lamps, however, a halogen additive in the bulb reacts chemically with tungsten, continually removing deposited tungsten from the bulb and redepositing it on the filament. The result is a lumen maintenance factor of almost 100 percent.

Varieties—The most commonly used incandescent lamps are *general-service lamps*, which range from the 15-watt A-15 to the 1500-watt PS-52 and are designed for 120-, 125-, and 130-volt circuits. All wattages are manufactured with either clear or inside-frosted bulbs; inside-frosted bulbs are the more popular in wattages of 200 and below. White lamps (Eye Saving T-Bulb and Soft White) have a coating of silica powder on the inside of the bulb for maximum diffusion of light from the filament without glare or harsh shadows. Super Bulbs, another white family, are filled with krypton to provide long life at relatively high efficacy.

Extended-service lamps provide longer life than do general-service lamps (2500 hours compared with 1000 hours). Longer life is achieved by use of a filament of different design, which is stronger at a slight cost in efficacy. They are for use where replacement costs are relatively high. A complete set of wattages paralleling those in the general-service line is available.

Industrial-service lamps have a filament of still stronger design and a life of 3500 hours, again at some sacrifice of efficacy. Rated initial outputs of three sizes of extended-service and industrial-service lamps are compared in Table 3, although that table is primarily for comparison of conventional lamps with the Econ-o-watt lamps discussed later.

Vibration-service and rough-service lamps have added support for the filament to provide lasting service in areas where high vibration frequencies, shock, or rough handling are encountered. The supports conduct some heat from the filament, lowering efficacy somewhat.

Reflectorized lamps provide controlled lighting for a wide range of indoor and outdoor applications. They have a built-in dust-free reflecting surface, so they do not require a fixture to direct the light. How-

Table 1—Characteristics of Basic Westinghouse Lamp Types

			High-Intensity Discharge (HID)		
Characteristics	*Incandescent (including tungsten halogen)*	*Fluorescent*	*Lifeguard Mercury-Vapor*	*Metal-Halide*	*Ceramalux High-Pressure Sodium*
Wattages (lamp only)	15 to 1500	40 to 219	40 to 1000	400, 1000, 1500	150, 250, 400, 1000
Life (hours)	750 to 12,000	9000 to 30,000	16,000 to 24,000	1500 to 15,000	10,000 to 20,000
Efficacy (lumens per watt, lamp only)	15 to 25	55 to 88	20 to 63	80 to 100	100 to 130
Color Rendition	Very good to excellent	Good to excellent	Poor to very good	Good to very good	Fair
Light Direction Control	Very good to excellent	Fair	Very good	Very good	Very good
Source Size	Compact	Extended	Compact	Compact	Compact
Relight Time	Immediate	Immediate	3 to 5 minutes	10 to 20 minutes	Less than 1 minute
Comparative Fixture Cost	Low because of simple fixtures	Moderate	Higher than incandescent, generally higher than fluorescent	Generally higher than mercury-vapor	Highest
Comparative Operating Cost	High because of relatively short life and low efficacy	Lower than incandescent; replacement costs higher than HID because of greater number of lamps needed; energy costs generally lower than mercury-vapor	Lower than incandescent; replacement costs relatively low because of relatively few fixtures and long lamp life	Generally lower than mercury-vapor; fewer fixtures required, but lamp life is shorter and lumen maintenance not quite as good	Generally lowest; fewest fixtures required

ever, a fixture or shield may be desirable to reduce brightness at certain viewing angles. Reflectorized lamps are available in both wide and narrow distribution patterns, and their wattages range from 30 to 1000. The primary types are the PAR for outdoor service and the R for indoor service.

Tungsten halogen lamps (formerly called quartz-iodine lamps) are used for general lighting as well as for various specialty applications. They are superior to other incandescent lamps in thermal shock resistance, combined high efficacy and life, lumen maintenance (as previously discussed), and compact size. They are available in a wide range of wattages and designs.

Application Considerations—Incandescent lamps form a necessary part of the lamp family because of their lower cost, greater versatility, and operating advantages, even though the newer lamp types have higher efficacy. The lamps themselves are lower in cost, and their fixtures are simpler and easier to install. They are more versatile in meeting specific lighting requirements because of the interchangeability of many types and ratings in the same socket. Also, they can be dimmed easily and economically. Versatility and easy dimming give them the best decorative qualities of the three types; imaginative use of the many kinds and shapes of lamps available can set the desired mood for an area.

Incandescent lamps have the operating advantage of continuing to provide light if the supply voltage falls below normal; fluorescent and HID lamps may fail to start or, if operating, may be extinguished. Moreover, the light output of incandescent lamps is not diminished by high and low ambient temperatures as is the output of fluorescent lamps.

Fluorescent Lamps

A fluorescent lamp must have an auxiliary, commonly known as a ballast, to limit current and provide the necessary starting voltage. It cannot be operated directly from the electric lighting circuit because the arc discharge probably would not be established and, if it were, current would rise until the lamp was destroyed. Each type of lamp requires a ballast specifically designed for its characteristics and cannot be interchanged with another type. The kinds of ballast generally used are preheat, instant start, and rapid start.

The electron-emitting material on the electrodes of a fluorescent lamp erodes during the normal starting and burning cycle. To maximize life of lamps operated in instant-start and preheat circuits, the lamps should be turned on and off as infrequently as possible. However, lamps operated in rapid-start circuits (where the cathodes are constantly preheated) show little change in life due to being turned on and off if they are operated for three or more hours per start. Thus, they can be turned off at lunch time, for example, and started after lunch with no loss in rated life. That is an important power-saving feature of rapid-start circuits. Failed lamps in all systems (and starters if required) should be replaced promptly so that abnormal operating conditions will not damage the ballast, starter, or remaining operable lamps.

Application Considerations—Fluorescent lamps have higher efficacy than incandescent lamps, so their total heat output for a given light level is less. In addition, a smaller proportion of their heat output is in the form of radiant ("sensible") heat. Conducted and convected heat, which account for the balance, are chiefly dissipated upward and contribute less to the sensation of heat derived from the lighting installation. However, where total heat is a consideration, as in computing air-conditioning load, the quantity that is important is the total lamp wattage rather than just the radiant heat. It is also necessary to add to the lamp wattage the watts consumed by

Table 2—Color Guide for White Fluorescent Lamps

Lamp Description	*Atmosphere*	*Efficacy (lumens per watt)*	*Color-Rendering Index*	*Coordinated Color Temperature (degrees K)*	*Lighted Appearance (ICI color coordinates)*	
					X	*Y*
Cool White	Cool	78	66	4100	0.372	0.375
Cool White Deluxe	Cool	56	87	4200	0.369	0.363
White	Warm	80	58	3500	0.409	0.394
Warm White	Warm	80	53	3000	0.435	0.402
Warm White Deluxe	Warm	54	71	3000	0.430	0.389
Daylight	Cool	65	73	6500	0.313	0.337
Living White	Cool	60	93	4300	0.369	0.363
Natural	Warm	52	77	3650	0.388	0.361
Supermarket White	Cool	58	85	4500	0.362	0.375
Merchandising White	Warm	60	80	3450	0.409	0.396

Modern HID lamps were first applied outdoors, and that is still a large application area because of their long life and high efficacy. Metal-halide lamps were chosen to illuminate loading areas at Minneapolis/St. Paul International Airport.

any ballast located within the area in question.

The starting of fluorescent lamps is affected by ambient temperature: low temperatures require higher voltages for reliable starting. Most ballasts provide voltages that start lamps down to 50 degrees F, and ballasts are available to start certain lamp types down to −20 degrees F.

Light output, also, is affected by ambient temperature. Rated lumen output is obtained when measured at 77 degrees F, and output may be less at higher or lower temperature. Therefore, it is important to select the proper lamp and fixture for the application temperature range.

Total performance depends on the voltage supplied to the ballast. In general, it is satisfactory when voltage remains within ±10 percent of rated voltage.

Another consideration that enters into selection of a lamp is its color appearance, or atmosphere (Table 2). A "warm" atmosphere has a connotation of friendliness, relaxation, or coziness, while a "cool" atmosphere connotes efficiency, alertness, and neatness.

Among the white lamps, cool white, warm white, and white have the highest efficacies and are normally used in industry, general office areas, and other places where economical light production is required. Where a high degree of color rendering is desired, however, the lamps with high color-rendering index should be used.

Color-preference ability is the ability of a lamp to make colors appear not as they actually are but as people prefer to see them. It is an important consideration in merchandising and other commercial applications, and it prompted development of the Living White lamp. The Living White lamp is particularly flattering to human complexions and also reveals the full beauty of house furnishings, merchandise, and other colored objects.

High-Intensity-Discharge Lamps

These are usually called HID lamps, and the term applies to any enclosed intense light source of the arc-discharge type. Light is produced in an arc tube by current passing through a vapor at relatively high pressure compared with the low pressure in fluorescent lamps. Arc-tube pressures for popular HID lamps range from about one-third to eight atmospheres. The arc tube is usually enclosed in an outer glass bulb. The HID family includes mercury-vapor, self-ballasted mercury-vapor, metal-halide, and high-pressure sodium lamps.

In mercury-vapor lamps, mercury forms the light-producing vapor. Metal-halide lamps contain not only mercury but also compounds of sodium and scandium with iodine. Phosphors are coated on the inside of the outer bulb of some mercury-vapor and metal-halide lamps to improve color, increase light output, and/or reduce surface brightness. High-pressure sodium lamps contain sodium and mercury; their name is perhaps misleading because pressures in the arc tube are always less than atmospheric, and the outer bulb encloses a vacuum.

All HID lamps require a few minutes starting time to develop full light output and characteristic color. Like fluorescent lamps, all except self-ballasted mercury-vapor lamps require an auxiliary control device generally called a ballast. Ambient temperature generally has little effect on mercury-vapor lamps, but it may influence the color and light output of metal-halide and sodium lamps.

Light Color—The mercury arc produces strong line spectra in the ultraviolet and visible region of the spectrum, with the visible output mainly in the violet, blue, green, and yellow areas. Phosphor-coated mercury-vapor lamps emit, in addition, some continuous energy provided by the fluorescent radiation of the particular phosphor used. Those lamps have gone far toward overcoming objections to the colors previously available in mercury-vapor lamps. For example, the Beauty Lite lamp produces light that is cool looking but flattering, and the Style-Tone lamp produces a warm-looking light that resembles incandescent light.

In metal-halide lamps, the basic mercury spectrum is modified or supplanted by radiations characteristic of the halides used in the lamp, improving the color. Color varies with the types of materials added and the quantities of each vaporized in the arc stream; the latter is a function not only of lamp design but also of auxiliary equipment and operating conditions, so some color difference among metal-halide lamps is normal.

High-pressure sodium lamps emit light mainly in the yellow and orange portions of the visible spectrum, with additional output in all other portions. They produce little ultraviolet radiation, so phosphors are not useful for color improvement.

High-pressure sodium lamps must not be confused with low-pressure sodium lamps, which emit a monochromatic yellow light. The latter are used to some extent in a few European countries, mainly for street lighting. They have found little use in this country, and Westinghouse does not make them, mainly because of their extremely poor color rendition. It is virtually impossible to distinguish the colors of vehicles illuminated by them, so they are objectionable to most police departments. Moreover, they are much bulkier than HID lamps of comparable light output.

Application Considerations—The popularity of HID lamps for outdoor use is the result of many advantages, including low operating cost per footcandle because of high efficacy and long lamp life, which minimizes relamping costs. Their light can cover wide areas because their fixtures can provide good optical control, especially with clear lamps. They have peak performance at all outdoor temperatures when operated with a suitable ballast. An appropriate color is available for almost any outdoor application.

High-pressure sodium lamps are the most widely used outdoors because they have high efficacy, optical control is excellent because of their small size, and their warm uniform golden-white color is suitable for such applications as streets, highways, building floodlighting, parking lots, and parks. Deluxe White or Beauty Lite mercury-vapor lamps are recommended for roadways where superior color rendition and good color uniformity are desired or to make people, buildings, poster-boards, or surroundings look natural. Style-Tone mercury-vapor lamps are recommended for similar applications where a warm tone, similar to that of incandescent lamps, is desired. Metal-halide lamps are recommended particularly for outdoor and indoor sports lighting, parking lots, building floodlighting, and other applications where their good color rendition is useful.

A wide selection of ornamental, compact, and efficient luminaires is available. Floodlights are available with various beam spreads for lighting ground areas, sports fields, buildings, and advertising posters.

For the interiors of industrial buildings, high-pressure sodium lamps are increasingly specified because their high efficacy makes them more economical than other light sources for most areas. Metal-halide lamps, although somewhat lower in efficacy, are also becoming more popular for industrial use, and Deluxe White mercury-vapor lamps continue to be used widely.

For the interiors of commercial buildings, both metal-halide and the best phosphor-coated mercury lamps (Style-Tone and Beauty Lite) are increasingly used. Examples are supermarkets, shopping malls, banks, department and discount stores, gymnasiums, libraries, auditoriums, and transportation terminals. Advantages are low operating cost because of high efficacy, low maintenance cost because of the relatively small number of lamps to be

Table 3—Performance and Economic Comparison of Conventional and Econ-o-watt Lamps

Lamp	*Power Consumption (lamp watts)*	*Rated Initial Output (lumens)*	*Rated Average Life (hours)*	*Power Cost Saving* (dollars)*
Incandescent, Extended Service				
Conventional	60	740	2500	
Econ-o-watt	54	645	2500	0.45
Conventional	100	1480	2500	
Econ-o-watt	90	1230	2500	0.75
Conventional	150	2350	2500	
Econ-o-watt	135	1990	2500	1.14
Incandescent, Industrial Service				
Conventional	60	670	3500	
Econ-o-watt	54	590	3500	0.63
Conventional	100	1280	3500	
Econ-o-watt	90	1090	3500	1.05
Conventional	150	2150	3500	
Econ-o-watt	135	1790	3500	1.59
Fluorescent, 48-Inch Rapid-Start Cool White				
Conventional	40	3150	20,000+	
Econ-o-watt	34	2800	20,000	3.60
Fluorescent, 48-Inch Rapid-Start Warm White				
Conventional	40	3200	20,000+	
Econ-o-watt	34	2900	20,000	3.60
Fluorescent, 96-Inch Cool White				
Conventional	75	6300	12,000	
Econ-o-watt	60	5220	12,000	3.60
Fluorescent, 96-Inch Warm White				
Conventional	75	6400	12,000	
Econ-o-watt	60	5340	12,000	3.60
Mercury-Vapor, Clear				
Conventional	400	21,000	24,000+	
Econ-o-watt	300	14,000	16,000+	48.00
Mercury-Vapor, Deluxe White†				
Conventional	400	23,000	24,000+	
Econ-o-watt	300	15,700	16,000+	48.00

*Approximate saving from use of Econ-o-watt lamps in place of conventional lamps.
Based on rated average life of Econ-o-watt lamps and on power cost of $0.03 per kilowatthour.
†Phosphor coated.

Steady improvement in the color of light from HID lamps has made them advantageous in many indoor applications. For example, Style-Tone mercury-vapor lamps are used at American Federal Savings and Loan Association, Des Moines, Iowa, to provide a bright yet comfortable environment for work.

serviced and the ease of replacing them (often with a stick changer), more attractive ceiling appearance as compared with some fluorescent fixtures, and, for stores, more vertical footcandles, making objects easier to see on lower shelves.

Adequate Lighting versus Costs

Lighting is one expense that is amenable to control because the various lighting systems have different first costs and operating costs, and because lighting levels can be controlled. In addition to the general desirability of controlling expenses, avoiding wasteful use of electric power is in the national interest in this era of energy shortage. Operating costs depend partly on power requirements, which can be controlled in several ways involving use of the more efficient lamp types and control of lighting levels.

Using More Efficient Lamps—When it is feasible to change the lighting system itself, electrical energy can be saved and/or lighting upgraded by substituting more efficient lamp types for less efficient types. If new fixtures with high-pressure sodium lamps are substituted for those with conventional mercury-vapor lamps, for example, the power saving can be as high as 40 percent while at the same time light output is increased 23 percent.

Controlling Lighting Levels—The lighting industry has, for many years, studied lighting requirements by laboratory measurements and also in real work situations. On the basis of the studies, the Illuminating Engineering Society has recommended minimum lighting levels for a wide variety of representative industrial operations and other visual tasks[1]. Many of the recommendations have been approved as standards by the American National Standards Institute (ANSI)[2]. The recommendations should be followed because lighting makes an important contribution to health, safety, productivity, sales, and security. Outdoor lighting is as important as indoor; high lighting levels on roadways, for example, reduce the "surprise factor" by making moving objects more visible. Any changes in lighting levels should be carefully planned with the help of a qualified lighting engineer.

However, if the lighting level in an area is higher than the recommended level, several options for reducing it are open to the user. By far the most efficient way is to keep lamps in all fixtures but replace existing lamps with lower-wattage lamps. Three new lines of lamps have been designed specifically for this period of energy shortage. These Econ-o-watt lamps include incandescent, fluorescent, and mercury-vapor varieties (Table 3).

Besides directly reducing the amount of electrical energy consumed by the lighting system, using Econ-o-watt lamps instead of just turning lights off can lower the cost of power by helping maintain adequate power factor. Most lighting equipment is a load with high power factor, which helps offset the low power factor of some machinery. If power factor is not maintained, extra charges may be imposed by the electric company, and those charges may far exceed the dollar savings that had been anticipated by turning lights off. For example, a large automobile manufacturer recently found that turning off a considerable number of lights in one plant lowered the overall plant power factor; the minimum power factor requirement was not met, explaining in part why monthly bills jumped 25 percent.

Use of Econ-o-watt lamps for reducing energy expenditure has the further advantage of preserving the general appearance and light distribution of the lighting system. It helps prevent creation of unsafe dark areas that can result from an improvised lamp-removal sweep through a facility.

Another acceptable way to control light levels is to connect individual or small groups of fixtures to convenient switches. Selected fixtures can then be turned off when not needed, and switched on again when a temporarily higher light level is required. Care must be taken to prevent dangerously dark areas. Switches should be prominently identified as to their purpose; for example, normally off switches can be labeled "For Temporary High-Level Lighting Only." Timers or photoelectric devices can be used to turn lights off when personnel are not available to do it.

Removing fluorescent lamps from some fixtures, or allowing burned-out lamps to stay in the fixtures, disrupts the lighting pattern. Besides, it does not necessarily save the full wattage of the lamps removed or burned out. For instance, when both 40-watt fluorescent lamps are removed from alternate two-lamp fixtures in a multilamp installation, the series ballast in those fixtures continues to consume 8 to 9 watts. Removing only one lamp in the modern starterless system (series-sequence) is not recommended because it can cause improper operation that could damage the other lamp and/or the ballast. If lamps must be removed, both lamps served by a two-lamp starterless ballast should be taken out. The ballast continues to use power, however, in an amount that depends on the type of ballast.

When a 400-watt mercury-vapor or metal-halide lamp in a multilamp system is removed from a fixture containing or connected to a regulated autotransformer ballast (common in such systems), the fixture continues to consume approximately 23 watts. If the lamp is a high-pressure sodium lamp, the power consumed by the ballast (with the lamp removed) may be as much as 88 watts; moreover, the starting circuit may be damaged and the ballast life shortened.

Lamps and ballasts may be important contributors to the heating of a building in winter months, so a substantial reduction in existing lighting could require use of considerably more energy to heat the building. The savings in lighting cost then are reduced by increased costs for heating. Moreover, the electric energy used by the lighting system is generated largely by fuel types that are not ordinarily suitable for heating buildings, so a reduction in lighting could increase the rate at which fuels in relatively short supply, such as gas and heating oil, are used up.

The light reduction caused by wattage-reduction measures can be minimized by some simple steps, which can also improve the output of an existing system. First, fixtures should be cleaned regularly. Dirt buildup on reflecting surfaces and lenses can reduce light output as much as 50 percent.

Second, the walls and ceilings of the facility can be cleaned and/or painted. Dirty or dark-colored surfaces greatly diminish the amount of light reaching the task area.

Third, lamps can be replaced more frequently than was done in the past. Light output drops as a lamp ages. The problem is especially severe with long-lived light sources such as fluorescent and HID lamps, because the light produced near the end of life may be less than 50 percent of the original value, although the lamp continues to use the same amount of energy. If relamping in incandescent systems is done more frequently than normal, lamps with greater light output but shorter life can be used. There is no single best time or way for all users to relamp, so the computer has been brought in to help solve the problem. An example is the Westinghouse computerized Lighting Cost Reduction Service. After human study and computer analysis, this service tells the user the most economical time for him to change his lamps. In addition, it suggests interchangeable lamps that may be more economical for his particular installation.

Conclusion

Lighting systems serve a wide range of applications that require specific designs for specific tasks. Incandescent, fluorescent, and HID lamps are made because all three are needed. Before changing the type of lamp or removing lamps in an existing system, or designing a new system, the lighting task should be carefully evaluated. A qualified lighting engineer can be of invaluable assistance.

The computer is instrumental in helping designers to determine the most economical and efficient lighting system and in scheduling group relamping. Its use is being continually expanded to compare lighting maintenance practices and to tailor lighting systems.

And technical advances continue. There will be more shades of white light available in both HID and fluorescent lamps, more use of HID lamps in stores and other commercial facilities, more specialized lamps of all types, and still more efficient light sources.

Incandescent lamps will be improved in versatility, resistance to breakage, and decorative quality.

The most significant development in fluorescent lamps will be a combination of phosphors that will provide light with efficiency comparable to that of existing cool white or warm white lamps but with the color rendition of deluxe lamps. That will drastically reduce the initial cost of a fluorescent system utilizing lamps of excellent color quality.

A greater variety of HID whites with high efficacy and improved color-rendering ability will become available, similar to the range of fluorescent whites now in use. HID indoor lighting costs, already favorable in high-ceiling locations, will become more comparable to those of fluorescent in stores and other relatively low-ceiling locations. Useful as metal-halide lamps are now, their most significant feature is their potential. They offer the greatest opportunities for developing higher efficacy and highly acceptable color rendition. Improvements also will be made in color uniformity, lumen maintenance, and life.

All in all, two things seem certain for the future: a user's lighting options will increase and, therefore, the task of picking the right lighting for his particular situation will become even more difficult. It will require even more careful consideration and expert help than it does now.

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[2] American National Standards Institute, New York, N.Y.

Half-Hour Weather Updating Provided by Satellite and Recorder System

Ground stations located anywhere in the western hemisphere can now receive pictures showing the hemisphere's cloud cover every 30 minutes. The stations record the changing cloud patterns day and night by monitoring signals being returned by the first synchronous meteorological satellite (SMS-1).

Small receiving stations (18- to 25-foot antenna dish) suffice to receive the weather data, which is then recorded on 22- by 22-inch dry film by means of a laser-beam recorder developed by the Westinghouse Defense and Electronic Systems Center. The recorder can produce a ready-to-use image of the hemisphere every 30 minutes with high resolution (half-mile square).

Using a laser beam to expose film has the advantages of high recording power, high signal-to-noise ratio, and ability to handle large amounts of data quickly. More than 10 billion bits of data must be handled in a 20-minute period to produce the high-resolution visible-light images of the earth. The laser film recorder has a rotating drum that is automatically loaded with 22-inch by 22-inch dry-process film from a supply cassette. A vacuum system holds the film to the drum during recording. The beam intensity of the helium-neon laser is modulated by the incoming video signal while the film drum rotates, and the scan lines are advanced by an incrementally driven lens carriage. When recording is complete, the film is unloaded from the drum into a heat processor for quick developing.

The SMS-1 satellite is positioned over the equator just off the coast of Brazil. It was launched by NASA for the National Oceanic and Atmospheric Administration (NOAA). Weather information from it is received at a very high data rate during a small portion of the satellite spin—when the sensor is pointed at the earth. Large antennas and complex ground equipment are required to receive this data at NOAA's Command and Data Acquisition Station, Wallops Island, Virginia. During the remainder of the satellite spin—when the weather sensors are pointed away from the earth—the Wallops Island station "stretches" the weather data and sends it back to the satellite at a slower data rate. The satellite acts as a transponder and retransmits the stretched weather data to smaller and simpler satellite stations that can be located anywhere in the western hemisphere. Westinghouse integrated the components of the SMS ground stations and built the ground-synchronizer and data-stretcher systems used at Wallops Island.

Production-Design AWACS Antenna Tested

Range testing and electromagnetic interference testing have been successfully completed on the production-design radar antenna for the Airborne Warning and Control System (AWACS).* The AWACS system can detect and track aircraft, even those flying at low altitude, in a large volume of air space. The Boeing Company

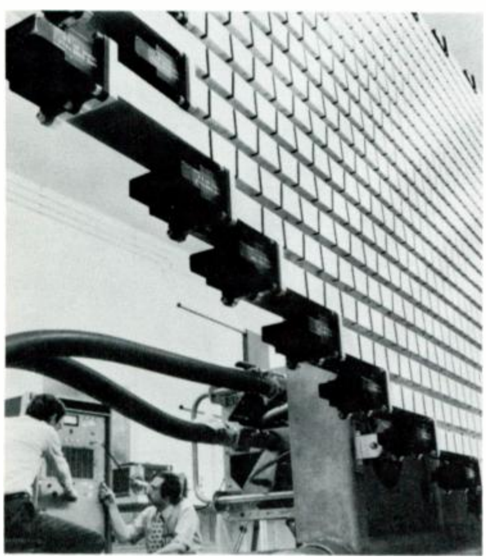
*R. E. Hendrix, "Overland Downlook Radar Is Key Element of AWACS," *Westinghouse ENGINEER*, July 1973, pp. 98-105.

Views of the western hemisphere with its weather patterns are transmitted from the SMS-1 satellite and recorded at ground stations by laser-beam recorders. A picture can be made every half hour for close monitoring of weather movements.

This equipment provides the means for controlling SMS satellites and for acquiring, synchronizing, and stretching the data received from them. It is located at NOAA's Command and Data Acquisition Station.

is prime contractor to the U. S. Air Force for the AWACS program, and the Westinghouse Defense and Electronic Systems Center is building the production-design surveillance radars for it. The radar is very difficult to jam with either airborne or ground-based countermeasures equipment because the latest counter-countermeasures techniques are built into it.

The production-design radar antenna is highly reproducible and requires no tuning after assembly and installation. It is essentially identical to the antenna produced for the brassboard competition phase of the AWACS program. The differences between the production-design and brassboard antennas are mainly repackaging and relocation of the phase shifters and electronics. The phase shifters, which provide electronic vertical scanning, were located at one end of the antenna for easy access during maintenance and for improved weight distribution. The electronics packages, which provide phase control and the first stages of signal amplification, were located at the other end of the antenna.



The production-design AWACS radar antenna is shown during preparation for electromagnetic interference testing.

Repackaging and relocation reduced antenna weight from 2800 to 2150 pounds.

Power Circuit Breakers Tested in New Laboratory

A new laboratory facility for mechanical testing of power circuit breakers and components expands the Westinghouse Power Circuit Breaker Division's testing capability by providing more space and sophisticated equipment. Tests that can be performed include static and dynamic straingage measurements, acceleration testing, static and dynamic pressure measurements, timing history and synchronization, life testing, high-speed photography, and seismic testing.

The 4200-square-foot facility has a rollup door 15 feet wide by 18 feet high, which provides easy movement of circuit breakers and other large equipment in and out of the test area. A 15-ton portable hydraulic crane is used to lift and move heavy equipment and material. Ceiling height is 33 feet.

Besides serving the Division, the laboratory's facilities are available on a contract basis to other organizations.

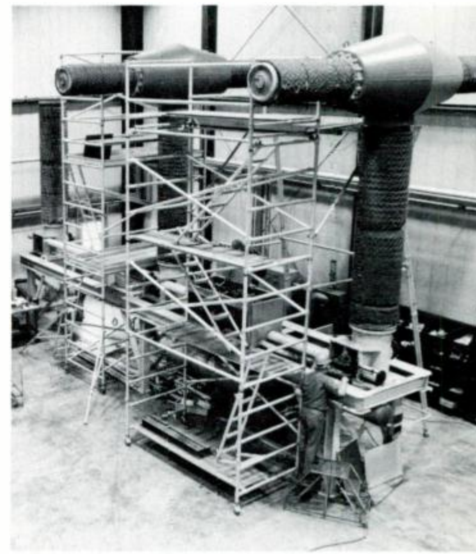
Independent Pole Operation Provided in Power Circuit Breaker

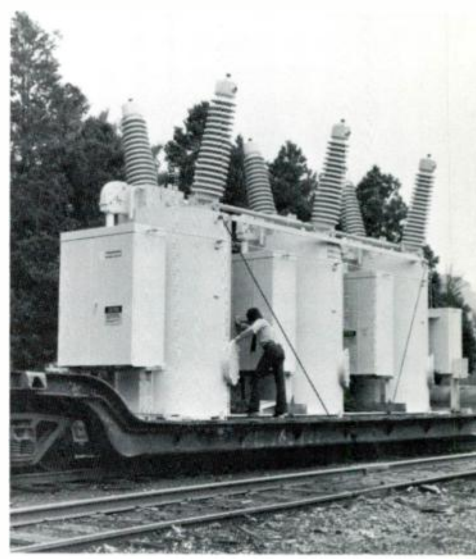
The first 242-kV Trim-Tank power circuit breaker equipped with independent pole operation (IPO) has been shipped by the Westinghouse Power Circuit Breaker Division. It went to Louisiana Power and Light Company's Motor Switch Siding substation near Metairie, Louisiana.

The new option of independent pole operation improves system stability by eliminating the possibility of all three breaker poles being stuck in the closed position during a three-phase system fault.* Each breaker phase unit is equipped with a separate pneumatic operating mechanism. If one or more mechanisms fail to operate during a system fault, the remaining mechanisms continue to operate.

The Trim-Tank IPO power circuit breaker is available in interrupting ratings from 40,000 to 63,000 amperes, with up to

*C. L. Wagner, H. E. Lokay, "Independent-Pole Circuit Breakers Improve System Stability Performance," *Westinghouse ENGINEER*, Sept. 1973, pp. 130-137.





Top—*Mechanical testing laboratory is shown wit tests in progress on an EHV power circuit breaker*

Bottom—*This Trim-Tank power circuit breaker i equipped with the optional independent pole operation*

Right—*The stator for a generator rated at 1,305,00 kW squeezes its way out of the yard at the Westing house East Pittsburgh plant. It was shipped to Duk Power Company's McGuire No. 1 nuclear powe station on a special Schnabel car.*

000 amperes continuous current. It can be hipped completely assembled to most ocations.

lassive Generator Shipped to)uke Power Company

'he largest generator designed and manu- actured by the Westinghouse Large Rotat- ng Apparatus Division has been shipped to)uke Power Company's McGuire No. 1 uclear station, located about 25 miles orth of Charlotte, North Carolina. The enerator is rated at 1,305,000 kW— nough to meet the electric needs of more han 600,000 people when it goes into oper- ition early in 1977. Assembled, the unit is early 50 feet long and weighs more than 00 tons. Its stator alone weighs more han 500 tons.

The stator was designed for shipment n Westinghouse's largest railroad car, a 2-axle Schnabel car. (See photograph.) A uitable route had to be mapped out with he railroads, and Duke Power Company uilt a special railroad track into its plant ite for the final leg of the trip.

Thorough engineering tests performed before shipment included, in addition to normal engineering verification tests, high-speed movies made during sudden short circuits. Other special tests analyzed the vibration characteristics of the unit's winding and bracing components.

A duplicate generator for Duke Power Company's McGuire No. 2 nuclear station will be shipped next year.

Flat Display Panels Employ Matrix of Thin-Film Transistors

Flat electroluminescent panels for information display have been developed by combining a large thin-film integrated circuit with a phosphor, all deposited on a sheet of glass. Prototype units demonstrated recently are 6 by 6 inches square and consist of 12,000 light-emitting elements. (See photographs on back cover.)

Potential applications include alphanumeric displays, vectorgraphic displays (such as radar screens), and video displays. The display panels are being developed at the Westinghouse Research Laboratories. The work is partly supported by the U. S. Army Electronics Command, which sees potential application in lightweight portable field message units.

The integrated circuit for a 12,000-element screen consists of a matrix of 24,000 thin-film field-effect transistors and 12,000 capacitors vacuum-deposited on the glass substrate. It is composed of one basic circuit repeated at each element location (see diagram). That basic circuit consists of an X-Y-addressed logic transistor (T_1), a power transistor (T_2), and a storage capacitor (C_S) interconnected by source, power, and gate bus bars. The completed integrated circuit is covered with an organic insulating film, which is opened at each element location to expose the drain pad of the power transistor. The circuit next is coated with a phosphor material, and then a front electrode is formed by depositing a translucent conducting layer onto the surface of the phosphor; those two steps form an electroluminescent cell at each element location. Finally, the panel is sealed with a glass cover plate.

For operation, the power bus bars are connected to a source of ac power, and the source and gate bus bars are connected to the outputs of a conventional display signal generator. A signal on a gate bus bar gates that entire row of logic transistors. Then, when a signal appears on a source bus bar, the logic transistor at the intersection (T_1) conducts power and thereby gates the power transistor (T_2). That transistor conducts, and the resulting voltage across the electroluminescent cell causes the phosphor to glow.

The brightness of the electroluminescent cell is determined by the voltage on the gate of the power transistor and across the capacitor. That voltage is controlled by controlling the voltage on the source bus bar, and brightness information is stored for a frame period on the storage capacitor. Brightness control can be used to provide shades of gray in the display.

The manufacturing process being developed employs vacuum deposition equipment that allows all materials to be deposited in a single pumpdown of the vacuum chamber, with material sources and masks changed for each step from outside the chamber. The process is well adapted to automation.

Continuing development work includes improving the resolution (20 lines per inch in the prototype), developing full color displays, and designing thin-film addressing, scanning, and decoding circuits that can be deposited on the substrate simultaneously with the matrix.

The thin-film circuits can be used with display materials other than phosphors. For example, panels have been built with nematic liquid crystals that act as light valves, instead of glowing, when a voltage is applied across them.

Production Integrated in New Distribution Equipment Plant

Production of electrical distribution equipment is now in full swing at the new St. Louis, Missouri, plant of the Westinghouse Distribution Equipment Division. The plant enhances the Division's ability to serve customers because of its increased capacity and because of the efficiencies created by consolidating two previous manufacturing facilities into one.

The plant manufactures panelboards, switchboards, and power assemblies used to protect the electrical distribution systems of commercial buildings and industrial plants. Its developer and general contractor was the Linclay Corporation; the architect was Eugene J. Mackey III.

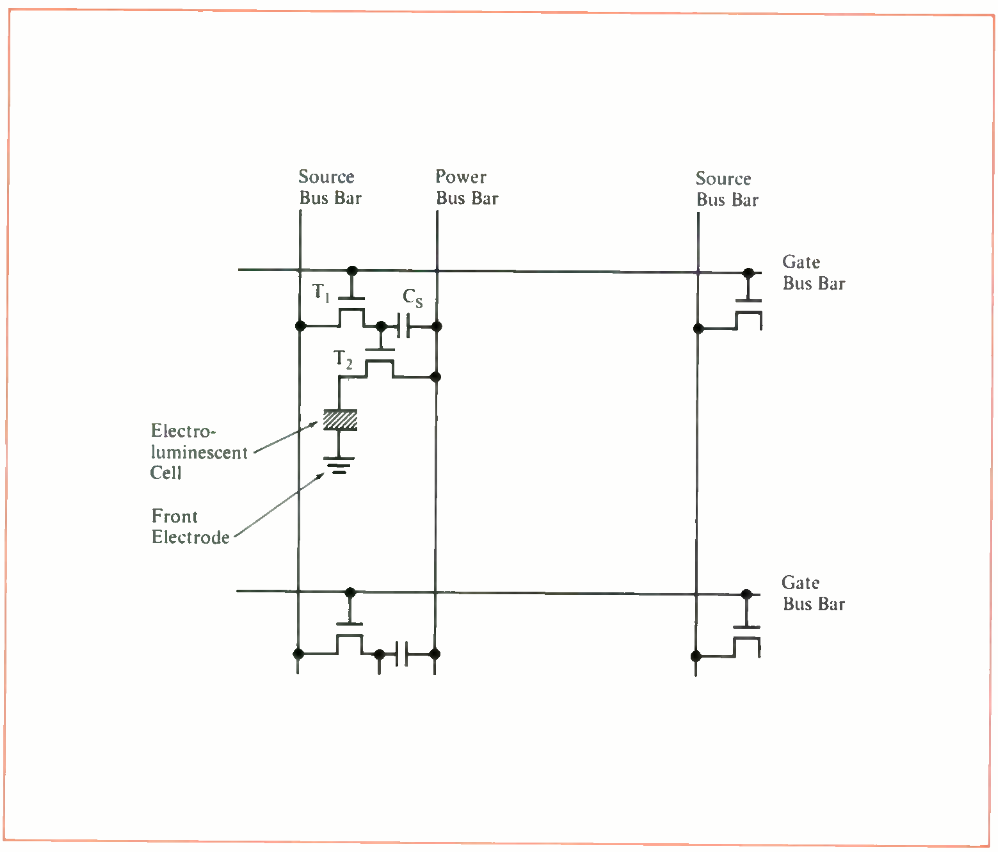
The plant's products are tested by putting electrical loads on them before they leave the plant. Then they are readied for shipment and sent to their destinations.

Data System Facilitates Medical Examinations

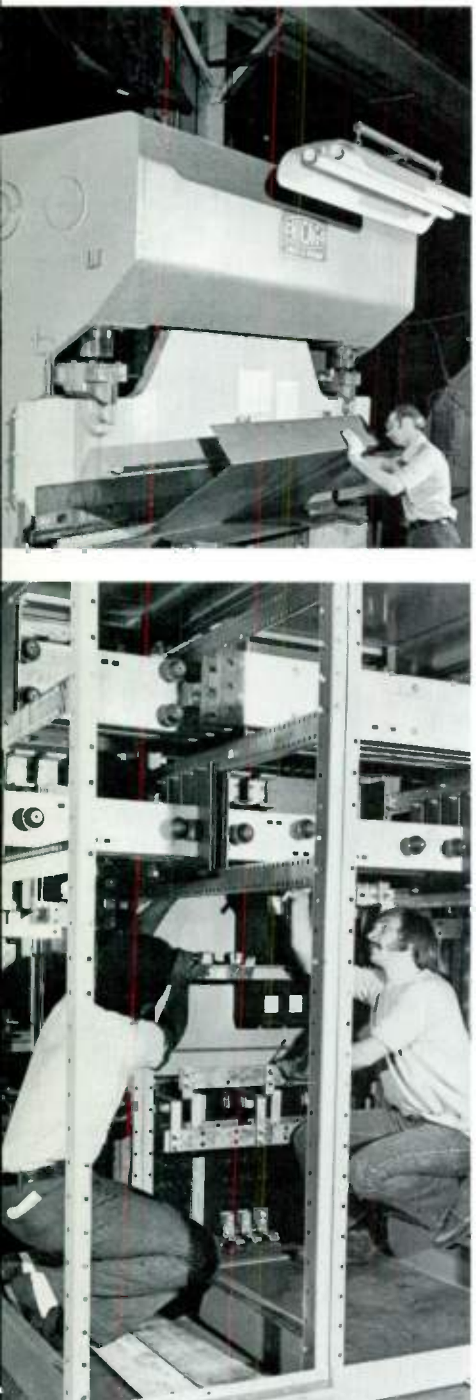
An audio system for taking medical histories has been developed by the Westinghouse Health Systems Department. Called the DataQuest I system, it allows a patient to give his history with little instruction. It produces a printed copy of the history either immediately or at a later time to guide the physician during the physical examination.

The system employs audio tape cassettes containing appropriate questions. The patient responds to each question by pushing buttons on a console, and his response to each question determines what question will be asked next.

Because the system asks the questions verbally, it can be used by nearly any patient including one who has difficulty



The flat display panel has a matrix of thin-film transistors and electroluminescent cells that form the information display. One intersection point in the matrix is diagrammed to show the basic circuit that is repeated throughout the matrix. When the logic transistor (T_1) *receives a signal from both the source and the gate bus bars, it in turn gates the power transistor* (T_2) *and thereby causes the electroluminescent cell to glow.*



Switchboards, power assemblies, and panelboards re manufactured in a new plant of the Distribution quipment Division. At top, sheet steel is being bent o form a panelboard box; at bottom, buswork and lectrical connections are being installed.

reading or has a language barrier. Questions can be asked in a foreign language and the responses printed in English. An option permits the patient to telephone his history from home, office, or hospital bed.

Although the DataQuest I system is not computerized, it can be linked to any computerized information system. Also, it can be applied without hardware modification to applications other than medical history taking, such as personnel interviews or counseling.

Reactor Guard Vessel Installed at Fast Flux Test Facility

The reactor guard vessel has now been installed in the Fast Flux Test Facility (FFTF) at Richland, Washington. Scheduled for completion in late 1977, the FFTF will be used to test fuels and components for liquid-metal fast breeder reactors.

The guard vessel weighs 122 tons, is 38 feet long, and is 23 feet in diameter—the largest diameter of any stainless-steel vessel ever manufactured in the United States. It was lowered into the reactor cavity, and then workers did the welding and other work necessary for installation of the 350-ton reactor vessel inside the guard vessel.

The guard vessel was built to the standards of the U.S. Atomic Energy Commission by Combustion Engineering, Inc., under contract to the Westinghouse Advanced Reactors Division. It is one of many safety features being built into the FFTF, providing a backup to the reactor vessel and assuring that coolant will always be available to the reactor core.

While work on the FFTF progresses, testing is under way in connection with the liquid-metal fast breeder reactor program at separate facilities of the Richland site. At the High Temperature Sodium Facility, scientists and engineers are testing a prototype of the FFTF's instrument tree, which will monitor temperature and flow characteristics of liquid sodium in the reactor vessel. Testing of a prototype of the in-vessel fuel handling machine is scheduled to begin this month. The machine will be used to move fuel assemblies in the FFTF by remote control.

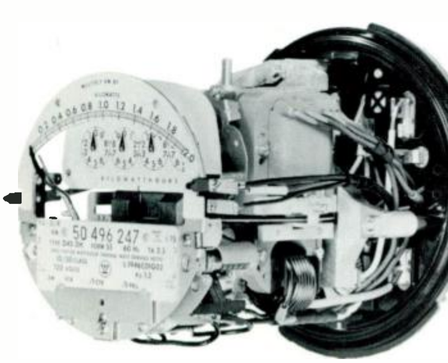
Westinghouse Hanford Company, a subsidiary of Westinghouse Electric Corporation, is responsible for development, construction, and operation of the FFTF and operates test facilities at the Richland site for the Atomic Energy Commission.

Workmen lower the Fast Flux Test Facility's guard vessel into the reactor cavity. The guard vessel is one of many safety features built into the FFTF, which will be used to test fuels and components for the nation's liquid-metal fast breeder reactors.

Postforming plastic laminate, called superform, can be formed more reliably over a broader range of temperatures and to smaller radii than other such laminates can. It forms easily to a half-inch outside radius over a temperature range of 300 to 350 degrees F; with properly adjusted equipment and skilled personnel, it has been formed successfully over even broader temperature ranges and to tighter radii. *Westinghouse Decorative Micarta Division, Hampton, South Carolina 29924.*

Polyphase thermal demand meters, Type D4S-H, are available in two-stator socket types for use with three-phase three-wire, three-phase four-wire delta, or three-phase four-wire wye connections, Class 100 or Class 200 self-contained and Class 20 transformer rated. Dual scale ranges of 10/20, 50/100, and 100/200 amperes as well as 120-, 240-, 277-, and 480-volt ratings are also available. The new meter series retains important features of the D4 polyphase family including a flat load curve for extended current load ranges, valve-type arresters for surge protection, magnetic bearing system, and filter-seal system for proper air flow and drainage. Other features are a simplified adjuster system on both the kilowatt demand and kilowatt-hour meter, interlocked dual scales with easily reversible ranges, bayonet-mounted thermal unit for simplified maintenance, color-coded leads for easy reassembly, improved design of the thermal heater assembly with sapphire ring jewels to reduce friction, and a combination potential coil and thermal unit voltage source. *Westinghouse Meter Division, 2728 North Boulevard, P.O. Box 9533, Raleigh, North Carolina 27611.*

Postforming Plastic Laminate



Polyphase Thermal Demand Meter

Smoke detector, Model 100, is a self-contained unit that senses smoke in the early stages of a fire and immediately sounds an alarm. It is activated when smoke enters a chamber and scatters light into the view of a photoconductive cell. The cell triggers a solid-state circuit, which energizes a built-in horn that sounds a steady raucous signal. The system is continuously self-supervised electrically; if a lamp fails, the horn generates a distinctive pulsating trouble call. Available in two styles for plug-in or permanent connection, the smoke detector meets the requirements of National Fire Protective Association Code 74 and Underwriters' Laboratory listing 168 for photoelectric smoke detectors. As many as five smoke detectors can be interconnected so that an alarm or trouble signal in one detector sounds a similar signal in all of them. *Westinghouse Security Systems, Inc., 200 Beta Drive, Pittsburgh, Pennsylvania 15238.*

Checkout simulator is programmed to simulate operation of the Westinghouse electrohydraulic control system for steam turbine-generators. The analog-computer device is interfaced with the control system for complete checkout of the electronic and hydraulic portions of the system. It generates outputs for turbine speed, impulse-chamber pressure, intermediate pressure, and load. In addition, it performs contact closing, duplicating the main circuit breaker. Besides its use for checking out control systems, the simulator is useful as training device for power-plant operators *Westinghouse Power Generation Servic Division, 1974 Sproul Road, Broomal Pennsylvania 19008.*

Ampgard high-voltage starter is now available for 7200-volt applications, making i particularly well suited for draglines, dredging equipment, and other mining machinery. The type 72L2 starter is rated a 200 amperes and can be applied to motor up to 2500 horsepower. Line and loa terminal connections are made from th front, and all components are front accessible for fast inspection or parts replacement Drawout construction allows simple removal of the complete contactor, current limiting fuses, and isolating switch. Fo maximum protection and safety, the isolating switch completely grounds the starte and isolates it from the line, leaving n high voltage exposed. The door of the high voltage section is locked closed with th isolating-switch handle, and the low-voltage control section is completely segregated from the high-voltage section. *Westinghouse General Control Division, 445 Genesee Street, P.O. Box 225, Buffalo, Ne York 14240.*

"Catalog of Courses and Seminars" list a wide range of management and professional training and development course available to business, industry, and government organizations. The courses use th latest techniques in instructional technology to provide up-to-date manageria concepts and methods. More than 9 courses are included under six categories conceptual development, management process, rational process, finance and computer, individual skill development, an local implementation. *Training and Development Division, Westinghouse Learning Corporation, Westinghouse Building, Gateway Center, Pittsburgh, Pennsylvania 1522*

bout the Authors

ıson B. Tharp returns to these pages for the
rth time, again to discuss his favorite subject
ommunications. He takes up where he left
last time with a solid-state low-frequency
ısmitter and adds the command and control
ction to provide the automated transmitting
ility described in this issue.
Tharp came to Westinghouse on the graduate
dent training program after graduation from
rthwestern University (BSEE) in 1941. He has
ce had assignments all over the radio-frequency
ctrum, from 10 kilocycles to 8000 megacycles.
is presently Manager of Program Develop-
nt in the Command and Control Division at
Defense and Electronic Systems Center.
Off the job, Tharp's interest in communica-
ıs moves up in frequency to the ham radio
ıds, where he operates W3EUN, sometimes to
nmunicate with his wife who is W3GQR.

J. Taylor is a design engineer in the special
oduct engineering section of the Medium Motor
l Gearing Division. He has engineering design
ponsibility for motors for air handling appli-
ions and nuclear power plants, and he also
esponsible for studies of mechanical systems
t contain motors, disc or shoe brakes, pulleys,
fting, couplings, bedplates, etc.
Taylor graduated from Cornell University
h a BSME degree in 1968. He joined Sylvania
ctric Products, Inc., where he worked in the
earch laboratory on automated methods of
nted-circuit manufacture. He joined Westing-
use in 1969, and his initial responsibilities
luded stress, vibration, and heat-transfer anal-
s of various motors and seismic qualification
motors. He has developed a procedure for
smic qualification of motors for nuclear power
nts, and he earned an MSME degree in 1974
m the State University of New York at Buffalo.

chard F. Cook came to Westinghouse on the
ıduate student training program after graduat-
; from the University of Cincinnati with a
EE in 1956. He obtained his MSEE degree
m the University of Pittsburgh in 1960 and
ended Harvard's Program for Management
velopment in 1971.
Cook spent eight years as a distribution
tem engineer, one year as an advanced de-
opment engineer, two years as a marketing
nsultant, and five years as manager of the
tribution systems and application section of
ectric Utility Headquarters Department. In
ıuary 1972, he was named Manager of Distri-
tion Systems for the T&D Group.
Cook is a Registered Professional Engineer
Ohio, and he has been active in IEEE, EEI,
d NEMA committee work.

odney V. Adams graduated from the Newark
ollege of Engineering with a BSEE in 1939.
e joined the Westinghouse Meter Division
ewark, N.J.) in 1940, where his first assignment was on thermal demand meters. Other engineering assignments have included work on the Mark Series of mechanical demand registers, "D" line thermal watt demand and ampere demand meters, and automatic meter reading by telephone and by distribution line carrier.

Adams has served as Engineering Section Manager of demand meter engineering and of automatic meter reading. He is now Engineering Department Section Manager responsible for Long Range Development. He is an amateur radio operator (WA4AGN) and a private pilot.

Ian A. Whyte obtained his Diploma in Technology (Telecommunications) from the Polytechnic Regent St. (London) in 1954. Before coming to Westinghouse, Whyte's experience included postgraduate training at Mullard Research Laboratories (Redhill, England), senior engineer at the K. B. Division of IT&T (Footscray, England), and Chief Engineer of Perdie Electronics, Ltd. (London).

Whyte joined the Westinghouse Research Laboratories in May 1963, where his responsibilities have been in the design of various communications systems and equipments. His first project was Phonovid, a system for recording television pictures and sound on long-play records. Later assignments included development of several nonstandard and unconventional monochrome and color CCTV systems.

He is presently Principal Investigator for the Distribution Line Carrier Communications Development Program at the Research Laboratories.

Edmond D. Neuberger graduated from Stevens Institute of Technology in 1959 with an ME degree. He worked first for Foxboro Company, becoming a senior project engineer, and then served in project management in Fisher Scientific Company and Calgon Corporation. He joined the Westinghouse Computer and Instrumentation Division in 1972, where his first responsibilities were in development, application, and marketing of digital/analog process control systems. He is now a senior application engineer, responsible for application and marketing of the oxygen analyzer described in his article.

Engineering developments that Neuberger has contributed to or been responsible for include automatic chromatographic systems, an on-stream automatic titrating analyzer, an analyzer for determining carbon, hydrogen, and nitrogen content of organic samples, an on-stream differential conductivity analyzer for determining alkaline concentration in kraft pulp digesters, an on-stream analyzer for determining the concentration of chlorine and chloride in stack gas, and an on-stream analyzer for determining concentration of low-level sodium in high-purity water.

Carl F. Jensen joined Westinghouse in 1926 as a technical trainee and has served in practically every phase of the lamp business. From 1945 to 1957, he was regional engineer for the Westinghouse Midwestern Region, where he was consultant to architects, engineers, and designers of lighting installations and equipment. Then he was made field lamp engineer for the region. He was active in the Chicago Lighting Institute during that time, serving in many capacities including chairman of the Technical Committee and instructor in specialized courses in illumination.

Jensen became Marketing Manager of Rayescent lighting for the Lamp Division in 1957. He served in the Central Region (Pittsburgh) as field sales engineer from 1962 to 1966, and then he became Manager, Fluorescent Sales Engineering. He retained that post in the new Fluorescent and Vapor Lamp Division when the former Lamp Division divided into three divisions in 1969. He was responsible for dissemination of technical information on fluorescent and ultraviolet light sources until his retirement last November.

Jensen has been active in the affairs of the Illuminating Engineering Society, serving on many local and national committees. He was a member of the board of directors of the Chicago section and served as president of the IES Study Club, secretary of the Chicago section, and chairman of the Pittsburgh section. Last year he was one of four recipients of the IES distinguished service award.

W. A. Murray joined the Westinghouse Lamp Division in 1957 as a junior commercial engineer. He moved into application and sales engineering for incandescent lamps, and in 1972 he became Product Planning Manager for the Incandescent Lamp Division. He advises the Division in product planning and coordinates the flow of information to customers via sales engineers. He graduated from Columbia University in 1957 with an AB degree in liberal arts.

William S. Till is Manager, Vapor Lamp Sales Engineering, Fluorescent and Vapor Lamp Division. He is responsible for technical literature, applications, product design guidance, and engineering assistance to customers and to the marketing staff. Till joined Westinghouse in 1942 as an engineering assistant, expediting manufacture of radar tubes. He went into sales engineering for high-intensity-discharge (HID) lamps in 1948, and that has remained his field of major interest. He assumed his present position in 1958.

Till has contributed to development of phosphor-coated mercury lamps and to standardization of HID lamps through the American National Standards Institute. He has published a number of technical papers and lectured widely on lighting. He is a Fellow of the Illuminating Engineering Society and past regional vice-president. After receiving a BA degree in geology at Princeton University, he went on to earn an associate certificate in electrical engineering at Newark College of Engineering in 1950.

Westinghouse Electric Corporation
Westinghouse Building
Gateway Center
Pittsburgh, Pennsylvania 15222

Right—This prototype flat display panel is only about an eighth of an inch thick. Electrical leads on two sides feed signals to a matrix of thin-film transistors that energize electroluminescent cells at the intersections of the rows and columns. For more information, see ***Flat Display Panels Employ Matrix of Thin-Film Transistors***, page 29.

Above—Each electroluminescent cell can be energized without activating other cells in the same row or column.