Westinghouse ENGINEER

November 1972

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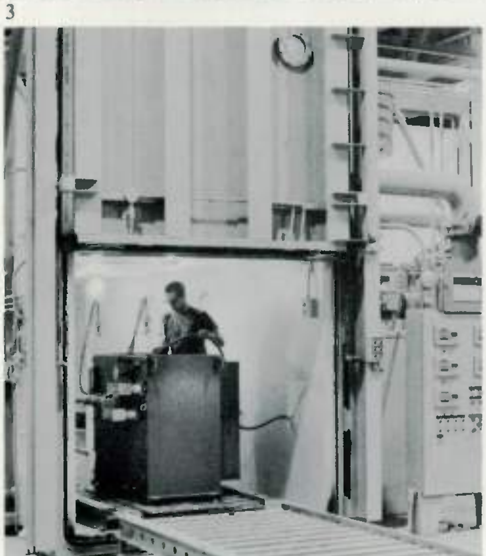

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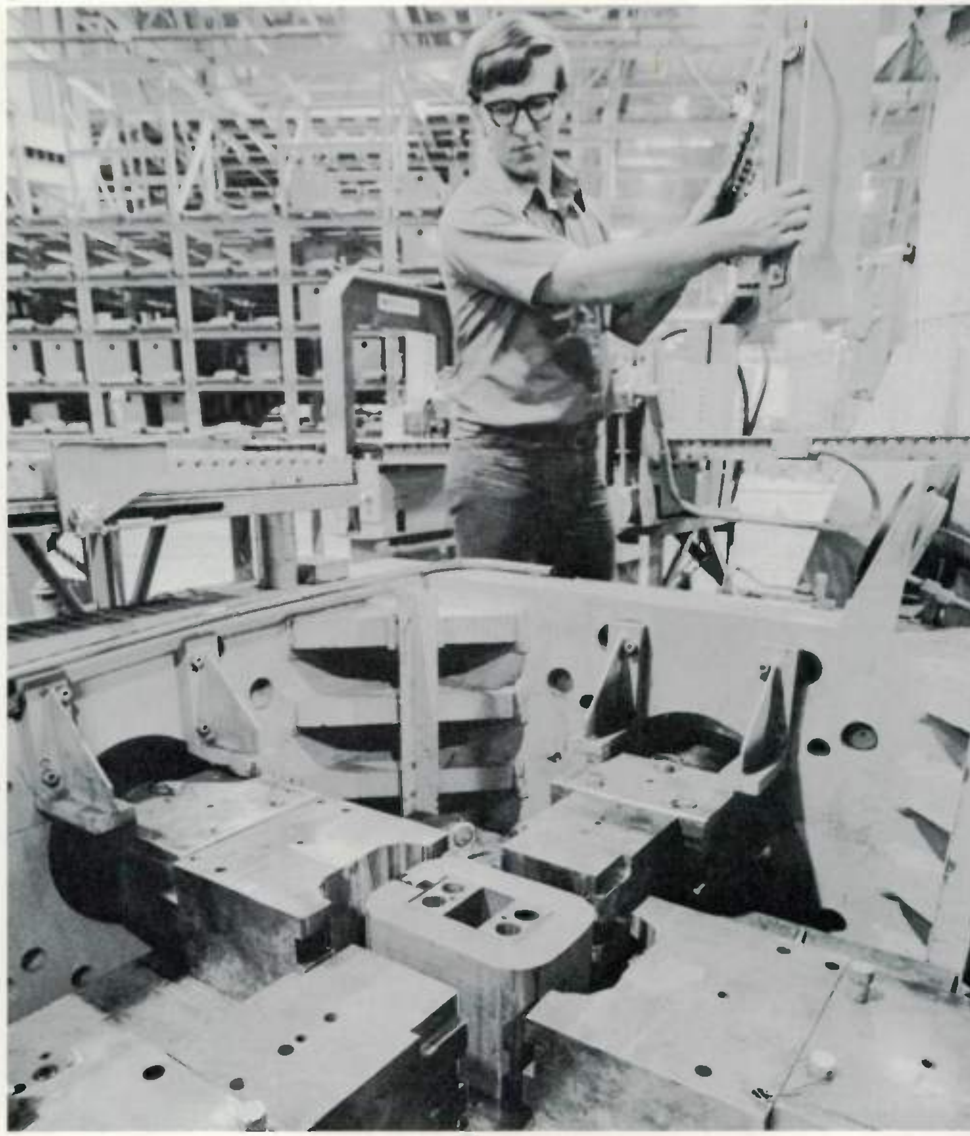

Underground and Pad-Mounted Transformers Produced in Efficient New Plant

Submersible and pad-mounted transformers for electric-utility distribution systems are now being made in a new plant of the Westinghouse Underground Distribution Transformer Division in Jefferson City, Missouri. The plant was built to meet the projected large growth in demand for such single- and three-phase transformers.

Design engineering is highly automated to assure fast and accurate transition from design to manufacture, and production is mechanized and accurately controlled for high product quality, low cost, and rapid delivery. The plant produces and tests transformers in a three-week manufacturing cycle.

Each product is designed in modules for ease of manufacture and interchangeability. Use of standard modules also assures that components are built the same way many times over, thus helping assure correct procedures and thereby enhancing reliability.

Data terminals throughout the plant feed information on the status of each part, component, and transformer to a computerized production control system. Collected data are processed to identify any manufacturing difficulty in ample time to correct it. The system minimizes manufacturing time by enforcing smooth flow of materials and maximum utilization of men and facilities, and it also provides accurate status information at all times for both inquiry and planning purposes.

Coil-winding machines wind the transformer coils from aluminum strip, and an automatic welder joins secondary leads to each coil (Fig. 1). A press forms the transformer cores in accurate dies under high pressure (Fig. 2). The cores are then annealed to relieve stresses.

Meanwhile, parts for the transformer tanks are being cut from sheet steel, punched, and formed. The parts are assembled and welded in an automatic welder. Tanks, cabinet parts, and other components are cleaned and then primed by electroferritic coating. In that process, the positively grounded parts move through a tank of zinc-chromate primer that has negatively charged electrodes immersed in it to give the parts a complete and uniform coat of the primer. They are then baked, given an intermediate paint coat by electrostatic spraying, and baked again.

The critical operation of assembling cores and coils is performed by hand, and a completed assembly is mounted in its tank and vacuum impregnated with oil (Fig. 3). The transformer is then tested on an automatic test carousel that can handle eight units at a time. Finally, the units are fitted with their cabinets and other accessories, painted again, and shipped.

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Front Cover: The offshore floating nuclear power plant was developed to overcome two major problems faced by the electric utility industry—a severe scarcity of suitable plant sites and lack of cost- and time-saving standardization in power-plant design. The solutions are expressed graphically in this month's cover design by artist Tom Ruddy, and the offshore floating plant is described in the article that begins on the following page.

Floating Nuclear Power Plants for Offshore Siting

Alan R. Collier
Roger C. Nichols

Offshore siting of nuclear power plants will permit them to be located nearer load centers without competing for valuable land. The combination of a floating platform-mounted plant manufactured in a shipyard-type facility and an offshore site protected by a breakwater provides advantages in site acquisition, site development, and plant construction. The offshore nuclear plant also offers significant environmental benefits.

To fully exploit the offshore nuclear plant concept, Offshore Power Systems, a joint enterprise of Westinghouse and Tenneco, has been formed to manufacture the floating plants. Commitments for the first two offshore plants have been received from Public Service Electric and Gas Company. However, additional orders from other utilities will be required if the enterprise is to be an on-going success for both the electric utility industry and the plant builder.

Two of the major problems the electric utility industry faces today are a severe scarcity of suitable power plant sites and lack of cost- and time-saving standardization in power plant design. The offshore floating nuclear power plant offers solutions to both of these problems.

On land, even the few suitable plant sites that are available are becoming more expensive and more distant from the load centers they must serve. The 5700-mile coastline of the United States, however, has thousands of potentially suitable sites for offshore plants. The only requisites are a geologically stable ocean floor and a water depth of about 45 to 70 feet. Ocean sites will be in position to serve more than 40 percent of the total U.S. demand for electrical energy because of the heavy population concentration within a 200-mile strip along the Atlantic, Gulf, and Pacific coasts.

Except for the nuclear steam supply system[1], little significant progress has been made in standardizing power plant design. Too often, specific needs and siting conditions force costly custom engineering to accommodate each site. The floating offshore power plant, in contrast, has a minimum of interface points with the site, so the plant design remains fixed even though site characteristics may vary. This floating-plant approach presents the first real opportunity to achieve genuine plant standardization with all its inherent advantages—repetitive licensing, reduced construction costs and time, and improved quality assurance. The United States Atomic Energy Commission has recently announced policies to encourage standardization as a way to facilitate the licensing process and has reacted very favorably to the floating plant concept.

A. R. Collier is Vice President, Engineering, and R. C. Nichols is Projects Manager, Offshore Power Systems (a joint venture of Westinghouse Electric Corporation and Tenneco, Inc.), Jacksonville, Florida.

Offshore Floating Plant Concept

Both the nuclear power plant and its supporting platform utilize existing and proven technology. Plant components and systems are nearly identical with those of comparable licensed land plants. The PWR steam supply system is a typical Westinghouse four-loop 3425-MWt unit with ice condenser containment. The power generation plant contains a standard Westinghouse turbine generator unit with a net output of 1150 MW. Thus, the only real innovation in power plant design is the platform structure that serves as the foundation for the plant.

The platform, honeycombed with watertight bulkheads, is 40 feet deep and measures about 400 feet square. The complete structure will stand 209 feet above the keel, draw about 30 feet, and displace about 150,000 tons. For a site some three miles from shore, the plant profile will appear in size roughly comparable to a large ship passing on the horizon.

Since the floating plant is completed and functionally tested before it is towed to the site, site development consists essentially of breakwater construction. The finished breakwater will extend 30 to 50 feet above sea level at high tides, encircling and shielding the plant from wave effects of the worst possible storms.

The offshore plant and its breakwater will require about 90 acres of ocean bottom, plus a small shoreland site for docking, electric switching, and support facilities. Electric power is transmitted from the plant to a shore station by underwater cable. Thus, except for the minor intrusion of the shore base, the offshore nuclear plant will leave the entire coastline and adjacent waters available for recreational and other activities.

The cost comparisons of a floating nuclear plant and a land-based plant are complex, but when all considerations are fully evaluated, offshore plant costs should be less. Major cost savings will result from standardized plant design, assembly-line construction in a shipyard-type facility, and reduced time-related costs. Breakwater construction will exceed the site development costs of land plants, and towing and underwater cable costs are additional; however, these costs will be partially offset by savings on site investments and cost of borrowing money. Since the offshore nuclear plants will take less time to build, payment schedules for construction loans will not peak until two years prior to operation, significantly later than with land plant construction. The shorter building period will also reduce escalation and interest costs, and the costs of other delays will be minimized. Offshore siting will also eliminate the need for long-term investment in land for future sites, freeing that capital for more productive use.

Platform Layout

The platform's almost 400-foot-square shape and multifloor arrangement for installing machinery accommodate an efficient layout of plant equipment without sacrificing working room during maintenance. The platform structure is 40 feet high, with 45 interior bulkheads spaced to provide both support and watertight compartmentation. The plant design is based upon mounting the plant on the platform with a minimum of equipment in the platform.

Since the plant floats, structures are arranged on the platform to maintain trim.

1—Artist's concept of floating nuclear power plant moored within protective breakwater. This view from the access side shows structure arrangement on the platform and illustrates the provisions for loading equipment and supplies.

The largest single mass, the containment building and its associated structure and equipment, is positioned slightly off the platform center (Fig. 1). Other major masses surround the containment building —the turbine generator, switchyard, and their foundations and equipment; the spent-fuel pit and its shielding; the shielded auxiliary components and the processing and waste treatment system; and the shielded engineered safeguards equipment.

The overall platform layout (Fig. 2) is divided into five major areas: the nuclear plant, power generation plant, electrical building and switchyard, instrumentation and control area, and administration and service area.

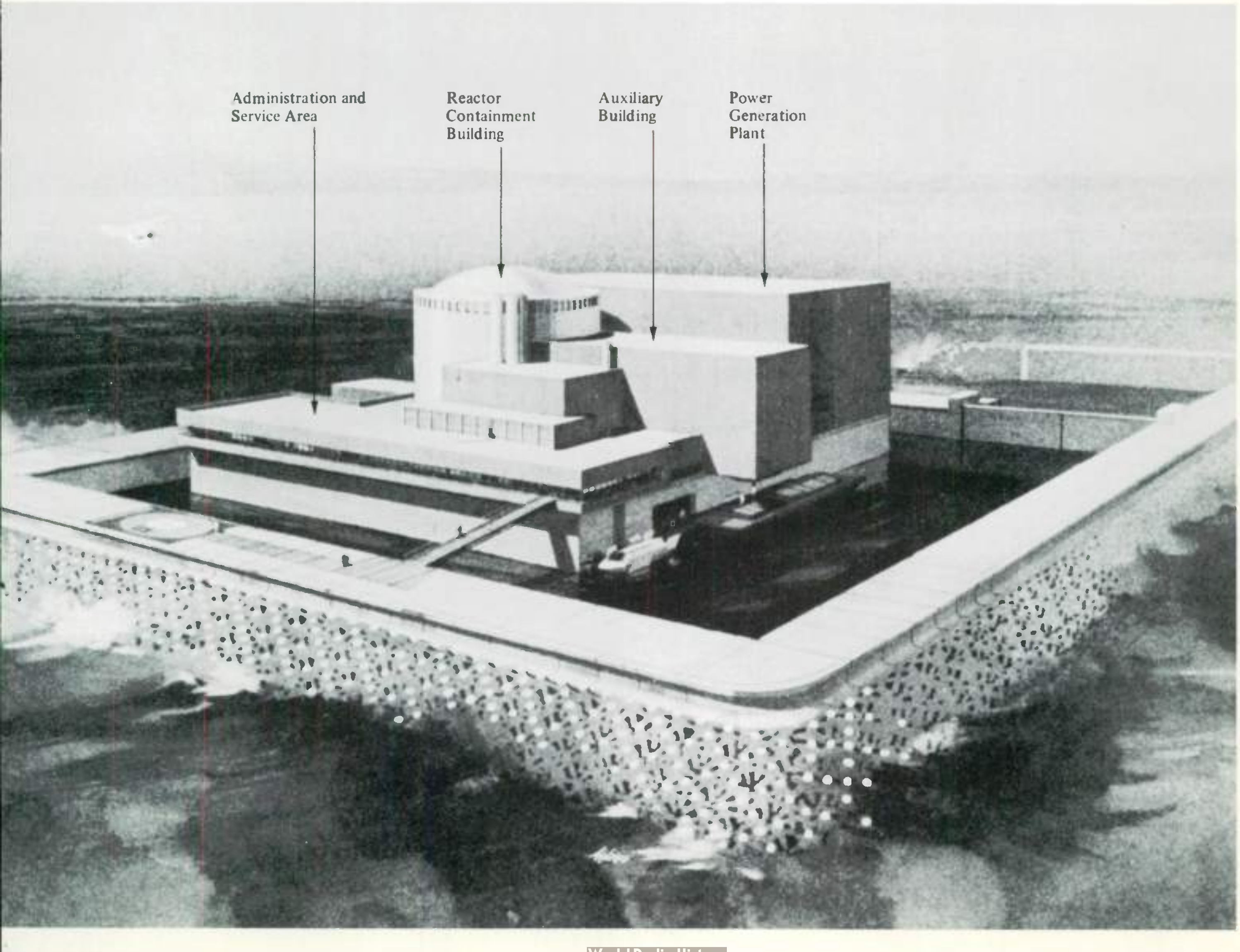
Nuclear Plant

The nuclear steam supply system (NSSS), shown by section in Fig. 3, is a standard Westinghouse four-loop pressurized-water reactor system, essentially identical to that provided for land-based plants of the same capacity. The major NSSS components are the reactor, reactor coolant system, chemical and volume control system, boron recycle system, residual heat removal system, and the safety injection system.

Reactor—The nuclear reactor is designed to operate at a normal core power rating of 3411 MWt. Sufficient margin is provided to allow for transient operation and instrument error without causing core damage and without exceeding the pressure settings of the safety valves in the reactor coolant system.

The reactor core is of the multiregion type, approximately cylindrical and made up of 193 fuel assemblies, each assembly containing 204 fuel rods of slightly enriched uranium encapsulated in zirconium tubes. Reactor control is provided by neutron-absorbing control-rod clusters and by a neutron absorber (boric acid) dissolved in the reactor coolant.

For uranium fuel operation, the reactor will be controlled by 57 full-length control rods and 8 part-length control rods. However, if the reactor is ever used for plutonium recycle operation, up to eight additional control rods may be required. To



provide for this possibility, the reactor includes provisions for adding eight control rods and their drive mechanisms. Other provisions, such as additional reactor cavity and containment penetrations, and future instrumentation and power cabling, are included to further facilitate modification for plutonium recycle.

Reactor Coolant System—The reactor coolant system consists of four essentially identical loops, each loop containing a reactor coolant pump and a steam generator. Coolant system pressure is controlled by a pressurizer attached to one loop. The entire reactor coolant system is contained inside the reactor containment.

Nuclear Steam Supply Support Systems—Four associated support systems perform functions essential to reactor and reactor coolant system operation:

The *chemical and volume control system*[2] maintains water inventory in the reactor coolant system and provides flow to the seal system of the reactor coolant pumps. It controls the chemistry, including boron concentration and purity, of the reactor coolant system.

The *boron recycle system*[2] processes effluent from the reactor coolant system and chemical and volume control system to remove particulate matter, fission products, and activation products and to reconcentrate boric acid. This processing minimizes plant discharge by enabling the boric acid solution and reactor grade water to be recycled.

The *safety injection system* supplies borated water to the reactor coolant system in the event of a loss-of-coolant accident or a steam line rupture. The system uses pressurized accumulators for rapid response, and it has high-, intermediate-, and low-head pumping systems for continuous injection and long-term recirculation.

The fourth support system is the *residual heat removal system*, which removes heat from the reactor core during plant cooldown and refueling and provides low-head injection as part of the safety injection system.

Other auxiliary systems that support the nuclear steam supply system operation include the waste treatment system[2], the fuel-handling system, the spent-fuel pit cooling and clean-up systems, the component cooling water system, and the essential service and essential raw water systems. These various systems serve to minimize radioactive waste released from plant operations, and they provide various equipment necessary for changing fuel or for providing safeguards following any possible mishap.

Power Generation Plant

The thermodynamic cycle of the power generation plant is similar to that used in many PWR power plants. The nuclear steam supply system provides about 15,140,000 lb/hr of steam at 1000 psi to the turbine generator. The steam turbine is a four-casing tandem-compound 1800-r/min machine consisting of a double-flow high-pressure element in tandem with three double-flow low-pressure elements (Fig. 4). Efficiency of the power generation cycle is optimized with six stages of feedwater heating, two stages of steam reheating between the high-pressure and low-pressure turbines, and use of extraction steam to drive the feedwater-pump turbines.

The generator is an 1800 r/min machine directly coupled to the turbine. Its rated gross output is about 1,211,500 kW. It has a hydrogen-inner-cooled rotor and a water-cooled stator.

A surface condenser is directly connected to each of the three low-pressure turbine exhausts. Large interconnecting ducts between the three condensers allow turbine generator operation with a condenser section out of service. The circulating seawater system uses seawater to provide the sink for heat rejected from the condensers. It is arranged in six parallel circuits, each circuit cooling a single condenser section.

Seawater is circulated through the tubes of the main condenser by vertical single-stage axial-flow pumps. Small debris is removed from the seawater flowing toward the circulating-water-pump suction well by traveling screens. These screens are normally not moving, but they are started automatically for cleaning when debris accumulation causes the head loss across the screen to reach a preset value. The screens are washed by high-pressure water sprays, and the washed-off debris is deposited in a trash trough where it flows by gravity to the trash collection tank. Each of the six seawater intake openings in the side of the hull is equipped with a fixed-bar screen to prevent the entrance of large debris that might be suspended in the water.

The heated circulating water from the condensers flows through the system discharge piping and overboard from the platform into a catchment basin built inside the breakwater. From there, the water flows through outfall piping under the breakwater to the open sea. Since the platform rises and falls with the tides but the catchment is stationary, the circulating-water discharge lines between the two are arranged to accommodate this movement.

A moveable stop gate is provided for each pump suction well to permit rapid isolation of the well from the sea. During normal operation, the gates remain in the raised position. When isolation is desired for maintenance work on the traveling screens or circulating water pumps, the gates are lowered to cover the hull intake openings.

Turbine Control System—A digital electro-hydraulic (DEH) control system is used for control of the main turbine-generator unit. The DEH control system together with the integrated lubrication oil system provide full protection to the main turbine and feed-pump turbines in the event of a malfunction affecting the safe operation of these turbines. Protective interlocks with the generator, transformers, and plant electrical distribution systems protect the main turbine against faults in the external electrical systems. Overspeed is limited to a maximum of 120 percent rated speed in the event of a maximum load rejection. Supervisory instrumentation is provided to monitor critical conditions of the turbine during start-up, operation, and shut-down.

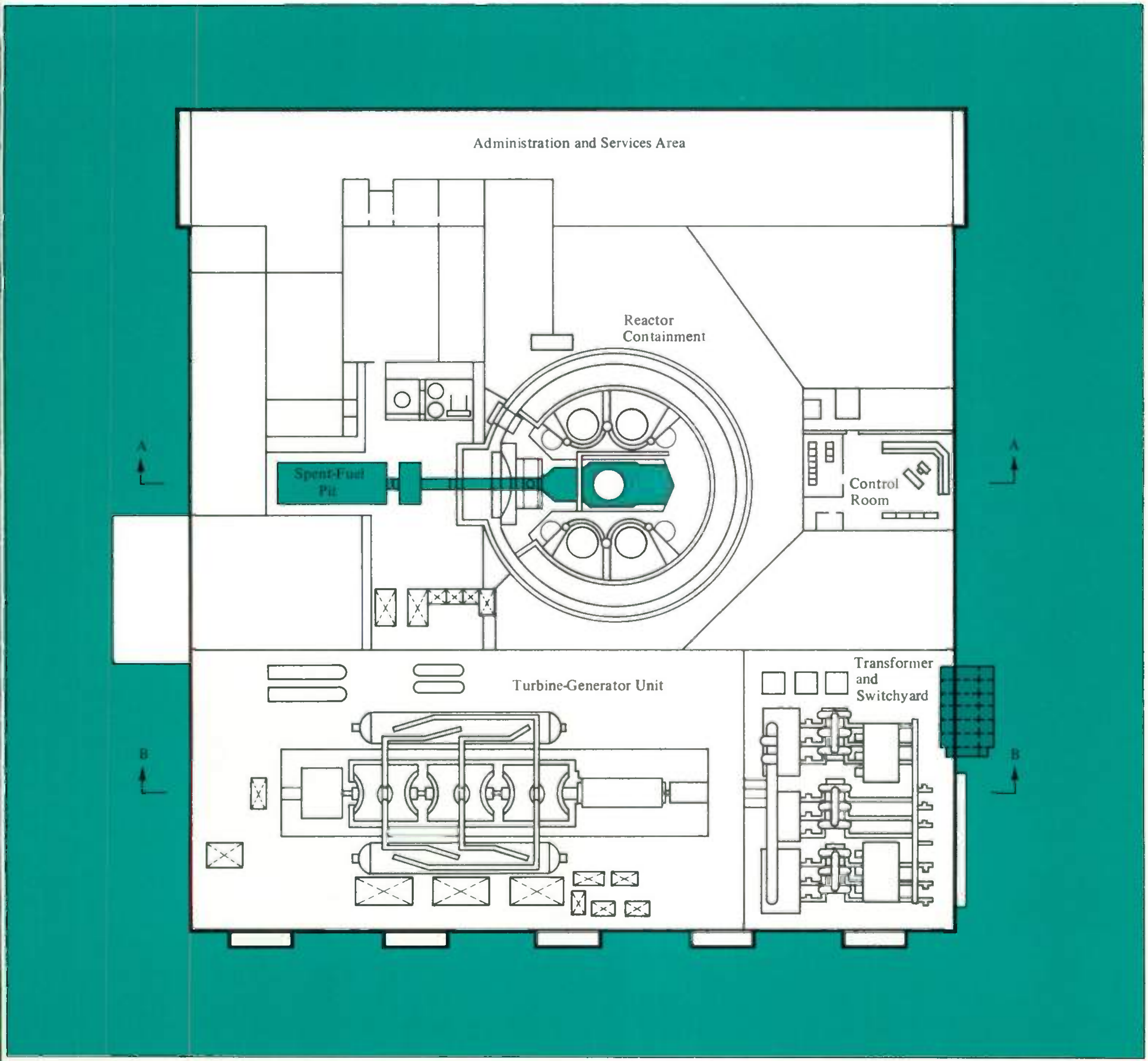
Electrical Building and Switchyard

The 25-kV generator leads exit beneath the turbine generator and run via isolated-

2—Plan view (at 94-foot elevation) shows major plant areas of floating nuclear plant.

phase bus ducts through a wall separating the electrical and turbine buildings.

The generator output voltage is stepped up to 345 kV through two half-sized transformers and connected to cable potheads on the platform through the SF_6-insulated substation located above the main transformers. The 345-kV substation provides the necessary control, protection, and termination facilities for two tie circuits to a shore-based 345-kV transmission system. The substation uses Westinghouse MGT (modular gas-insulated transmission system) equipment to minimize space requirements, maximize safety and reliability, and reduce maintenance. The equipment consists of three modified SF_6 power circuit breakers rated 345 kV nominal, along with all necessary lightning arresters, isolator switches, ground switches, portable grounds, and other ancillary equipment. Potheads are furnished for termination of the underwater cables at the side of the plant. The bus connections and arrange-



ment permit delivery of half the generator's rated output over each of the two circuits.

The substation also includes a start-up transformer, and its control and protective equipment, for initial and subsequent plant start-up power requirements. The start-up transformer can be supplied by either of the two circuits to shore.

Instrumentation and Control Area

The main control panel provides a single point of control and indication at a centralized location for all critical plant systems. It contains those indicators and controls most frequently used by the operator. Auxiliary control panels contain those devices that do not demand frequent use or that require less stringent observation.

A computer system presents information to the operator to assist him in operating the plant and to inform him of any off-normal conditions. Although the computer system is mainly for the nuclear plant, it also monitors all inputs from the power generation plant that are used in connection with the nuclear plant programs. The basic computer equipment includes a central processing unit, an input-output unit, a fixed-head disc, an operator's console with output typewriters and line printer, and a programmer's console.

In addition to the normal reactor plant instrumentation and control systems and various turbine-generator unit monitoring systems, some further protective systems are provided. For example, a hull-leakage surveillance system will notify plant operating personnel of water in any of the watertight hull compartments. An emergency instrument power supply is provided to supply both normal and emergency power to plant electronic instruments. This system is normally fed from the plant's ac system, but upon power loss, it transfers immediately to a 125-volt dc battery.

A fire detection system monitors specific areas or zones within the plant. If a fire is detected, the system activates an alarm and by remote control provides indication of the fire location.

A process radiation monitoring system[3] monitors radiation levels at selected plant process locations and activates alarms if predetermined normal or safe values are exceeded. An area radiation monitoring subsystem measures gamma radiation levels in various areas or locations throughout the plant. Radiation levels are locally indicated and alarmed and are also transmitted to the radiation monitoring system control cabinet in the main control room for indication and recording.

Administration and Service Area

Administration and service functions are housed in a three-level building. The highest level (76 feet) contains work facilities typical of a land-based plant. A shielded emergency relocation area also located on the top level has space for sleeping facilities and contains emergency supplies and communication equipment. The emergency relocation area's ventilation system is separate from other administration and service ventilation equipment and can be powered from diesel generators.

The second level (58 feet) contains the hotel facilities for the floating nuclear plant. Crew quarters are arranged in self-sufficient modules containing beds, lockers, showers, and washroom facilities.

The loading dock is on the 40-foot level. This area provides facilities for receiving small loads and includes an adjacent area for stores and warehousing. It is readily accessible to all plant levels via two freight elevators.

Environmental Considerations

The environmental impact of a platform-mounted nuclear plant will be reviewed and evaluated with the same criteria used for land-based installations. However, the offshore nuclear plant has certain features unique to its design and siting that will help minimize its environmental impact.

A major concern for any power plant installation is the dissipation of rejected thermal energy. The use of inland waters as heat sinks has led to the adoption and enforcement of stringent discharge-water temperature limitations. Siting power plants in river estuaries and on the ocean shore helps the situation but does not overcome the concern for disturbing the breeding grounds of various marine species. The offshore site significantly reduces the thermal effects of effluent cooling water because discharge water will rapidly dissipate its heat into a small area of the cold ocean. It has been estimated that the two million gallons per minute discharge from a two-unit offshore installation, at 16 degrees F above the local water temperature, would result in a temperature increase of only 5 degrees F over a three-acre area. Advantage can be taken of offshore siting flexibility to locate plants where local currents, tides, or winds can help reduce thermal impact. Furthermore, multiple outfalls can be spread out, spangers can be used, and the direction and depth of discharge can be tailored to the specific site to further reduce localized effects.

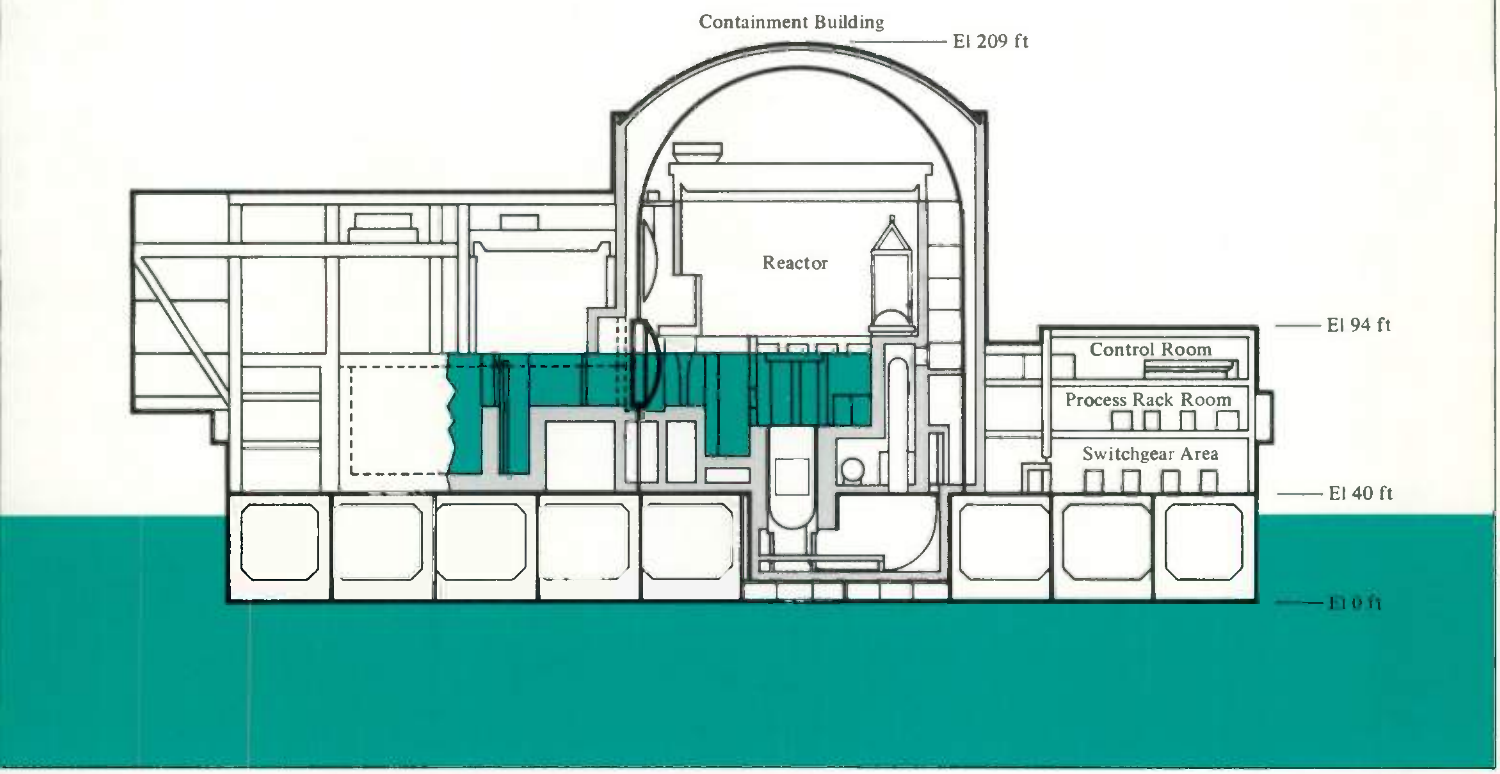
Another important factor in evaluating the effects of the circulating water system on marine plankton and small fish larvae is the residence time in the elevated temperatures of the discharge water. Data have shown that for many species, a long residence time in heated water is much more detrimental than a short exposure to water at a higher temperature. With the plant installation in the ocean, the discharge system can be designed to keep the length of piping to a minimum consistent with other requirements to minimize the residence time in the heated discharge water. Offshore installations of the plant described in this article can be designed to achieve a residence time of about three minutes. Also, the breakwater and plant cooling water intake have been designed to minimize fish entrapment, particularly for small species that are critical to the marine food chain. Intake openings have been designed to maximize area (approximately 2000 square feet) and thereby minimize intake velocity to a very low one foot per second.

Operating experience with existing nuclear plants indicates that the levels of radioactivity in air and water emissions

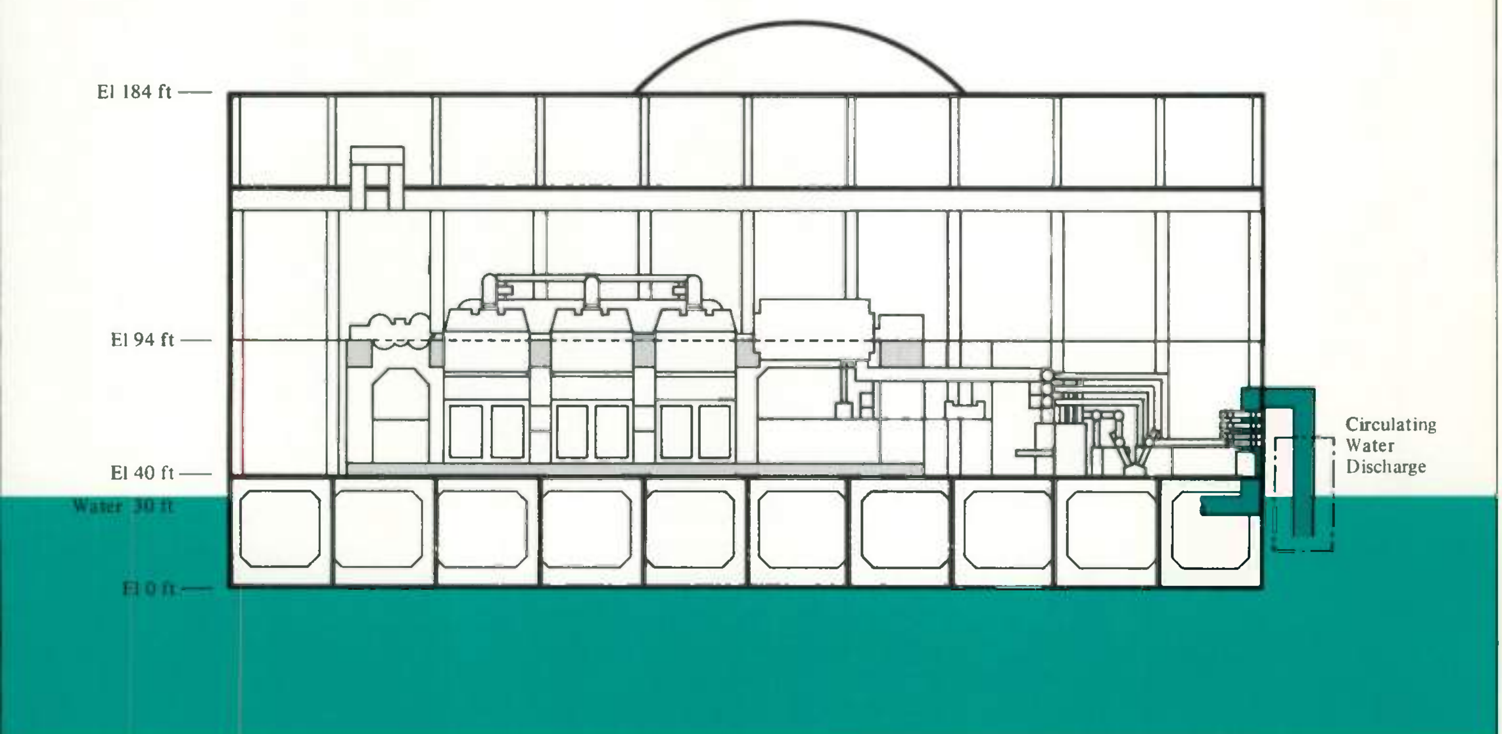
3—Cross section A-A of plant through center of reactor containment shows location of major NSSS components.

4—Cross section B-B of plant through turbine hall and electrical building and switchyard illustrates the multilevel arrangement of general components.

Section A-A



Section B-B



have been well below AEC acceptable limits. The floating nuclear plant will utilize the latest technology in waste processing systems to keep the release of radioactivity to the environment as low as practicable. In fact, the degree of liquid effluent dilution possible with an offshore site is far greater than for sites on lakes, rivers, estuaries, or at ocean-front sites.

Furthermore, the direction and velocity of the offshore nuclear plant discharge can be controlled to take advantage of local hydrological conditions to enhance dilution and dispersion.

5—A production-line approach will be used in the new shipyard-type facility to be built for manufacturing floating nuclear power plants. Components and subassemblies will be manufactured in shops on both sides of the production slip. The platform is built in a graving dock at the inland end of the slip. When the platform is completed, the dock is flooded and the platform moved to its first outboard position in the slip. As succeeding plants are launched, the plants move down the slip. Subassemblies, components, and equipment are assembled and erected along the way.

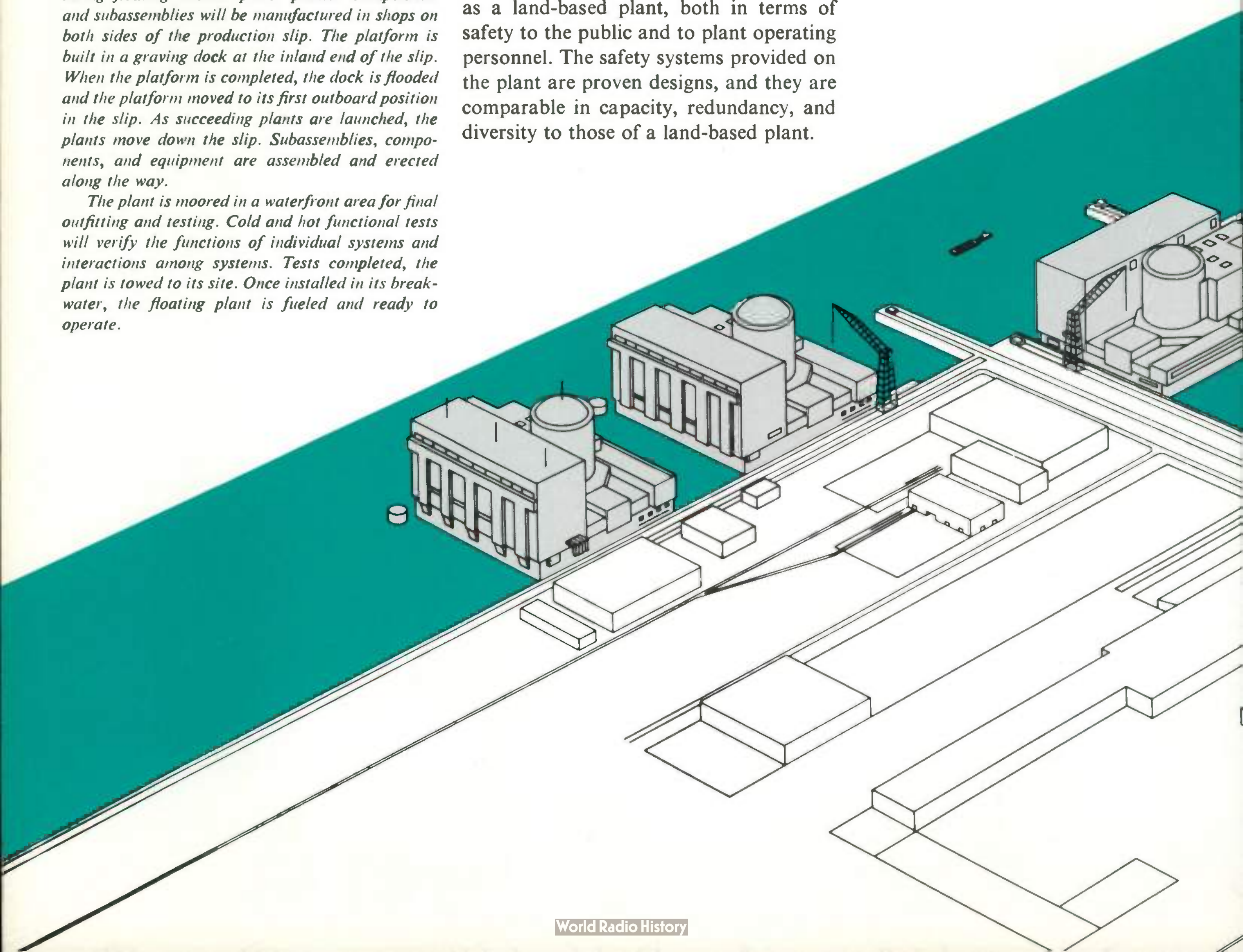
The plant is moored in a waterfront area for final outfitting and testing. Cold and hot functional tests will verify the functions of individual systems and interactions among systems. Tests completed, the plant is towed to its site. Once installed in its breakwater, the floating plant is fueled and ready to operate.

Chemical discharge from the plant has also been carefully considered. Solutions are monitored and neutralized prior to release to the environment at metered rates via the circulating water discharge. The on-board sewage treatment plant discharges essentially pure water overboard. The plant design includes a solid-trash handling system that compacts and packages refuse in leakproof containers for transport to shore. Water from the platform drain system is processed to remove oil and other chemicals prior to release.

Safety Considerations

The offshore floating nuclear plant is designed to meet the same safety standards as a land-based plant, both in terms of safety to the public and to plant operating personnel. The safety systems provided on the plant are proven designs, and they are comparable in capacity, redundancy, and diversity to those of a land-based plant.

The floating nuclear plant concept does introduce two additional major plant safety considerations. First, since the platform moves under the influence of tides, winds, and any wave motion in the basin, the breakwater and mooring system design are essential to plant safety. The breakwater must limit wave motion within the basin, from any source, to plant design values, and it must also assure an adequate cooling-water supply. The mooring system must be designed to limit movement of the plant under all conditions. The mooring system is also designed to transmit only those loads within the plant design values.



The second major safety consideration is the potential hazard from shipping in the vicinity of the site. Studies have shown that breakwaters designed and proportioned for depths of water typical for a floating nuclear plant will stop the largest ships that can sail those depths, and that most types of ships will be stopped entirely outside the breakwater. Based on data from ship collisions with offshore structures, the probability of a ship running into the breakwater is sufficiently high so that the breakwater must be designed for such an occurrence.

Therefore, the breakwater and plant designs must consider the possible consequences that could result from such a collision. If, for example, a collision partially blocks the cooling water intake or discharge, the turbine would be tripped and the plant shut down using either offsite or on-board electrical power and the basin water for a heat sink.

One further safety consideration concerns earthquakes. In this case, the offshore concept has an advantage because the sea will help insulate the nuclear plant from shockwaves. The design-basis earthquake ground acceleration is 0.3g horizontal and 0.2g vertical.

New Manufacturing Facility

To facilitate the manufacture of the offshore nuclear plant, a completely new shipyard-type facility is being designed and constructed in Jacksonville, Florida (Fig. 5). It will be capable of manufacturing up to four floating nuclear plants per year. Manufacture of the first plant will require 50 months, but by the time the eighth plant is completed, projected improvements in production techniques should have reduced total manufacturing time to only 26 months. Delivery of the first plant is presently planned for July of 1979.

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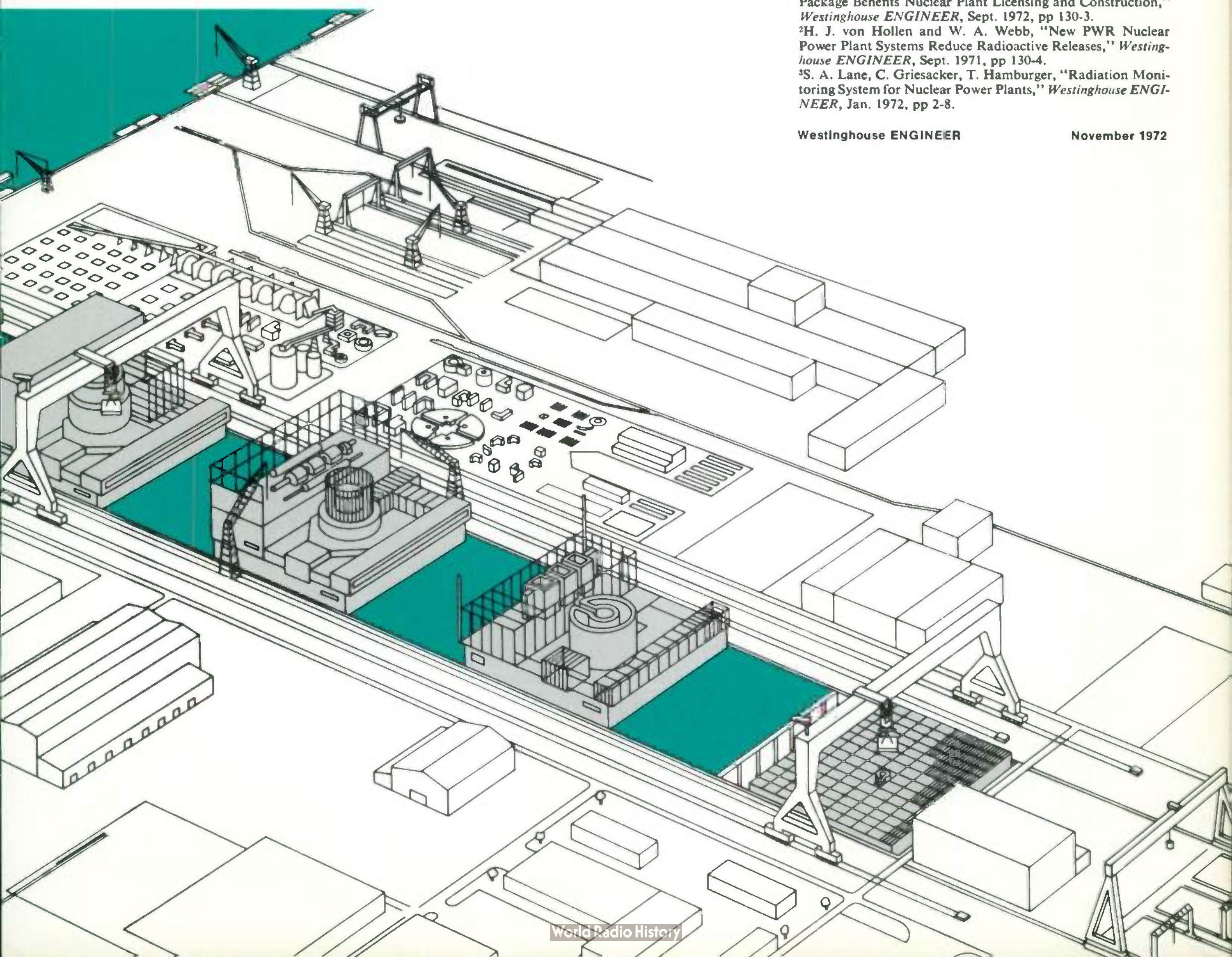


Relating Commercial Uses of Color to Human Color Vision

W. A. Thornton

Three particular colors apparently have a basic relationship to the human visual system. Their use in illumination, television, photography, printing, dyeing, and painting can produce coloration that people prefer and appreciate even more than "natural" coloration.

Man's vision is three-dimensional in color as well as in space (red or yellow for example, pale or intense, dim or bright). Not counting brightness differences, he can distinguish several million colors. About 150 of them are the brilliant, pure, vivid spectral colors, light of a single wavelength. Three of those appear to be the essential, or prime, colors of his visual system.

The term "prime colors" in this article is distinguished from the older popular term "primary colors," which usually refers to a set of three colors that, by proper combination, can match many other colors. There are countless useful sets of primary colors, no one set of which has been shown to be unique. Nevertheless, scientists such as George Palmer, Thomas Young, and James Clerk Maxwell as far back as the late eighteenth century apparently sensed that there *is* a unique set; that set appears to be the one identified here and called the three prime colors. Those three are the brilliant pure colors that probably appear to most people to be both special and the brightest in the spectrum when sunlight is dispersed into its constituent parts by a prism shape of water, glass, or ice. They are a blue-violet, a green without hint of yellow or blue, and an orange-red that is really neither orange nor red (Fig. 1).

Recent studies show that man simply appreciates most colors, but gives a few his careful attention.[1] The latter are "identifiable" colors; that is, they are associated with particular things that are important to man. They tend to be the colors people complain about in advertisements, color photos, color TV, and apparently any other color reproduction. They include the blues of sky and water, the greens of foliage, the colors of many foods (meat, butter, bread, fruits, vegetables), and complexion colors (which are the reference used in color television because mismatches in them are the most objectionable to viewers).

Some of the identifiable colors share a most interesting and important characteristic: *they are preferred considerably different in color than they are usually seen.*[1] Those preferences have been determined by presenting observers with an array of color chips of varying chromaticity (under the particular illuminant used) and asking the observers to pick the chip most representative of a certain identifiable color not simultaneously in view.

To be specific, reds are preferred redder, greens greener, and blues bluer. Meats, red fruits, and red vegetables, for example, are preferred redder (less yellow) and more saturated (less pale or pastel). So are complexions, all of which are similar in their spectral reflectances except in degree. Green vegetables and foliage are preferred much greener (less yellow) and more saturated. This is certainly a sort of paradox, that man should prefer important identifiable colors to be significantly different than he has always seen them in daylight.

It is as though man prefers many of the colors important to him to take on the qualities of the three prime colors—redder and greener in the sense of less yellow, bluer in the sense of less green or purple, and also redder, greener, and bluer in the sense of more saturated. The three prime colors seem to be the reference colors of man's visual system.

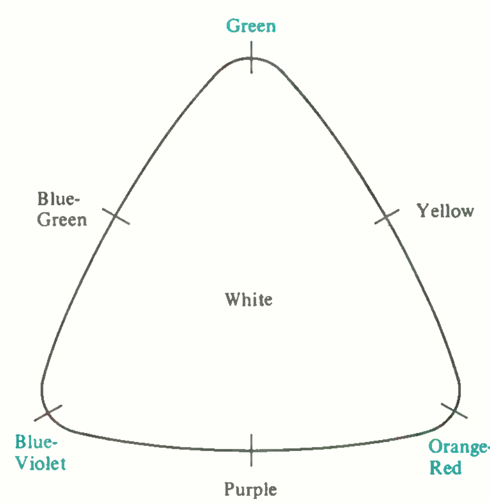
Yellow, blue-green, and purple are at "dead center" between the prime colors (Fig. 1). Preference testing indicates that the yellows of butter, corn, tea, and potato chips are preferred just as they are seen in daylight, and there is no evidence that the relatively rare blue-greens and purples in nature are preferred other than as they are seen in daylight.

Appreciative Viewing

Perhaps in less than one in a thousand glances at a colored object does a person require that one color match, or bear an exact relationship to, another color also in view. Mostly he is simply enjoying. It seems to follow that for maximum appreciation or enjoyment the important identifiable colors should be presented as they are preferred.

This conclusion relates importantly to commerce because colored scenes are artificially presented for man's pleasure in many commercial endeavors, including artificial illumination, television, still photography, movies, printing, and painting. This profusion of man-made or man-altered colored scenes can eventually be presented in *preferred* colors by making better use of the three prime colors. Doing so would provide illumination that is more satisfying, color television pictures more pleasing than the televised scenes, color photographs more attractive in every respect than the scene photographed, movies shown in color more enjoyable than that at the studio, and fabrics, magazine advertisements, and even artists' works more vivid or agreeable than before.

The basis of the methods by which scenes can be presented to the viewer in



1—The prime colors are at the vertices of this color diagram, and the colors that are ineffective and unwanted for appreciative viewing are midway between them. The periphery is the locus of spectral colors, while the central region represents white mixtures of spectral colors.

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their preferred colors is simply to make sure that light reaching the eye from any colored object lies primarily in the neighborhood of the three prime colors (Fig. 2). Light of the undesirable colors—blue-green, yellow, and deep red—must be subtracted, if it is present, before it reaches the eye. The centering of the desirable light bands on the wavelengths of the prime colors is very critical. The bands may be broadened somewhat, but much of the undesirable light must be prevented from reaching the eye if the preferred colors are to shine forth as they should. Control of light reaching the eye can be gained either by illuminating the colored objects in the scene by white light composed primarily of the prime colors, as in Fig. 2, or by interposing between the scene and the eye a filter that subtracts the unwanted colors of light from the scene.

If Fig. 2 represents transmission of a filter, and if the peaks of the allowed bands are properly adjusted, the color of a white object in a scene still appears white and natural. But identifiable things appear much as they are preferred rather than as they appear "naturally," and the scene appears more brightly colored.

Illumination

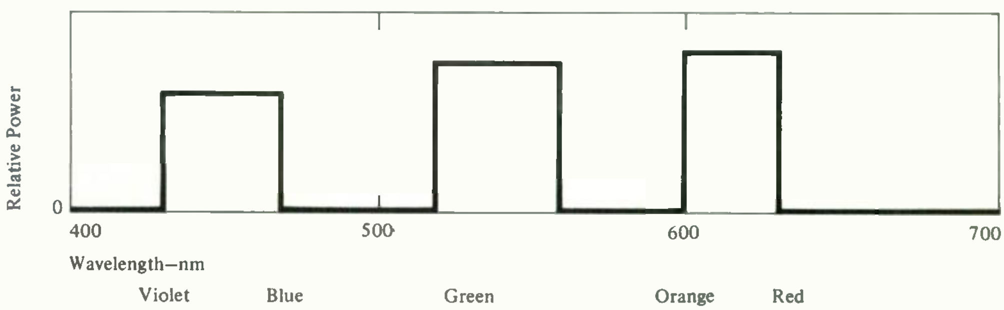
An earlier article described how study of white mixtures of a few pure colored lights led to identification of the three prime colors.[2] White mixtures of those three prime-color lights perform very well as illuminants, both in rendering colors (color-rendering index) and in luminous output.[3]

The absence of blue-green, yellow, and deep-red light in no way restricts the gamut of perceived colors in a scene. In fact, it is one of the fascinating ramifications of color vision that such subtraction of some of the undesirable colored lights *increases* the gamut of perceived colors.[4] Colored objects illuminated by white light of the same color as daylight, but composed of a mixture of the prime colors alone, take on even higher coloration than in daylight, and many appear in their "preferred" colors. If blue-green light is added to this "preferred" illuminant, blue and yellow colors become paler and less satisfactorily rendered. If yellow light is added, red and green colors become paler and less interesting, and the gamut of perceived colors as a whole shrinks rapidly. If too much deep-red light is added, purple colors become unnaturally and unpleasantly saturated. Thus, light of the latter three colors is best removed from the illuminant as completely as possible. One must understand that blue-green objects are rendered more than satisfactorily by blue light plus green light, yellow objects by green light plus red light, and—surprisingly—deep-red objects by orange-red plus blue light.[4]

Over the past 5 or 6 years, about 150 observers experienced in evaluation of illuminants have overwhelmingly preferred color rendering by white light composed of the prime colors. Fruits, vegetables, flowers, meats, complexions, and foliage were among the objects illuminated. The response was remarkably consistent and led to the suspicion that these three-prime-color illuminants were somehow rendering colors even better than does daylight. The mystery was apparently solved when a form of color-preference index was substituted for the color-rendering index, and values of 120 were measured compared with 100 for daylight.[5] In view of this preference, and its basic relation to color vision, it seems inevitable that most artificial light all over the globe will assume the three prime colors as sole constituents as rapidly as technological progress will allow.

Fluorescent lamps are the first to conform rapidly to the three-prime-color requirements because their spectral power distributions are so tractable. Westinghouse plans to produce and market such lamps. Trials in offices and homes are under way, with the favorable response typical of the early observers.

New phosphors developed to emit the prime colors are already almost as efficient and long-lasting as the conventional phosphors used for many years in standard lamps. They contain the less-common elements strontium, yttrium, and europium, so they are considerably more expensive



2—Spectral power distribution of a light mixture that yields preferred coloration of any scene is shown by the curve. The three bands of wavelengths are centered on the prime colors, and the unwanted colors are not present. The curve can also represent the transmittance of a special optical filter; looking through such a filter at a colored scene would reveal the scene in preferred coloration. That kind of filtering, in effect, can be applied to such diverse uses of color as television, photography, printing, dyeing and painting.

at present; however, the marked superiority of their performance in white-light-emitting blends should ease their entrance into commercial use until demand and mass production lower their cost.

The new illuminants preeminently afford "appreciative viewing." Since by definition their spectral power distribution takes the shape of the curve in Fig. 2, any scene illuminated by them takes on the preferred colors. Also, the efficiency of the lighting is much higher than it would be if part of the white-light mixture had to be wasted by filtering it out, and the gamut of colors is increased beyond that under real daylight.

Since most artificially illuminated scenes are, above all, to be appreciated, the new illuminants can be helpful in many applications. Museum lighting, for example, back lighting of large transparencies, or lighting of any other public or private display for appreciative viewing sets the subject off to good advantage if done by a three-prime-color illuminant.

Color Television

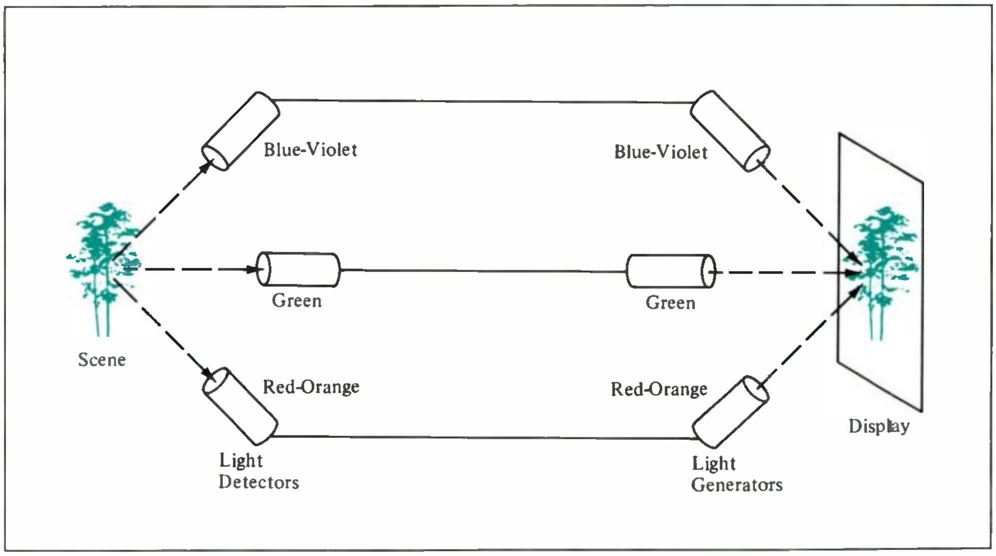
Present color TV systems, in their ideal forms, are based in principle on the traditional methods of colorimetry. That is, the responses of the three "eyes" of the color camera have the forms of color-matching functions based on the three real primary colors of the receiver. The signal from each "eye" is then proportional to the needed output of that primary color generator at the receiver. At its very best, such a system reproduces colors on the receiver that exactly match the corresponding colors in the televised scene.[6]

However, the cost of such an ideal system is far too great for commercial TV. In practice, cost is reduced to manageable proportions by a series of shortcuts that degrade the quality of the color match and sacrifice some of the proper color relationships in a scene. Complexion colors are used as reference because mismatches there are the most objectionable to viewers. That reference leaves some inherent mismatches of other colors, although many of the mismatches are such as not to detract too much from the quality of the picture.

However, since color TV systems have three channels, the camera could be made to pick up one prime color in each channel and eliminate the undesirable colors. Let the response of each channel of the proposed system to incoming light from the scene be one of the desired bands of Fig. 2. No channel responds to deep-violet, blue-green, yellow, or deep-red light. There is no overlap—one channel sees only blue light centered around 450 nm, one sees only green light centered around 540 nm, and one sees only orange-red light centered around 610 nm (Fig. 3). Suppose each channel drives a light generator that responds with the same distribution, and suppose the intensity of the light of that color is proportional to the intensity of the light seen by that channel in the camera. Then the picture on the receiver glows in the preferred colors and so is much more pleasant, even, than the scene at the camera (assuming the scene is illuminated with daylight or ordinary artificial light).

Present color receivers are already in pretty good shape because the three colored lights they generate lie roughly within the desired bands. The main trouble is with the camera, which essentially responds to the wrong colors. Typical responses of present TV cameras overlap strongly in the yellow and thus are much too responsive to that color, and the "red" response is peaked in the orange—a small but critical difference from that of the human visual system. When present color TV systems were designed in the 1950s, the objective was exact color match. It was not yet recognized that the human visual system samples light from its environment primarily near the three prime colors,[7] nor that elimination of the undesirable color regions from the light reaching it would yield the colors for which mankind shows a strong preference.[4]

Adjustment of camera response is a relatively simple matter, but the assumed need for overlapping responses, stemming from traditional colorimetry and the original hope of achieving exact color matches, remains ingrained in color-TV thinking. Unfortunately, exact color matches have



3—A proposed color television system has three isolated channels, each responding to and generating light in one of the bands of Fig. 2. No channel responds to any of the undesired wavelengths—deep violet, blue-green, yellow, and deep red.

been found economically unrealizable. Substituting the goal of *preferred* coloration makes realization of the goal much simpler by evading the complexities of conventional colorimetry.

The proposed approach to color TV in effect mirrors the human visual system in some of its newly discovered characteristics. The TV camera eye is made to see like man. The same can be done for that other eye, the film camera.

Color Photography

The problems and limitations of present color photography are similar to those of color TV, but more marked in some respects. Corresponding to the three channels of the TV camera are the three film layers responsive to blue, green, and red light. Corresponding to the receiver, where three colored lights are generated, are three dyes (produced in the processing of exposed film) that generate three colors by subtracting part of whatever light falls on the completed color picture.

Present dye layers go by the name of yellow (blue-subtracting), magenta (green-subtracting), and cyan (red-subtracting). A given dye is *suppressed* in the final print to the degree of exposure by the colored light that it would otherwise subtract in the final print. For example, strong exposure by blue light alone completely suppresses formation of yellow (blue-subtracting) dye; the other two dyes fully form and subtract green and red light from the light falling on the print, leaving a strong blue color.

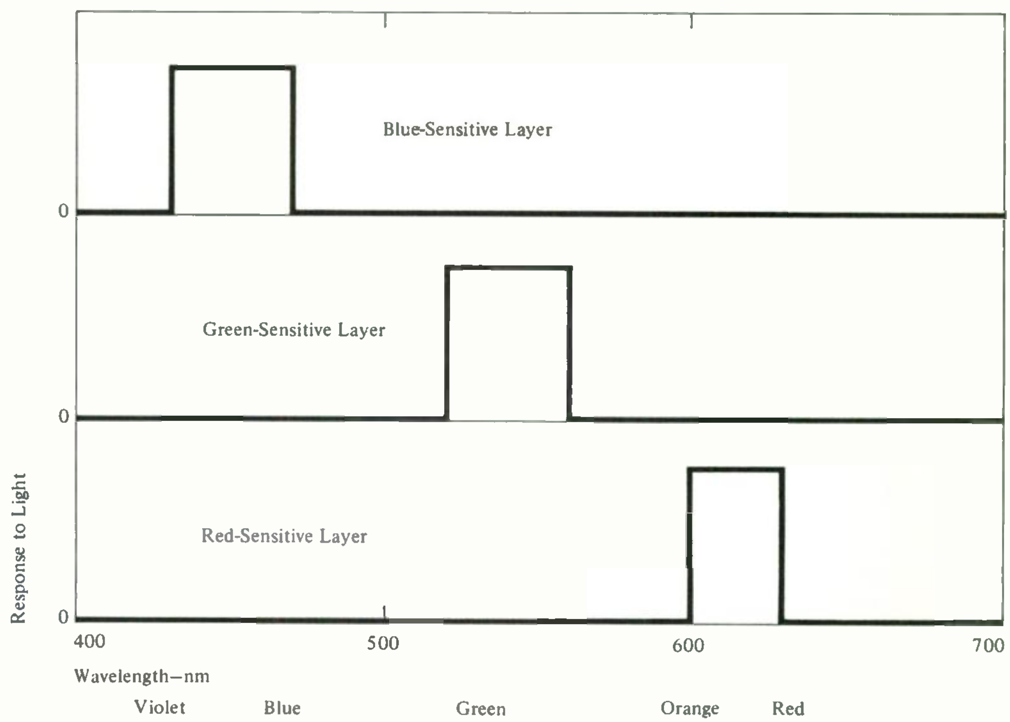
The laws of colorimetry cannot be fulfilled in color film at any cost. The "output" of the processed color film consists essentially of three real primary colored lights, but the laws of colorimetry require that the responses of the light-sensitive layers of the unexposed film be positive to some colors of light and negative to others. While positive and negative responses are possible (at considerable cost) in color TV systems, or can be avoided by elaborate transformations of the electrical signals to a simpler set of camera responses, no such expedients are available in color photography.

Trial and error over a century has led to the present serviceable, and admirable, compromise and to the often satisfying results we all enjoy in color prints, transparencies, and movies. But fidelity in color match between an element of scene and print is not there, much less a rendering in the preferred colors we all unconsciously hope for. As we have seen, preferred colors result when deep-violet, blue-green, yellow, and deep-red light are minimized. Present color film responds too strongly to all of those colors, quite unlike the human visual system, and, when developed, its dyes fail to subtract the unwanted light colors.

Ideally, how should the manufacturer design the many layers and materials in color film so that the picture would unfailingly present to the viewer colors he would enjoy, and colors that would pass his critical inspection as well, even more thoroughly than the daylit scene that was photographed?

The answer is again in Fig. 2. For greater clarity, the requirements are spelled out in Figs. 4, 5, and 6. The blue-sensitive film layer should respond only to light of wavelength within the blue band (Fig. 4); cutoff needs to be quite sharp so that deep violet and blue-green light have little effect. The same for the green-sensitive and orange-red sensitive film layers. Present films respond strongly to violet and to deep-red light, and those two tendencies, especially the latter, are at the root of the trouble.

The present dye layers are fine for the proposed film system, provided the three critical regions of response of all the layers are defined more sharply and positioned more knowledgeably. Transmissions of the proposed dyes, when fully formed, are shown as they should be in Fig. 5. Taken in



4—In a proposed color photography system, the spectral response of each of the three photosensitive film layers is also in accordance with Fig. 2. No layer responds to any of the undesired wavelengths.

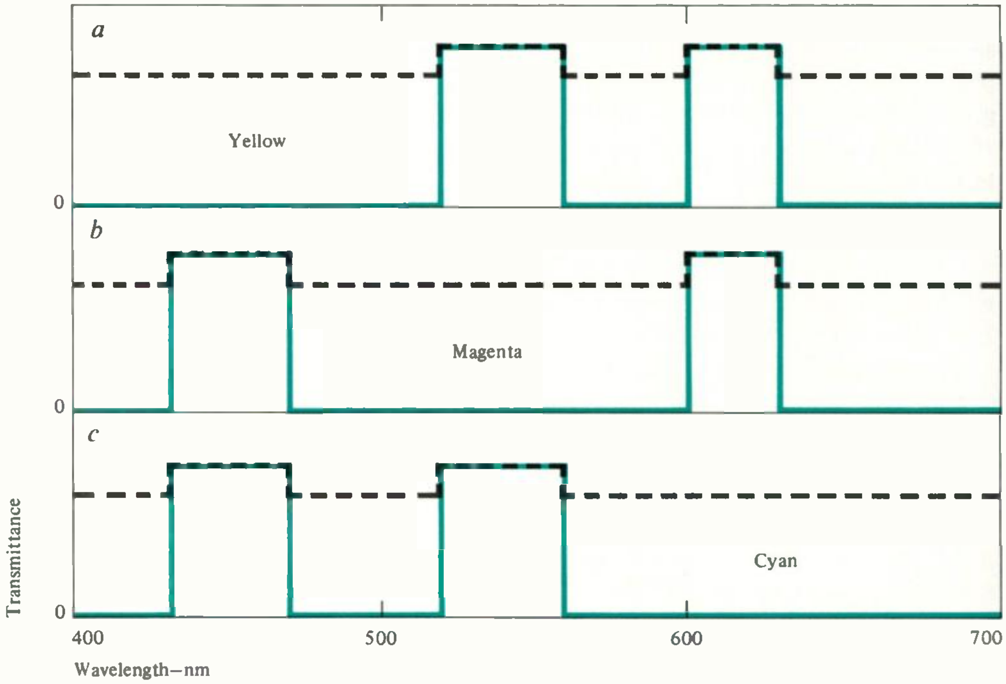
pairs, the ideal dyes only transmit one of the prime color bands, and thus they yield deep blue-violet, deep green, or deep orange-red on the final print. Exposure by strong white light suppresses formation of all dyes, transmission on the print is then high for all colors, and a bright white area results.

Suppose, for example, that the photo includes a patch of bluish-white sky. The strong blue light suppresses formation of yellow dye completely, but the magenta and cyan dyes are partially formed (dashed lines of Figs. 5b and c). The transmission of that patch on the print (Fig. 6) accentuates the blue slightly over the green and orange-red so as to get the blue tint of the sky, and it also shows a most important double subtraction of the unwanted light. That is, the partially formed magenta and the partially formed cyan dyes subtract some of each of the unwanted wavelengths from the incident light. That double subtraction is what saturates the blue color a bit and provides the preferred sky color in the print.

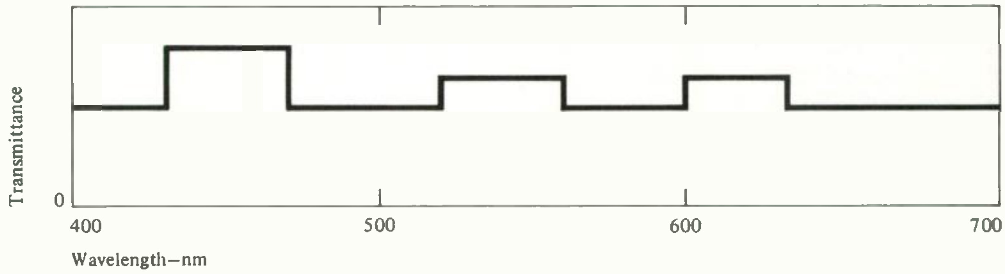
Similarly, a complexion color comes out a little less yellow and a little more saturated, on the print, and appears as the viewer thinks he remembers it (if he knows the subject) or as he believes it ought to be (if he does not). The same is true of the green of grass or vegetables and the colors of the other important identifiable objects.

The reason dye transmissions should match photoresponses in color photography is so that we see, in the finished print, the same colors (the preferred colors) "seen" by the photosensitive layers. Those preferred colors are of course the ones of Fig. 2.

Any scene to be photographed or televised is most efficiently illuminated by a three-prime-color illuminant, since there is then no wasted power. Moreover, the scene is enhanced in pleasurable appearance. In photography, proper design of a film and processing system can make the illuminated scene and the finished color print identical in preferred coloration. Similarly, the picture on a TV receiver can be made identical to the scene, an achievement impossible with present color TV systems, by adoption



5—Spectral transmittances of the yellow (blue-subtracting), magenta (green-subtracting), and cyan (red-subtracting) dyes in the proposed film are illustrated here. The dashed lines represent partially formed dyes; the solid lines, fully formed. All dyes subtract at least some of each of the undesired wavelengths in addition to the one desired color for which each dye is named, e.g., blue*-subtracting. Subtraction is in proportion to the degree of formation of the dye, and degree of formation is inversely proportional to exposure by light of the color in question.*



6—The film of Figs. 4 and 5 would provide this spectral transmittance for an area on the finished photo with the color of bluish-white sky. The yellow dye is completely unformed, i.e., completely suppressed by strong blue light in the exposure. The magenta and cyan dyes are only slightly formed, each subtracting some of each of the undesired wavelengths and thus rendering the sky in the preferred blue color.

of the principles outlined in the preceding section. However, a major strength of the proposed approaches is that neither photographed scene nor televised scene *needs* special illuminants; such illuminants only provide pleasurable coloration at the scene and enhance the power efficiency of the lighting.

Inks, Paints, and Dyes

The proposed ideal transmittance curves of Fig. 5 can also be considered reflectance curves. They apply to all colorants whether they be pigments or dyes, and thus they apply to inks, paints, enamels, and other means of using colorants.

The huge color printing industry is based on the same considerations as color photography. Color fidelity is important in a few applications of printing, but color *appreciation* and color *preference* are controlling factors in most. For a bright, pleasurable, satisfying color picture, the inks used must transmit or reflect predominantly the three prime colors and selectively eliminate the undesired bands of color (Fig. 5).

There are several advantages in so doing. First, with ordinary white light illuminating the color picture, its coloration is of course produced by subtraction, i.e., by absorbing and wasting a good fraction of the incident light. This waste cannot be avoided with ordinary illumination, and it is greater the deeper the colors wanted in the picture. But the colors of light to retain and discard, in achieving the desired coloration, can be chosen with care. Again, the three prime colors seem to be most effective, per watt, in establishing color in the human visual system. Conversely, blue-green and yellow light are much less effective per watt, as are deep-violet and deep-red light, so it is the latter four colors that are best discarded. The remaining prime colors produce the most coloration per watt entering the eye.

A second advantage is that the proposed inks hold the bright colors in the picture more nearly constant when the completed color picture is illuminated by different light sources. The printer uses some particular lamp to examine his color work; he can use practically any set of colored inks to obtain a desired complexion color under that lamp. But what happens when the customer takes the picture out of the shop and examines it in daylight or under a different incandescent or fluorescent lamp? A poorer choice of inks upsets the relationship of the complexion color to other colors in the picture.

Third, the proposed inks will afford a much larger gamut of color than present inks do, once technological advances bring about their use. Those advances will consist of transforming the reflectance curves that are characteristic of colored inks from broad rounded forms to forms with sharper cutoffs and more precise placement of pass bands and rejection bands.

In fabric colors for clothing and home furnishings, matches and relationships between colors are much more important than in most other color experience. Distressing shifts in match or relationship of the colors in an ensemble often occur with change in illuminant, say from daylight to incandescence. Two of the coming technological advances involving the prime colors will help to eliminate that problem: if a certain color match or color relationship exists between two or more ordinary dyed fabrics under any illuminant whatever, a three-prime-color illuminant has (whatever its color) the peculiar capability of preserving that match or relationship; if, instead, dyes with the transmittance or reflectance of Fig. 5 are used, the desired color match or relationship will tend to be preserved under *any* illuminant.

What about artists? Those whose works tend to be subdued, dark, or dim, those for whom museum and gallery lighting is sufficiently constant and adequate in intensity, and those who are satisfied with the impact of their works as rendered under whatever natural or artificial illumination is available have perhaps little to gain by the proposed approach. But where an artistic work in color is meant to evoke such reactions as striking, dramatic, eloquent, exciting, pleasurable, remarkable, exhilarating, disturbing, moving, stimulating, provoking, rousing, or enjoyable, attention to the possibilities of indulging the human visual system is in order.

To reiterate, the proposed pigments and dyes will afford a very large color gamut, more pleasurable color, maximum visual response per reflected watt of illumination, and good stability of color gamut with change of illumination.

Conclusion

Three particular colored lights, mixed together to form white light, yield breathtaking color rendering when used to illuminate a scene. Work related to experiments of many years ago establishes those particular colored lights as profoundly involved in the human visual system.

Moreover, use of the three prime colors in such vast commercial applications as illumination, television, photography, printing, painting, and dyeing results in perceived colors that man prefers. The colors are those that he (mistakenly) thinks he remembers when the original is not at hand, colors that he wishes the original had when he sees it in daylight, and thus colors that are in a sense foreign to the daylight in which man presumably has evolved and yet are innate to his own nature.

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Side-Look Radar Provides a New Tool for Topographic and Geological Surveys

R. E. Powers

Originally developed for military reconnaissance, side-look radar has been adapted for application to earth resources development.

Side-look radar (SLR) imagery is now being used for mapping large areas of the world, particularly equatorial regions where existing maps are inadequate or nonexistent. Also, geologists are beginning to recognize the capability of SLR to display land forms and surface expressions of subsurface geological structures. Such topographic and subsurface geological surveys are extremely useful for investigating areas where the potential for finding mineral or oil deposits is good but where exploration and development has been held back for lack of accurate maps and geological information.

The principal reason for that lack of maps is the inability to acquire aerial photography in areas where ground surveys are also practically impossible. Aerial photography for mapping purposes requires cloud-free conditions with a high sun (short shadows). These photographs can be used not only to make maps as we generally know them, but also to prepare geological maps that help the field geologist find areas of potential mineral and oil deposits. Unfortunately, even with today's high technology, many equatorial areas are almost constantly covered by clouds that prevent effective photography. Dense jungle cover of these same regions also reduces the effectiveness of aerial photography for geological surveys.

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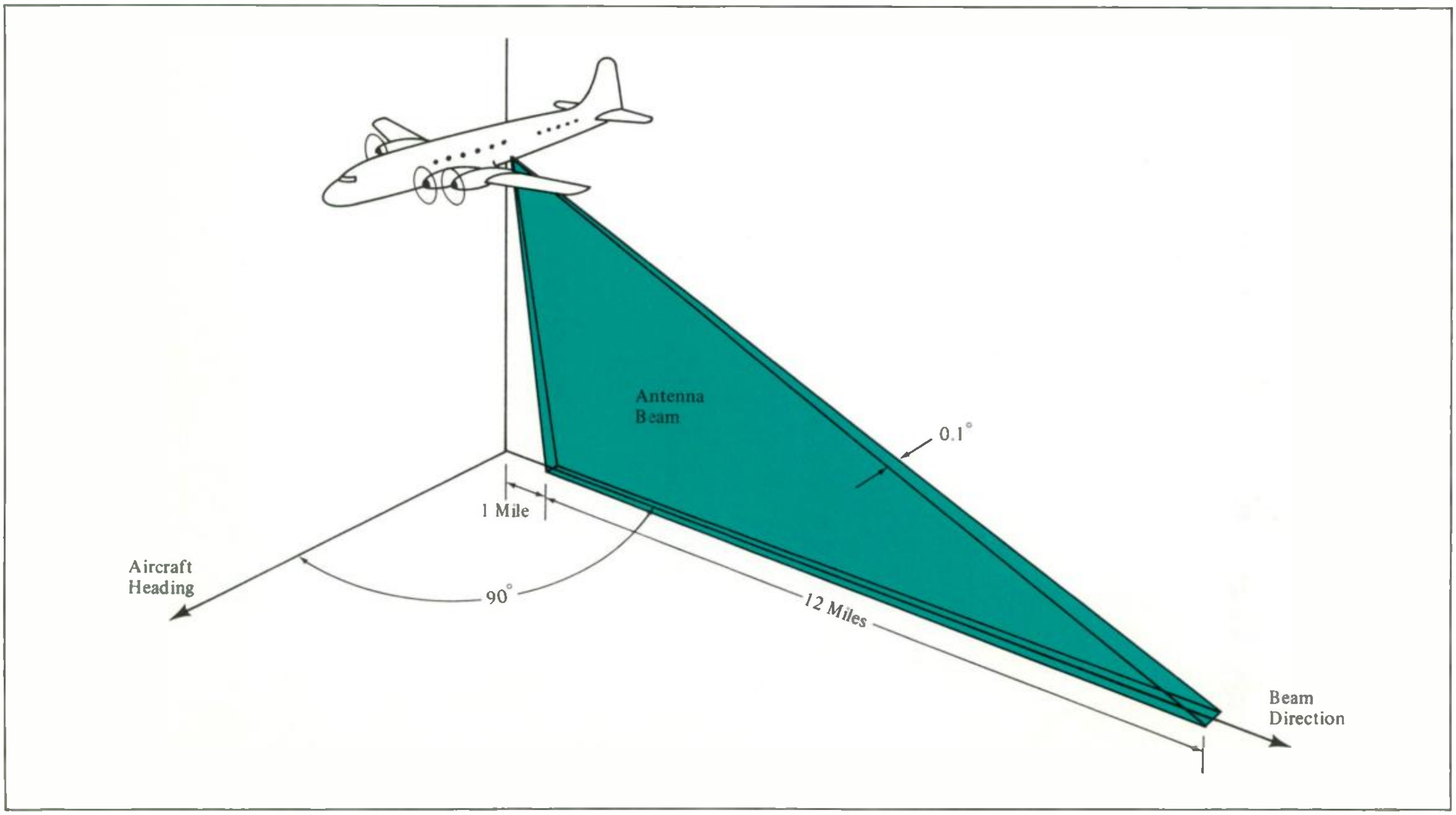
A Role for SLR

The utilization of radar for mapping was originally investigated by the U. S. Army Electronics Command. Recognizing the radar signal's ability to penetrate clouds, fog, and haze, the military asked industry to develop a radar technique that could produce imagery similar to that provided by aerial photography. One of those early radar systems developed by Westinghouse for the U. S. Army Electronics Command Engineering Topographic Labs for radar



1—High-quality imagery from side-look radar requires an extremely narrow radar beam pattern. As the aircraft moves along the area being scanned, the return from each radar pulse provides a line trace of each illuminated ground sector on the face of a cathode-ray tube. SLR imagery is produced by recording those traces on film that is drawn across the face of the tube at a velocity proportional to aircraft ground speed.

Right—Even though covered by a dense jungle, geologic features are made clearly visible with SLR imagery, as demonstrated by this survey of an area of New Guinea. SLR imagery reveals geological features that merit further exploration, and it provides base maps for planning a method of entry to unmapped areas.

mapping and reconnaissance, designated the APQ-97, has now been adapted for commercial application to provide SLR surveys for customers, principally in the oil and mining industry, and for foreign governments. Those customers are not so concerned with the technical aspects of radar as with the quality of its imagery.

SLR Resolution and Distortion

The quality of side-look radar imagery is usually expressed in terms of its resolution and distortion, although those terms do not have the same meaning for radar that they have for aerial photography.

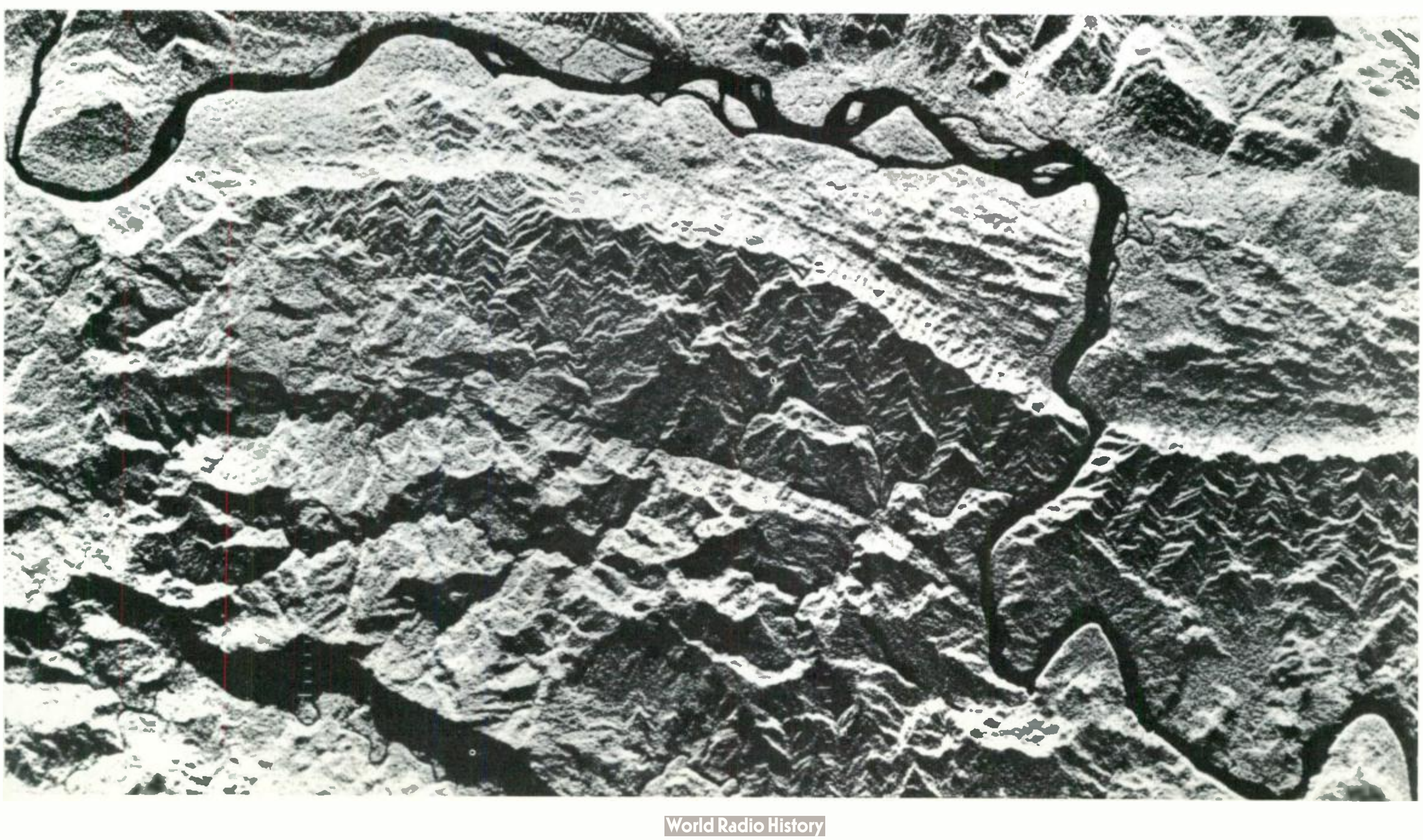
With aerial photography, resolution is a measure of the size of objects that a particular lens/film combination can record. With SLR, on the other hand, resolution refers to ability to discriminate between two objects *regardless of size.* If an object has the proper constituents to reflect sufficient energy back to the antenna, the object is recorded. It may appear on the film as a white dot without an indication of its shape. For example, if the resolution of the radar system is 40 feet, two such objects separated by 40 feet are recorded as two dots, whereas if they are separated by only 35 feet, they are recorded as one larger dot.

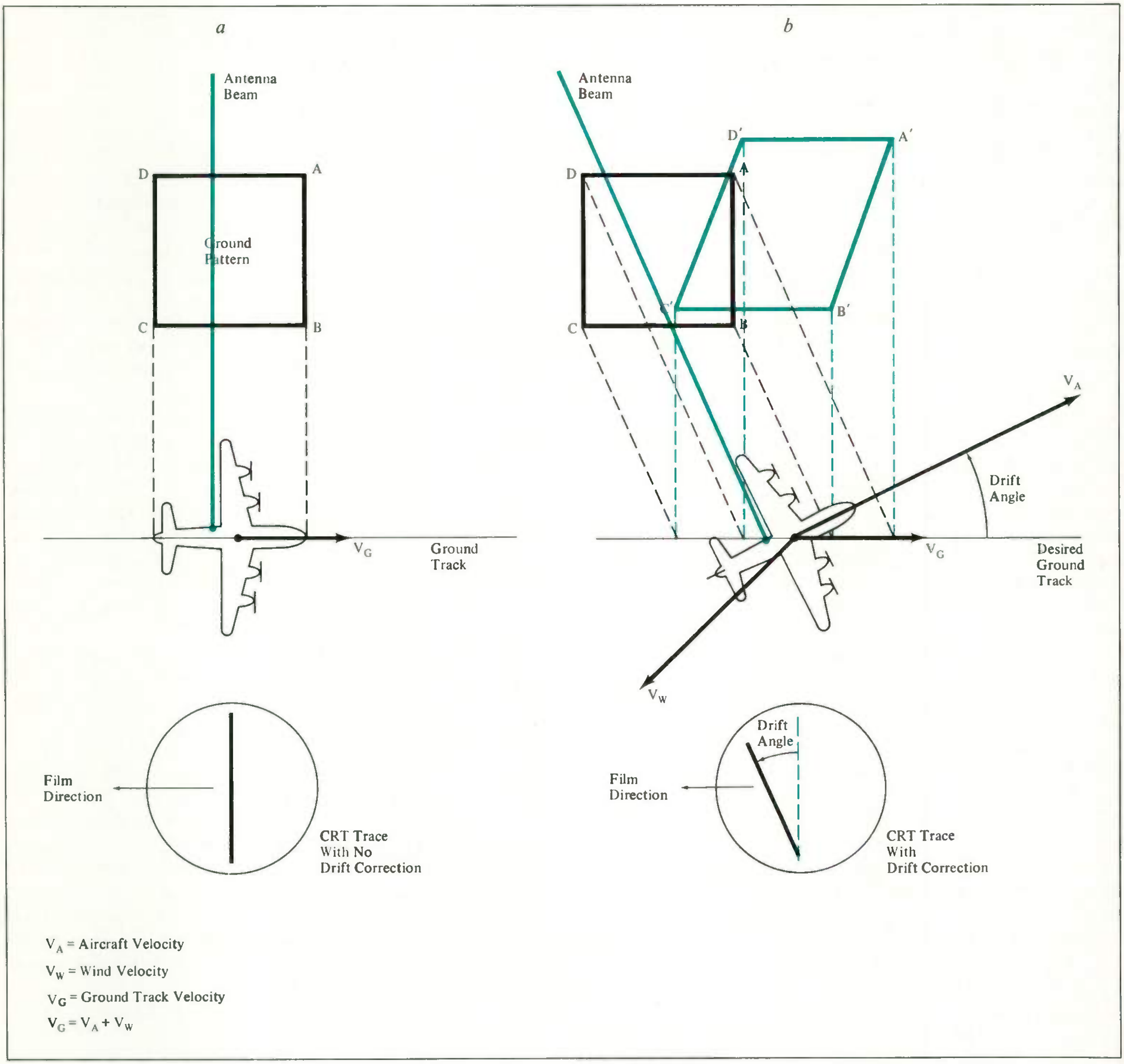
Also, SLR resolution should not be confused with aerial photography's sharpness of image, which depends on correct focus of the camera. With SLR imagery, sharpness is degraded by background noise or by excessive signal and film processing.

SLR imagery is particularly susceptible to distortion because of its method of construction. Although similar in appearance to strip photography, SLR imagery is constructed by recording a television-like picture one line at a time. The traversing cathode-ray-tube (CRT) trace varies in intensity as the returning signal amplitude varies, and each trace is recorded on film that is drawn across the face of the CRT at a speed proportional to the aircraft's speed over the ground. Unlike photography, SLR imagery can have distortion due to dissimilar scales in orthogonal directions if misadjustment in the recording process introduces scale dissimilarity into the recorded image. Scale dissimilarity causes objects to be recorded in shapes other than their true shape and in incorrect horizontal locations relative to other objects.

Scale across the film is controlled by adjusting the length of the CRT trace across the face relative to the radar swath width on the ground. Specifically, for Westinghouse equipment one CRT sweep records approximately 12 statute miles of low-relief terrain (Fig. 1). That 12-mile scan can be recorded in various scan lengths on film; it is normally adjusted to provide a scale of 1:250,000. Scale along the length of the film is controlled by adjusting the speed of the film-drive mechanism. Ground speed information generated by the navigation system is converted electronically to control the film drive to a speed that will provide the same scale of 1:250,000 (Fig. 2a).

Another source of distortion for SLR imagery is aircraft drift. If the antenna pattern is not continually positioned at 90 degrees to the direction of the ground track, some form of distortion correction must





2—The side-look radar antenna is attached to the aircraft, and azimuth scanning is provided by the motion of the aircraft. Each radar echo modulates the CRT trace, which registers on recording film that moves past the CRT face to duplicate the spatial scanning provided by aircraft motion.

When aircraft orientation coincides with the ground track (a), *the square area* ABCD *is reproduced as a square on film by coordinating film speed with aircraft speed* (V_G) *to provide the same scale in the ground-track direction as obtained by the azimuth scan* (*normally 1:250,000*).

If aircraft orientation is skewed (b) *relative to the ground track to compensate for wind velocity, a CRT trace with no drift correction would reproduce square* ABCD *on the ground as the parallelogram* A'B'C'D' *on film. However, by applying drift correction to the CRT trace,* ABCD *is reproduced as a square. Again, it is necessary to coordinate film speed with aircraft ground track velocity* (V_G) *to maintain identical orthogonal scales.*

be provided to prevent square fields from being recorded as skewed parallelograms (Fig. 2b). Since a 14-foot antenna slung beneath the aircraft is difficult to swing to correct for drift, a better technique is to keep the antenna stabilized and feed drift information from the navigation system to the deflection mechanism of the CRT. By adjusting the angle of the CRT trace, distortion caused by drift can be corrected.

The sum of drift correction and other minor corrections provide distortion-free SLR imagery, suitable for combining into mosaics. Large mosaics are used for the construction of planimetric base maps of areas that have not been previously mapped.

To make each scan of imagery suitable for mosaics, all imagery must have a "single-look" direction; i.e., all shadows in the same direction. (If a low-sun-angle vertical photograph is viewed from a direction opposite that from which the photograph was taken, inversions occur and rivers seem to run along ridges.) Therefore, the SLR antenna has been constructed so that data can be recorded from either side of the aircraft; this allows the operator to switch antennas when the aircraft makes a 180-degree turn for a return run to record an adjacent strip. Thus, all scans are viewed from the same direction.

Like photography, the most difficult SLR distortion to correct is that caused by terrain relief. A vertical photograph of hills records the distortions illustrated in Fig. 3a, which shows why line-of-sight positions on undulating terrain are horizontally displaced when reproduced on a flat surface.

With SLR, the problem is similar but the geometry is different (Fig. 3b). Here, the position of each point imaged on film is dependent on the time its echo arrives at the antenna. The uneven terrain causes time displacements in the reflected signals that reproduce on film much like photographic distortion.

Fortunately, the photogrammetrist has learned to remove photographic distortions to produce a corrected photograph known as an orthophotograph. The technology also exists to produce ortho-SLR imagery, but the method is still being developed.

SLR for Geological Reconnaissance

In 1964, SLR began to receive recognition as a geological reconnaissance tool. The initial investigations, accomplished with Westinghouse imagery, demonstrated the feasibility of producing regional geologic maps of unexpected accuracy. For example, this study led to investigation of a series of ring dikes located in the southeastern corner of Wyoming. (Ring dikes are formed by intruding magma or molten rock into oval or arcuate fractures occurring in the country rock. After erosion takes its toll on the country rock, the earth's surface shows an oval or arcuate pattern of magma that has solidified.) No existing geological map showed those structures in this area.

Until 1969, SLR was not available for commercial application because of military classification. When Westinghouse SLR then became commercially operational, some SLR-based geologic maps began to show greater detail than maps made by other airborne methods. For example, geologists have found that SLR imagery defines the drainage network of an area exceptionally well. In the Oriente province of Ecuador, a drainage map produced by interpreting Westinghouse SLR imagery proved superior to a drainage map produced by interpreting black and white infrared photography, the method often used for this purpose.

Another outstanding use for SLR is the location of geologic linear patterns to define subsurface cracks and faults. (Linears are faults or fractures formed in relatively straight lines by some type of geologic action. Further identification requires additional investigation.) In one instance, SLR imagery in the southwestern United States clearly defined faults controlling production on a known oil field. This faulting could not be seen on aerial photographs.

In New Guinea, SLR imagery demonstrated ability to show the location of intrusives (formed when molten rock, under pressure, is forced into another portion of the earth's crust) and provided a unique signature that identified limestone even though the area is covered by dense jungle. Although it is generally accepted that a radar signal (1-cm wavelength) does not penetrate foliage, SLR has demonstrated a unique ability to reveal surface expressions of geologic structures under dense jungle cover. Terrain features can be sensed because the radar signal is reflected by the jungle cover, and this cover generally follows the contour of the earth's surface. Surface features caused by geologic action are further identified because geologic action affects the moisture content in the ground, which in turn affects the moisture content, type, and height of the covering vegetation. As a result of these features, geologists are beginning to recognize the value of SLR as a reconnaissance tool for jungle-covered areas.

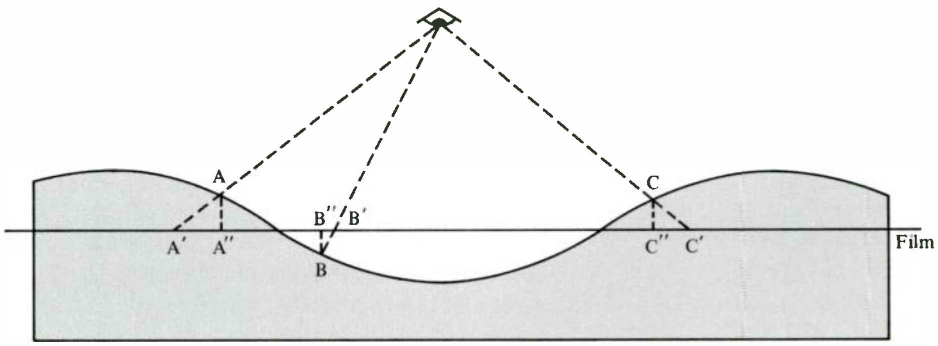
In the late 60's, experiments were conducted at the University of Kansas to determine if SLR could discriminate between various agricultural crops. Although much work has yet to be done to effectively complete the investigation, it was found that sizes of fields and clearings in forested areas can be identified with a high degree of reliability. Production of generalized vegetation maps was found to be well within the capability of SLR. Many developing nations do not have maps giving this information, but SLR imagery can make it available within a few months after data acquisition. For example, it took only seven days to obtain SLR imagery for the entire country of Nicaragua. Four months later, comprehensive maps had been prepared showing geology, geomorphology, surface drainage, generalized land use, and vegetation. With Westinghouse SLR imagery, interpreters were able to define all major geologic structures of a particular area within two weeks; local geologists had required six years to define those same structures using aerial photography and field exploration.

Future Tasks for SLR

Side-look radar, because it is an active system (provides its own illumination), can operate day or night over clear or cloud-covered terrain. Thus, SLR can be used to survey large areas in a relatively short time. Since radar seems to be the only system other than photography that has the potential for accurate mapping, it would be highly advantageous to develop SLR for use in map updating. The technology needed is becoming available, but further research is required to develop methods and techniques to produce planimetric and topographic maps that conform to National Standards of Map Accuracies. This accomplishment will require development of distortion-correcting methods allowing the production of radar imagery free of distortion due to terrain relief.

Another area for further research is signature identification, where, under given conditions, the properties of the return signal can be used to describe the material from which it was reflected. This technique would provide a form of automated SLR

a

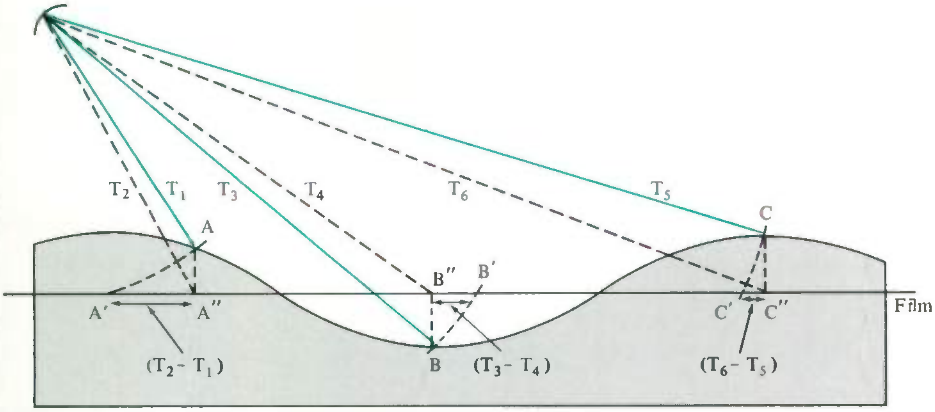


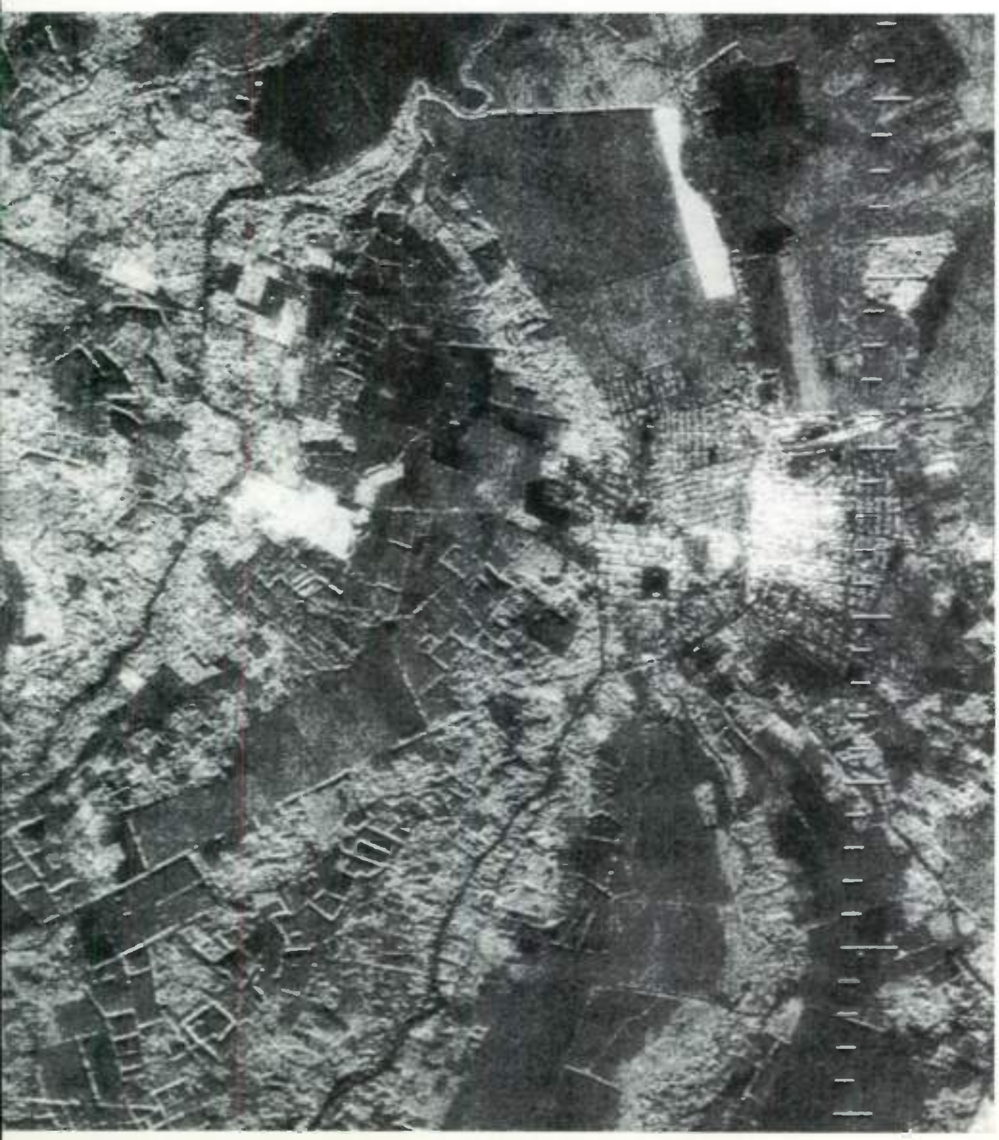
3—Distortion occurs in a vertical photograph of rolling terrain (a) *because points* A, B, C *on the land surface are recorded as* A′, B′, C′ *on the film plane; actually, the correct positions on the film plane are points* A″, B″, C″.

With SLR imagery (b), *distortion of rolling terrain is similar but the geometry is different. The location of each terrain point on the film is dependent on the time at which the radar echo from that point arrives at the antenna. Thus, points* A, B, *and* C *on the terrain have reflection periods of* T_1, T_3, *and* T_5 *and are therefore recorded at* A′, B′, *and* C′ *on the film plane, whereas the points correctly belong at* A″, B″, *and* C″. *For point* A *to register at point* A″ *on the film plane, the reflection period should be* T_2, *rather than* T_1. *Therefore,* A *is imaged* T_2—T_1 *too early on the film plane. Similarly, point* C *is imaged early by* T_6—T_5. *Point* B, *on the other hand, is imaged late by* T_3—T_4.

Right—SLR imagery is now being used for mapping remote areas, such as this low swampy area in Ecuador. This survey was done for the Hydrology Commission, which was investigating the surface drainage system.

b





imagery interpretation for extracting earth resources data. Present procedures require human interpretation in the same manner that photogeologists, foresters, soils scientists, and land-use experts must interpret aerial photography.

Accumulated experience with side-look radar is leading to its acceptance throughout the world as an earth resources mapping tool. Oil geologists have successfully used it in Ecuador to identify geomorphic anomalies that later led to successful drilling for oil. In West Irian, Indonesian mining geologists successfully applied SLR imagery interpretation to identify areas with high potential for economic development of mineral resources. And in Nicaragua, the government chose SLR to map their entire country to accelerate the location, description, and development of natural resources. In the Amazon basin, Brazil is using SLR to provide geologic maps and base maps (general maps that do not have the accuracy of cartography) where previously there were none. With these new maps, Brazil hopes to speed up the development of this largely unsettled but resources-rich area.

Of all the relatively new remote sensors in use (IR scanners, radiometers, scatterometers, etc.), side-look radar has been the most useful and most successfully applied tool for earth resources development.

T-Tap Switch Solves a Variety of URD Problems *

Roger K. Peterson

The T-Tap switch was designed expressly for switching on a three-phase underground feeder. Modular design permits custom construction to meet any system's particular requirements.

The Westinghouse T-Tap switch is a multi-functional switching device that allows system design flexibility while increasing convenience and reliability on underground residential distribution (URD) systems (Fig. 1). It provides three-pole switching for sectionalizing three-phase main feeder circuits and is available with an optional number of fused or unfused tap-off points for serving single-phase laterals. Two basic switch configurations are available—the standard three-phase gang-operated design and a double-ended (duplex) design for use on loop-feed and alternate/preferred systems (Fig. 2).

For submersible installations, the T-Tap switch is housed in a molded fiberglass-reinforced tank with a stainless steel roof; the entire unit is sealed against occasional submersion. For pad-mounted installations, the switch is provided with a weatherproof housing secured by lockable hinged doors. Both designs are manually operated by a handle. A feature of the pad-mounted T-Tap switch is modular construction, which enables the user to create a design or change it to meet varying needs. Modules include single- and double-ended switches with various bus configurations, fused and unfused tap-off points, lightning arresters, and potential transformer and space heater combinations.

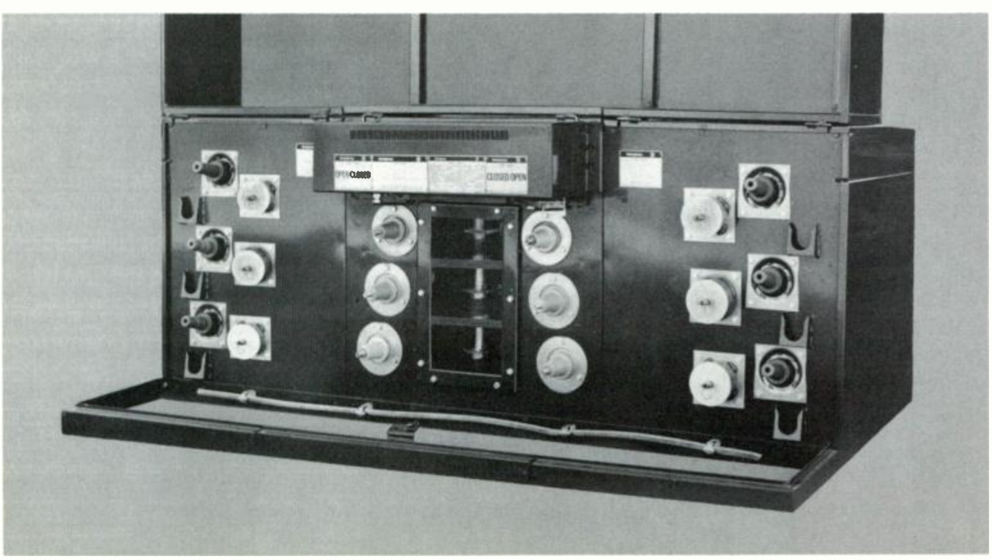
At the time this article was written, Roger K. Peterson was Marketing Representative on the Vacuum Switch Development Program, Distribution Apparatus Division, Westinghouse Electric Corporation, Bloomington, Indiana.

Distribution System Configurations

A basic shortcoming of the utility industry has been lack of commonality of thought as to how three-phase URD systems should be designed. In many cases, adequate master plans have not been developed for total three-phase underground feeders. Moreover, economics and other practical considerations have dictated that only certain segments of the three-phase distribution feeder could be placed underground. Consequently, development of equipment for URD systems has been rather sporadic, with many products offered as versions of overhead distribution equipment modified to withstand the rigors of submersible and pad-mounted installations. Most three-phase gang-operated switches, for example, have been adaptations of industrial switches, transformer switches, or overhead switches and were not designed specifically to solve underground residential distribution problems but rather modified to offer a half-step solution.

Besides frequently compromising reliability, flexibility, and performance, such hybrid equipment was often expensive, and it often complicated system design. Figure 3 shows a simplified overhead three-phase circuit as used on most utility systems. Approximate installed costs are shown at the various system components. On this type of system, loss of the three-phase feeder could be taken care of quickly since each single-phase lateral could be tied into another lateral emanating from the opposite side of one of the three-phase sectionalizing switches on the main feeder. Since overhead single-phase laterals were easily identifiable, they could be traced visually if need be. A fault on the three-phase segment of the feeder could be readily isolated and the single-phase laterals backfed by closing a normally open single-phase tie point and opening the tap-off switch.

Many utilities began to use such overhead-type configurations on their underground feeders. However, several considerations make this an inadequate approach. For example, costs of the three-phase switches, tap-off points, lateral switches, and normally open single-phase loop tie switches are considerably higher than those of overhead equipment (Fig. 3). Also, tracing the single-phase lateral circuitry to ascertain which switch should be thrown to backfeed into a single-phase lateral affected by a lost three-phase feeder segment is extremely difficult, since there is no visual indication and adequate system maps are not always available. This results in exceptionally long outage times. Average three-phase outage time is 1 to 2 hours on



1—This pad-mounted T-Tap switch contains two three-phase gang-operated switches (center module) and one fused tap module on each side of the switch module. The window at the center of the switch module allows visual determination of the position of the three-phase switching contacts.

2—The two basic switching configurations available in the T-Tap are the single-ended three-phase switch (a) and the double-ended (duplex) version (b). Though both designs are shown with three fused taps emanating from the buswork, as many fused or unfused taps can be supplied as desired.

an overhead circuit, but it is about 8 hours on an underground system of the same design.

Such factors created the impetus for the development of the T-Tap switch for three-phase underground circuits. Figure 4 shows the simplified system discussed earlier as most utilities now approach it on a total underground basis. Note that all load emanates from double-ended (duplex) T-Tap switches, thus maintaining the integrity of the three-phase cable between adjacent switches. In the case of a lost three-phase feeder, the system can be rapidly switched to restore power to all laterals. Conservative estimates are that switching operations could be performed in a maximum of 30 minutes and probably considerably less time depending on the utility's use of automatically resettable fault indicators and/or supervisory indication of fault current in the switch. Systems employing the duplex switch also look better, since fewer locations are required for sectionalizing devices.

The duplex switch system in Fig. 4 requires more trenching for single-phase cable than does the conventional system in Fig. 3. However, not as much additional cable as might initially be suspected is needed since, on most systems, duplex switches can be located in areas central to loads. Moreover, the comparison of single-phase cable becomes less one-sided when one considers the amount of single-phase loop runs required to provide backfeeding capability on the conventional system. Overall system economics favor the duplex switch concept, and the installed cost can frequently be further reduced by running a single-phase lateral in the same trench as the three-phase feeder cable when a long lateral is needed to serve a load.

Another application area for the duplex T-Tap switch is where preferred/alternate manual throwover schemes are required. Shopping centers, condominiums, and any load center served by the utility at 15 kV are candidates for this approach. A sectionalizing device that switches automatically is being developed.

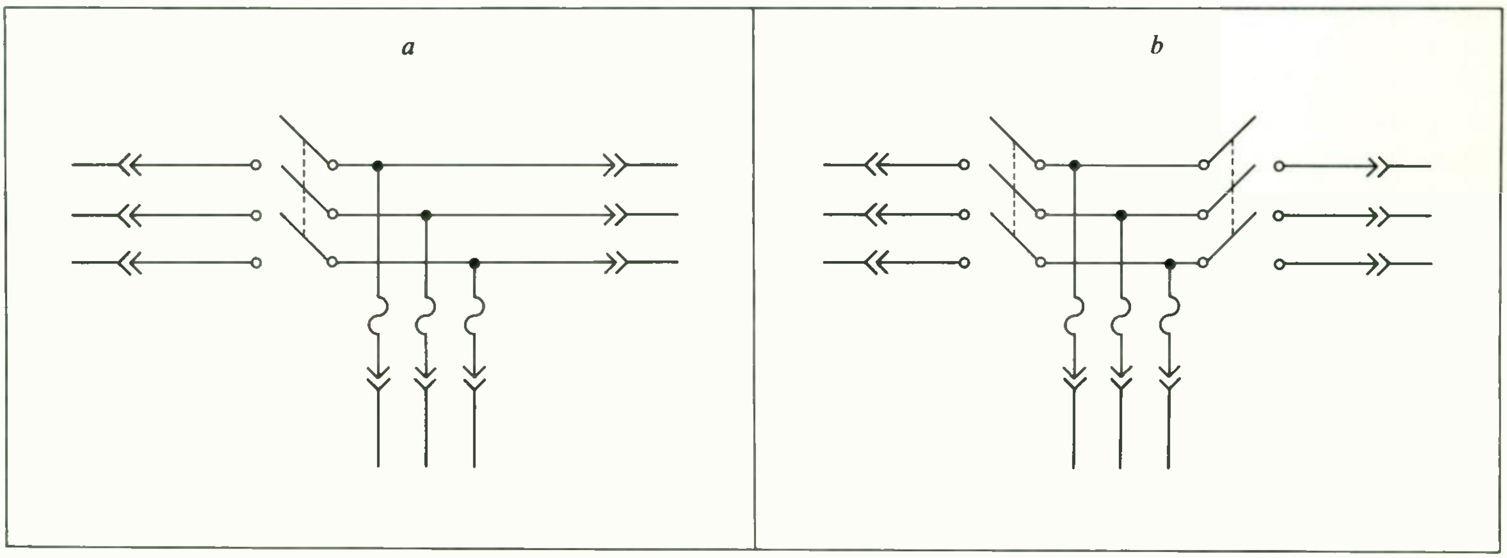
While automatic switching should afford great efficiency in service restoration and changing feeding schemes, automatic reclosing is generally considered unwise on URD systems. Reclosers have traditionally been used on overhead circuits because of the high incidence of transient faults (approximately 80 percent). However, on underground circuits there is no such thing as a transient fault. Reclosing on an underground circuit would do little more than stress equipment unduly by subjecting it to fault current on the reclose that could cause far greater damage than that from the initial fault.

T-Tap Switch Features

Design of the Westinghouse T-Tap switch concerned not only adequate internal construction but also careful planning of all operational requirements for maximum user flexibility. Such operational considerations as safety, grounding, phasing and phase testing, switch siting, field expandability, lowness of profile, and visible break indications were carefully considered. Feeder loadings and diversity of loadings also were considered very closely as were momentary values, make-and-latch capabilities, and so on.

To provide the proper switching function regardless of the distribution system design, the T-Tap switch is available in both single- and double-ended (duplex) versions (Fig. 2). Both versions have 600-ampere continuous three-phase through feeds and 200-ampere single-phase lateral tap-off points.

Safety was a prime consideration of the T-Tap, since such pad-mounted devices are usually installed at locations where they are readily accessible to the general public. Interlocking doors, reverse-loop seams, padlocking, and penta-head bolts were included in the design. These features alone, however, were deemed inadequate safety precautions because anyone with simple tools could gain access. Consequently, the T-Tap switch also employs dead-front construction, provided by separable elbow connectors, as a back-up system to assure that anyone gaining entry through the locked doors still has some degree of safety.



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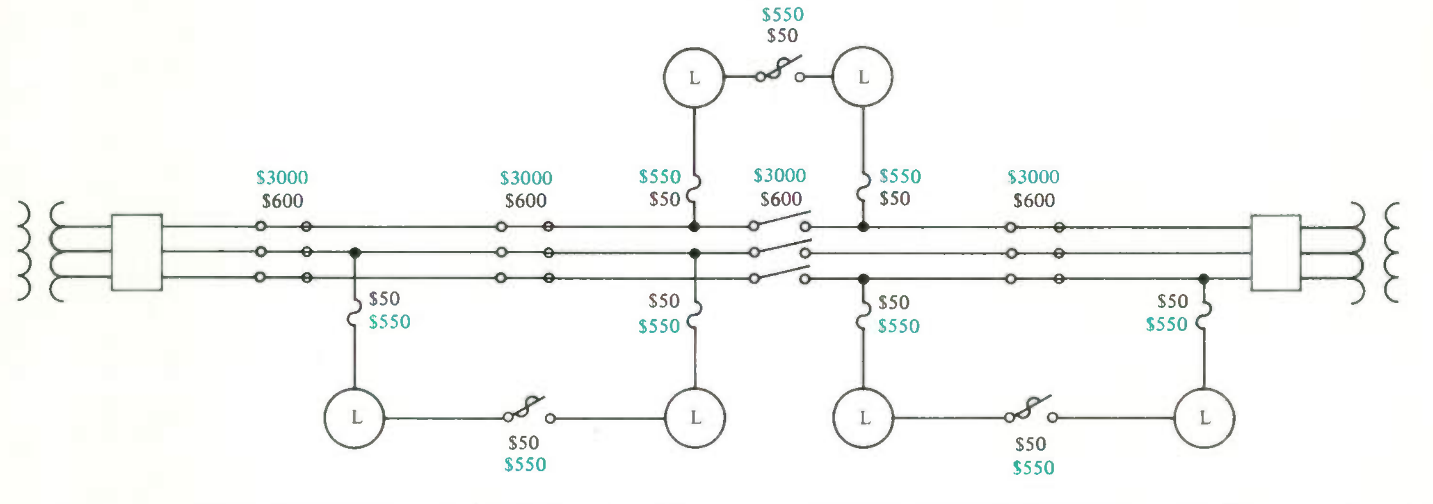
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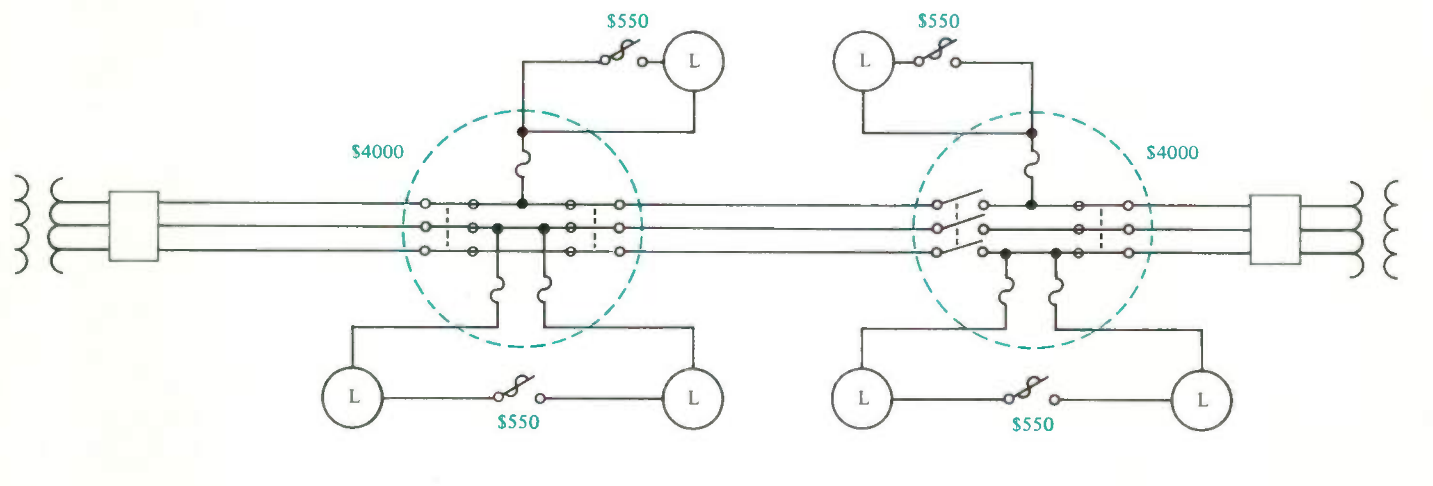
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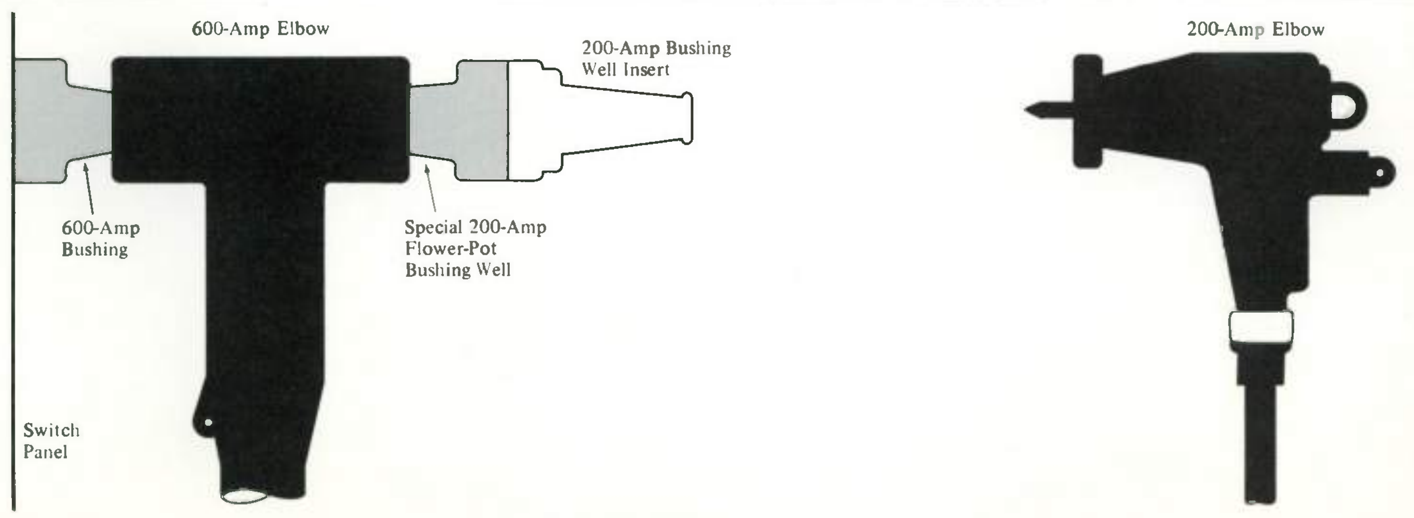

600-Amp Elbow
200-Amp Bushing
Well Insert
600-Amp
Bushing
Special 200-Amp
Flower-Pot
Bushing Well
Switch
Panel
200-Amp Elbow

The 200-ampere portion of the switch has universal flower-pot bushing wells that accept any manufacturer's bushing well inserts for coupling with 200-ampere elbows. Depending on the user's choice of inserts and elbows, either load-break or non-load-break (dead-break) switching of the 200-ampere laterals is possible. Single-pole switching of the 200-ampere laterals by separable elbows is an acceptable technique so long as the laterals serve single-phase loads. If three-phase transformers with delta or ungrounded wye primaries are served, three-pole switching on the 200-ampere portion might be desirable to prevent electrical unbalances due to ferroresonance effects, which could result from single-pole switching. However, very few three-phase pad-mounted transformers are sold with those primaries; when they are so applied, switching them single-pole with some load (4 percent or greater) virtually eliminates the ferroresonance. Three-pole switching of the 200-ampere lateral taps can be provided on the pad-mounted T-Tap switch but is not supplied as standard. The standard use of single-pole switching on the 200-ampere section results in a less expensive and smaller switch.

The 200-ampere cables can be grounded by disconnecting the elbows from the switch and connecting them to grounding terminals. Phasing and phase testing are easily performed from the live or capacitance test point on the elbows or from the associated grounding and isolating devices. On the 600-ampere portion of the circuit, the epoxy cabinet bushings accept any of the currently available 600-ampere dead-front-type elbows. However, a different technique is used to perform phasing and grounding operations on the 600-ampere cables, since some utilities do not use the capacitance test point on the 600-ampere elbows and the elbows are not easily disconnected from the switch. The technique is provided by a special 600-ampere connection system, which is somewhat more elaborate than the 200-ampere system. On the back end of each 600-ampere elbow is inserted a special 200-ampere flower-pot bushing well in place of the usual insulating plug/capacitance-test device. The thread size at the bottom of this special bushing well is larger than a normal 200-ampere one in order to fit the stud on the end of the 600-ampere epoxy cabinet bushing. Into this special bushing well is plugged a universal 200-ampere insert, which is covered with an insulating cap during normal use. The cap is removed to provide a live test point for phasing and phase testing. The 600-ampere cable is easily grounded by plugging a ground-connected 200-ampere elbow onto the 200-ampere insert (Fig. 5). There is adequate space in the cable compartment for the doors to be closed and padlocked with the grounding connections intact.

Training of the 600-ampere cables is fixed in either of two configurations upon installation because the cable is too stiff for easy maneuverability inside a reasonable size cable compartment (Fig. 6). Plenty of room is provided in the cable compartment for maneuvering the 200-ampere cables for routine switching operations, grounding, and dead ending.

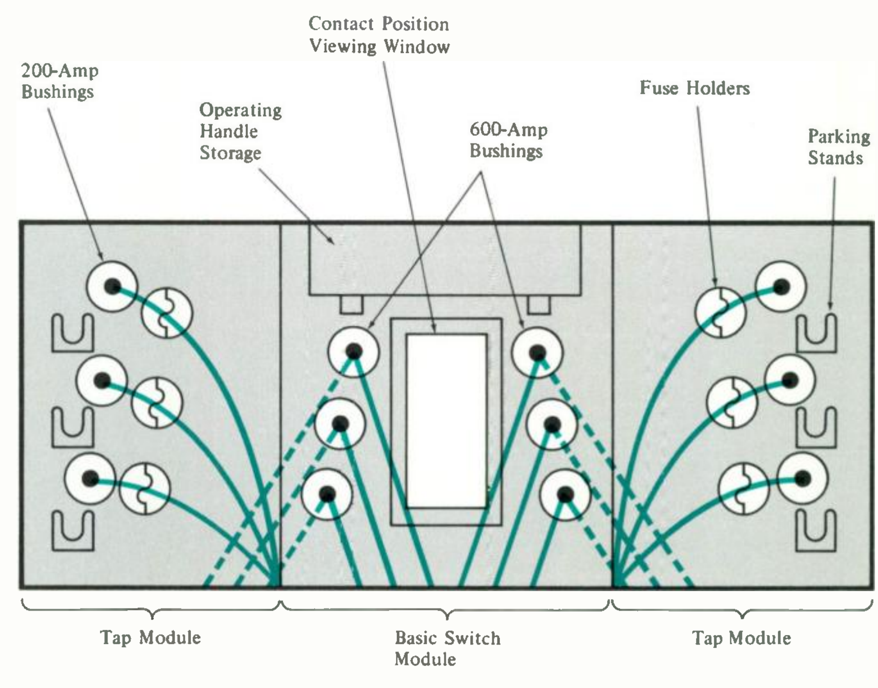
3—One of the main drawbacks of imitating an overhead circuit for underground use is the expense. In this simplified looped three-phase distribution feeder system, dollar figures in black indicate the approximate installed costs of the various components if used in an overhead system, and colored figures indicate the cost if used in an underground system.

4—A more reasonable approach for an underground version of the circuit shown in Fig. 3 is through the use of duplex switches, which are illustrated within the dashed circles. Not only is the overall expense less, but the system benefits from greater reliability and simplified operation.

5—Each phase of the 600-ampere connecting system includes a cabinet bushing, 600-ampere elbow, and a piggybacked combination of special bushing well and bushing-well insert. For normal operation, the insert is covered with an insulating cap, but the cap can be removed to provide a live test point and to connect a 200-ampere elbow for grounding the 600-ampere cable.

6—The 200-ampere and 600-ampere cable training techniques are illustrated in this simplified schematic of a pad-mounted T-Tap. The 200-ampere cable (from tap modules) passes in front of the fuseholders to provide an interlock system—the fuseholders cannot be removed without first disconnecting the elbows. Two cable training configurations are possible for the 600-ampere cable—recommended (solid lines) and alternate (dashed lines).

6



The cable configuration provides an inexpensive safety interlock by passing in front of the fuseholders. While the fuseholders are dead-break devices, they can be removed with the main bus hot by first disconnecting and parking the 200-ampere load-break elbows. With the 200-ampere cables out of the way, the fuseholders can be withdrawn by a standard shotgun hookstick and the fuses removed.

The 200-ampere single-phase lateral taps are protected by type CLB current-limiting fuses expressly designed for the T-Tap switch. They provide additional operator safety on making and latching the 200-ampere elbows by greatly reducing the peak value of fault current to an elbow if the circuit is made on a fault. The combination of dead-front construction with the CLB fuses provides the T-Tap with the lowest profile in the industry for an air-dielectric design. Devices using live-front construction usually employ boric-acid or horn-fiber type fuses and are exceptionally tall. The excessive height is needed for vertical fuse insertion and withdrawal and to allow adequate area for expulsion of gaseous materials through mufflers connected to the bottoms of the fuses.

CLB fuses are available in ratings of 30, 45, 60, 80, 100, and 125 amperes. In contrast to many boric-acid fuses, a 125-ampere CLB current-limiting fuse has sufficient overload capability to carry continuous current to a sensibly loaded 200-ampere feeder.

Make-and-latch and momentary capabilities of the T-Tap switch are identical. (Many other switching devices, in contrast, have safe make-and-latch ratings considerably less than their momentary current-carrying capability.) The capabilities are 20 kA rms asymmetrical to provide added safety in the event of closing on a fault. Such an occurrence is more likely on an underground circuit since it is not always possible to visually ascertain that the fault has been cleared.

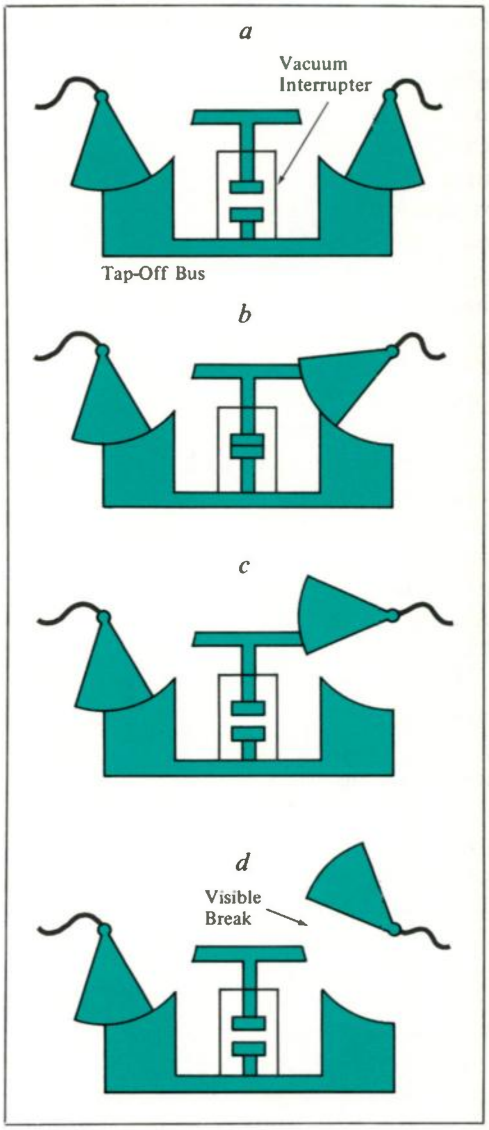
The standard basic insulation level (BIL) of the T-Tap switch is 95 kV. The 110-kV BIL that was once traditional in overhead distribution equipment has now been rendered a rather conservative value, mainly by the increased margins of protection afforded by modern distribution class lightning arresters. Many utilities are using 95-kV BIL on circuits rated 12,470/20,800 volts grounded wye and higher with good success.

Air dielectric is used in the T-Tap switch because of the inherent safety and lack of maintenance requirements. Many smaller switches, e.g., 200 amperes, use oil dielectric and are frequently protected by current-limiting fuses, which greatly reduce the probability of catastrophic failure. However, an in-line three-phase main feeder switch occupies a position where fault current may be considerable, and the switch generally is not protected by current-limiting devices. Such an oil-dielectric switch could fail catastrophically if called upon to perform in excess of its design capabilities. In contrast, an air-dielectric switch such as the T-Tap does not present a hazard to the operator or passerby even under a worst-case failure.

Another disadvantage of oil dielectrics and also of gas dielectrics is the considerable amount of maintenance they require. Gas systems must be periodically checked to assure proper pressure, and oil dielectrics must be checked for proper quantity, tested, and filtered to assure that the moisture content is not above acceptable limits. Practically the only disadvantage of air dielectric is the somewhat larger physical size it demands of the switch.

The T-Tap switch employs gang-operated three-phase main feeder switching. Many other switches, because of their prior use as overhead or industrial equipment, had utilized single-pole switching of the three-phase system. However, single-pole operation of a main line sectionalizing switch too often was picked up as an unbalance by the ground trip relay in the up-line breaker, thus dropping the entire feeder. This was quite costly if it did occur, and taking steps to prevent it by disarming the ground trip relay was expensive and unwise from safety aspects.

Another safety feature of the T-Tap is a viewing window, which enables an operator to verify that all main feeder switching contacts are in their fully opened or closed



7—The three-phase 600-ampere switching arrangement of the T-Tap employs vacuum interrupters but also makes the break visible when the main contacts are open. One side of one phase of a duplex switch's opening sequence is shown. (The leads emanating from the movable air contacts connect to the 600-ampere bushings.) Each contact pair shares a vacuum interrupter so that only three interrupters are needed for a duplex switch. Dead-break air contacts carry continuous current with the vacuum interrupters "floating" on the tap-off bus and carrying no current (a). *In* (b), *the vacuum contacts are closed and the air contacts are so positioned that the load current is shared between the air contacts and the vacuum contacts. In* (c), *all load current is shifted to the vacuum interrupter and the circuit is then interrupted by opening the vacuum contacts. The switching operation concludes in* (d), *with the air contacts clearing the vacuum interrupter and achieving the desired visible break.*

position. The safety afforded by the viewing window is combined with the durability provided by vacuum load-break interrupters. These two seemingly incompatible features are obtained by use of a mechanism that inserts a vacuum interrupter in parallel with each main contact pair during load-make and load-break operations but allows the main contacts (visible through the window) to carry current under normal conditions (Fig. 7). Each switching operation is achieved by the action of a charged spring to assure proper speed.

A vacuum interrupting device has several advantages—it is inherently safe since catastrophic failure is practically impossible, it has exceptionally long life, and it requires very little maintenance if any. Its safety supplements the safety advantages stemming from use of air dielectric in the T-Tap switch.

A major problem with vacuum interrupters heretofore, especially on underground equipment, has been inability to have a visible break when using ceramic envelopes on the bottle. (Glass envelopes are available, but the seals are subject to leakage and deterioration, and the metal shields required to protect the tube from arc plasma make it difficult to determine whether the contacts are opened or closed.) This problem is avoided with the unique switching arrangement of the T-Tap.

On most other switches, almost full accessibility is required on all sides for routine switching function and maintenance. That requires at least 8 to 10 feet between the switch and an adjacent building, fence, hedge, etc. The net effect is a site requirement approximately two to three times larger than the switch. With the T-Tap switch, all routine switching functions can be performed on one side of the switch with access through panel doors. Any other function (maintenance, internal inspection, etc.) is performed through the back panels, which are removed by unlatching fasteners in the front compartment of the switch and then lifting off the rear panels.

A major advantage of modular construction in the pad-mounted version of the T-Tap switch is provision for increasing the number of fused or unfused taps at a later date. While this capability may have some advantage in deferring initial capital investment, it is primarily intended as backup protection if the original load predictions were not adequate. Previous duplex type switches were limited to a maximum of six lateral single-phase tap positions, but the T-Tap permits as few as three heavily loaded single-phase laterals or an unlimited number of lightly loaded ones. Many utilities are adopting the approach of light feeder loadings with an increased number of single-phase laterals, so that minimal load would be dropped during a single-phase lateral failure. Far more faults occur on single-phase laterals than on the three-phase main feeder because of the laterals' greater exposure and vulnerability to man-instigated faults.

While the pad-mounted T-Tap is basically intended as a 600-ampere through-feed switching device with 200-ampere lateral taps, it can also be provided as a series of tap modules to act as a load/fuse center for 200-ampere circuits only. Such a device is switched exclusively with load-break separable connectors.

Lightning arrester modules are also available for the pad-mounted T-Tap switch. On a URD system, distribution class lightning arresters generally need only be applied at the transition point from overhead to underground and at the normally open tie switch of the looped three-phase feeder. If intermediate class arresters are used at the transition point, usually no arresters are needed at the normally open point of the system. However, to allow flexibility of system design, two configurations are possible for installing distribution class arresters at the normally open switch. In one scheme, all six arresters can be provided in one T-Tap switch with the addition of two arrester modules. Another technique that is gaining popularity deploys the arresters in two separate switches, one arrester module per switch. Three arresters are placed in the tie switch and three in the first switch up line on the normally open side of the tie switch.

Ventilation to remove moisture from the pad-mounted T-Tap switch is adequate in all but a few applications, such as at coastal areas where humidity is abnormally high. For those applications, a space heater module is available to evaporate the excess moisture. It can be ordered with the switch or may be added at a later date in the field. The unit consists of a potential supply source, for taking power off the internal buswork of the switch, and resistance heaters that can be thermostatically controlled if desired to maintain the proper temperature.

Conclusion

A fully common school of thought has not yet developed in the utility industry as to how URD systems should be designed. Once common system specifications are given to manufacturers, they can provide low-cost and reliable devices for URD systems. Meanwhile, the T-Tap switch line has been designed to meet as fully as possible the needs of any utility system for its underground feeders.

BART Service Begins; São Paulo Metro Cars in Prototype Testing

The first completely new rapid-transit system built in the United States since 1907 has gone into limited service over 28 miles of subway and elevated lines in the San Francisco area. (See photograph on back cover.) Bay Area Rapid Transit (BART) now serves the east side of San Francisco Bay between Oakland and Fremont, and it will soon be extended to 75 route miles in three counties.

BART is also the first metropolitan rail transit system to be completely automated. It will have as many as 105 trains in operation during peak hours, capable of running with headways as close as 90 seconds. The 72-passenger cars, assembled in trains up to 10 cars long, can be operated safely at speeds as high as 80 mi/h. An automatic control system protects against collisions and operates the trains as a coordinated system rather than as independent units, supervising both their scheduling and their routing. It keeps the trains on schedule to the maximum degree possible; as unavoidable delays occur, it continually adjusts the schedule of each train to maintain a spacing that minimizes passenger waiting time. The system includes a central control complex, local control units at the 34 stations and at the train yards, car-mounted control packages, and the communications equipment required to link the system together.*

A BART train races down the track at 80 miles per hour under automatic control, which is the normal mode of operation. The control panel enables an attendant to operate the train manually, if necessary, at low speed.

The train control and communications system was provided under a prime contract by the Westinghouse Transportation Division. Under a separate subcontract from the car builder, Rohr Corporation, Westinghouse also provided all equipment involved in movement and passenger comfort for the system's 250 initial cars, including motors and gears, solid-state propulsion control equipment, brakes, trucks complete with wheels and axles, air suspension, air conditioning, and auxiliary power supplies.

Meanwhile, prototype cars for the São Paulo Metro rapid-transit system in Brazil are being tested on the first 2 miles of subway track completed. A fleet of 198 cars is being built for the system's initial leg, which will be a 10.5-mile north-south line through South America's largest city. It is scheduled to be in operation in 1974. Additions planned for the future will bring the total route length to 120 miles.

The stainless-steel cars are propelled by four 150-hp series-connected dc motors, with 750-volt power supplied by a third rail. They can accelerate at 1.12 m/sec^2, brake at 1.0 m/sec^2, and attain a maximum speed of 62 mi/h. Motor speed is regulated by a dc chopper control with the capability of regenerative braking. Friction braking is supplied by four air-operated disc brakes on each truck.

The cars are being constructed in São Paulo by a consortium of industries headed by Mafersa, the car builder. Traction equipment is being supplied by the Westinghouse Transportation Division, which is also supplying an automatic train control system similar to that in BART.

*R.C. Hoyler, "Design Techniques for Automatic Train Control," *Westinghouse ENGINEER*, July 1972, pp. 98-103. R.C. Hoyler, "Automatic Train Control Concepts Are Implemented by Modern Equipment," *Westinghouse ENGINEER*, Sept. 1972, pp. 145-51.

Versatile Family of Tactical Air Defense Systems Developed

A family of air defense systems that can be tailored to meet a wide variety of tactical situations has been developed by the Westinghouse Aerospace and Electronic Systems Division. Called tactical air defense systems (TADS), they have capability for surveillance, air traffic control, and ground-controlled intercept. Their primary radar coverage is three dimensional, giving range, bearing, and height.

Secondary radar coverage results from an IFF (identification—friend or foe) subsystem. The IFF information and the primary radar data are displayed for operators and weapons controllers at the TADS site. The TADS voice and teletype communications subsystems enable the operators to communicate with aircraft and relay information to other sites.

Solid-state electronic circuitry is used except for a few components such as cathode-ray tubes and high-power transmitting tubes. Data outputs are compatible with automatic data-handling equipment.

This radar is part of a tactical air defense system, shown undergoing field tests. The AN/TPS-43 three-dimensional radar provides the necessary information for both aircraft warning and control capability.

Stability Computer Program Simulates Loss of Generator Field

If a short circuit in the field winding of an operating utility generator causes sudden loss of the field, the generation and transmission system must supply a considerable amount of reactive power to the affected machine. If the affected machine is relatively large, the system may not be able to support the machine without intolerable voltage drop or possibly loss of synchronism of nearby machines. In addition to those adverse effects on the system, the unit that suffers the loss of field rapidly accelerates.

Consequently, generator protection usually includes a loss-of-field relay that can be connected to perform a variety of tasks: to trip the unit off on loss of field, to trip the unit off only if the loss of field is accompanied by an undervoltage condition, or simply to sound an alarm. To help determine which of those procedures to use for any given unit, the stability computer program developed by Westinghouse Power Systems Planning, Advanced Systems Technology, has been modified to simulate a sudden short circuit on the field of a generator. Loss-of-field relays can be represented in the stability simulation, and each of the procedures can be tested. A loss-of-field relay can be represented by up to two impedance zones plus an undervoltage element.

Since increased system flows are required to hold the faulted machine, it is possible that line relays see conditions due to system swings that cause them to operate. Those relays can be represented in the stability simulation to automatically trip system breakers. An important part of a loss-of-field study is to find out if any breakers trip lines that may be critical to the stability of the system.

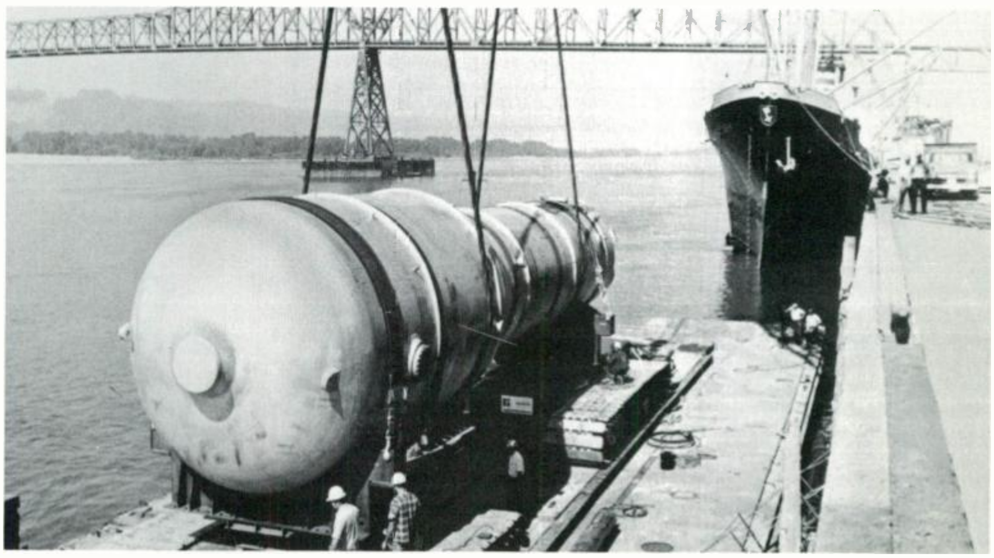
Steam Generators Delivered to Trojan Nuclear Plant

The four steam generators have been installed at Portland General Electric Company's 1130-MWe Trojan nuclear power plant after a journey from Florida by ship and barge. They arrived two at a time at the port of Longview, Washington, lashed to the decks of ships.

To unload the steam generators, workmen first rigged slings under one of them. Then the ship was ballasted to cant four degrees toward the dock to compensate for the weight removal when the unit was lifted. As a large crane lifted the 330-ton steel cylinder clear of the deck, the ship returned to a more even keel. A large barge containing two crawler transporters came dockside, and the steam generator was lowered onto the transporters. (See photograph.) Then tugs moved the ship out into the river and turned it around for delivery of the second unit, located on the opposite side of the deck. That unit was unloaded in the same way. The barges were towed upstream to the Trojan plant site, where the steam generators were taken off by the crawler devices.

The steam generators were manufactured by Westinghouse in Tampa, Florida. From Tampa they were transported by barge to New Orleans, where they were loaded aboard the ships for transport through the Panama Canal to Longview.

The Trojan plant is scheduled for completion in September 1974. It is a joint project of Portland General Electric Company, Eugene Water and Electric Board, and Pacific Power & Light Company. PGE is constructing the plant and will operate it.



Steam generator for Trojan nuclear plant was transferred from ship to barge for delivery to the plant site. The plant has four steam generators.

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Author Index

Author biographies appear on the inside back cover of each issue.

About the Authors

Alan R. Collier is Vice President, Engineering, for Offshore Power Systems, a joint venture of Westinghouse and Tenneco. This new corporation was formed to design and construct floating nuclear power plants.

Collier joined Westinghouse in 1957 to work on the design of PWR fluid systems and has progressed through a variety of assignments. After directing systems and physics tests for the Yankee PWR plant, he was appointed Manager, Reactor Fluid Systems, in 1963 to be responsible for the functional design of all fluid systems.

His next assignment was Project Manager for the Commonwealth Edison Zion plants and for American Electric Power Company's Donald C. Cook plants. Collier was then made Manager, Licensing and Reliability, for the Nuclear Energy Systems Division, responsible for obtaining AEC licenses for nuclear steam supply systems (NSSS) and turnkey plants and for quality assurance on NSSS equipment. After a short assignment in PWR Systems Marketing in 1971, he was appointed Engineering Manager of the Special Project Division. He was elected to his present position in July 1972.

Collier graduated from Syracuse University in 1954 with a BChE degree. He has completed the University of Pittsburgh's Business Management Program (1961) and Harvard's Graduate Business School Program for Management Development (1970).

Roger C. Nichols graduated from the University of Illinois in 1959 with a BSME, followed by an MS degree in Nuclear Engineering in 1960. After three years in the U. S. Army Ordnance Corps, Nichols joined the Atomic Power Division of Westinghouse to work in licensing and safety evaluation engineering.

In 1966, Nichols was appointed Project Engineer for the Public Service Electric and Gas Salem plants and for the Pacific Gas and Electric Diablo Canyon plants. Two years later, he was appointed Project Manager for the Diablo Canyon plants.

In 1969, Nichols was appointed Project Manager for the Portland General Electric Trojan plant. He transferred to the Westinghouse Special Project Division in 1971 to be Manager of Nuclear Systems Engineering, responsible for nuclear plant fluid systems design and for overall plant safety evaluation and licensing during the development of the floating nuclear plant design. When Offshore Power Systems was formed in mid-1972, Nichols was appointed Projects Manager.

W. A. Thornton earned his BS degree in physics at the University of Buffalo in 1948 and his MS and PhD degree in physics at Yale University in 1949 and 1951. He then joined General Electric and worked in the company's Research Laboratory.

Dr. Thornton came to Westinghouse in 1956 at the former Lamp Division. He worked first in electroluminescence, then in lamp phosphors, and in 1965 was made section manager, Phosphor Research. He is now Research-Engineering Consultant in the Fluorescent and Vapor Lamp Division. where his work consists of consulting and research in lamp design, luminescence, color, color vision, color standards, and color rendition.

Dr. Thornton has 17 patents to his credit, plus 13 in filing status. He has contributed to the development of many lamps including the new Beauty Lite, to the Division's Phosphor Advanced Development Section program, to development of phosphor-evaluation and lamp-evaluation techniques, and to the understanding of color vision.

R. E. Powers graduated from the University of Minnesota (1958) with a B.A. in Geology. After working in the Naval Oceanographic Office on research and applications for oceanographic surveys, Powers joined Raytheon (1965) to explore the geoscience potentials of side-look radar. He also investigated lunar orbiter photography.

In late 1971, Powers came with the Westinghouse Defense and Electronic Systems Center to become Manager of Earth Resources Mapping. There, with his geology background, he has worked primarily at promoting and updating the earth resources mapping radar capability of Westinghouse, some of which is described in his article that appears in this issue.

Roger K. Peterson graduated from Fort Hays Kansas State University with a BBA degree in 1966, and he has since taken courses toward an MBA at Wichita State University. Peterson has also studied electrical engineering at Finlay Engineering College.

His early professional experience included three years working at various purchasing, accounting, and engineering functions with Central Kansas Power Company. Peterson joined Westinghouse in 1966 and served first as Assistant Sales Engineer and Field Sales Engineer for Electric Utility Field Sales (now Power Systems Marketing). He became a Sales Engineer for the Electric Utility Repair Division (now the Electric Service Division) in 1967. The following year, he joined the Distribution Apparatus Division at Bloomington, Indiana, as a Product Engineer and then became Marketing Representative for vacuum switching products. Peterson has contributed to the development of the T-Tap switch in such areas as modular construction, cable training techniques, and electrical ratings and configurations. He is currently District Manager of Field Sales for Burndy Corporation in Los Angeles, California.

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The BART regional rapid-transit network in the San Francisco area includes 34 passenger stations at locations convenient to the public. Automatic train-operation equipment operates the trains within the safety precautions imposed by an automatic train-protection system. It closes a train's doors after a predetermined stop time at each station, accelerates the train at the appropriate rate, controls its speed to maintain its schedule, decelerates the train as it approaches the next station, brings it to a precise stop, and opens the doors. In addition, a central control monitors the positions of all trains and adjusts their performances for system optimization. For more information, see page 188.