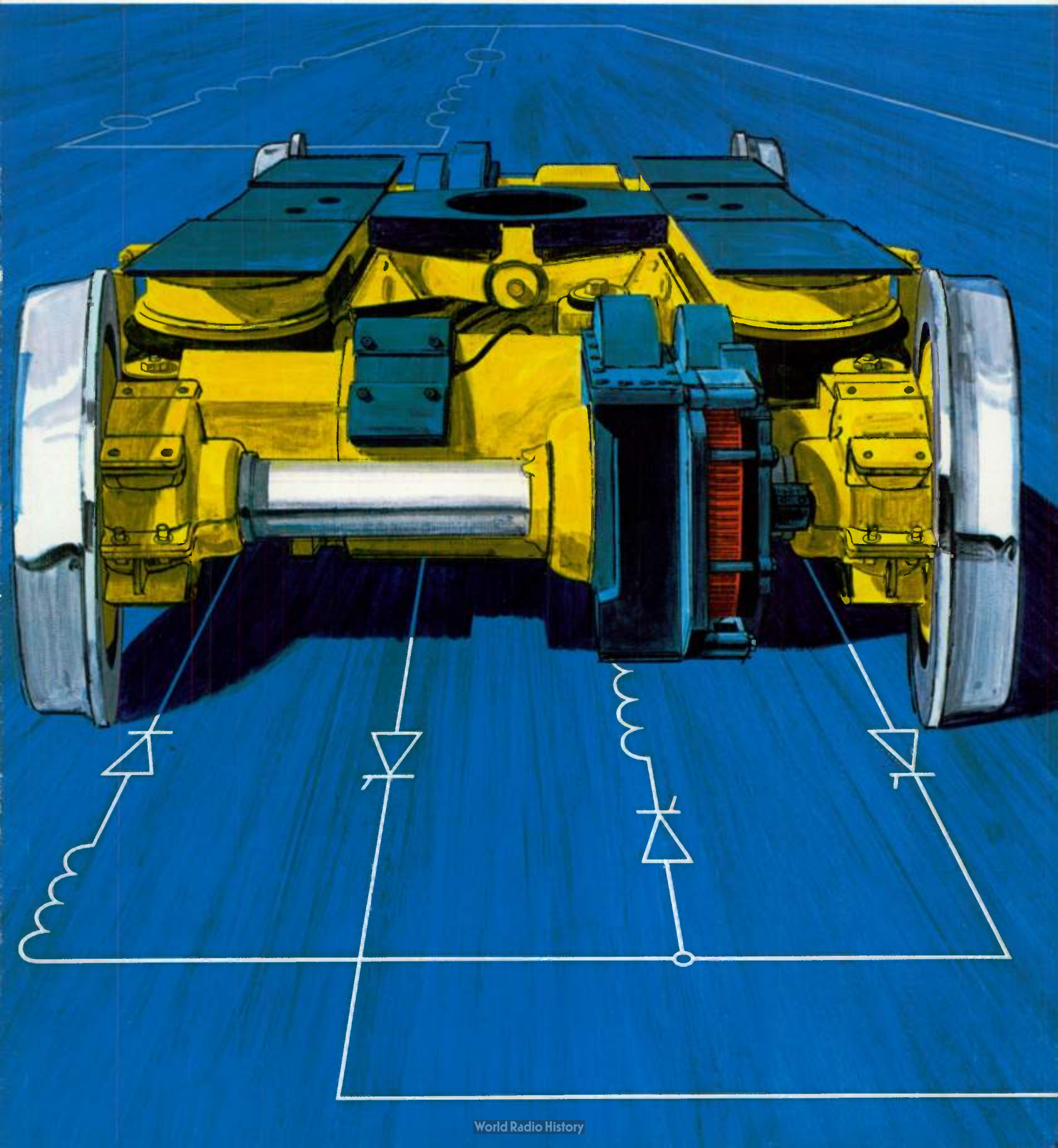
Westinghouse ENGINEER March 1973



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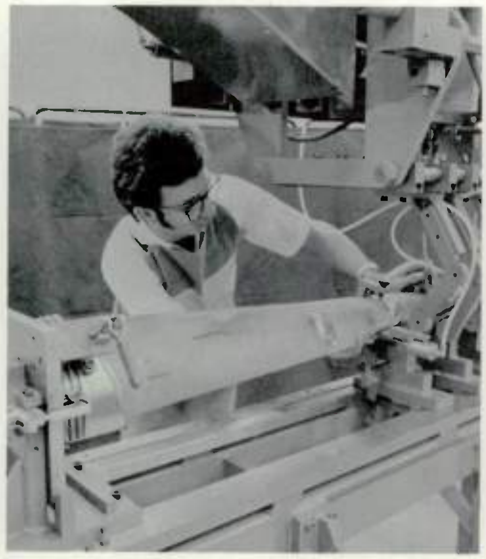

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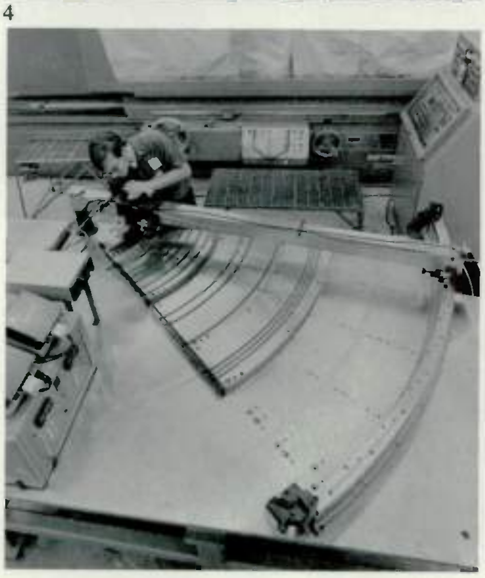

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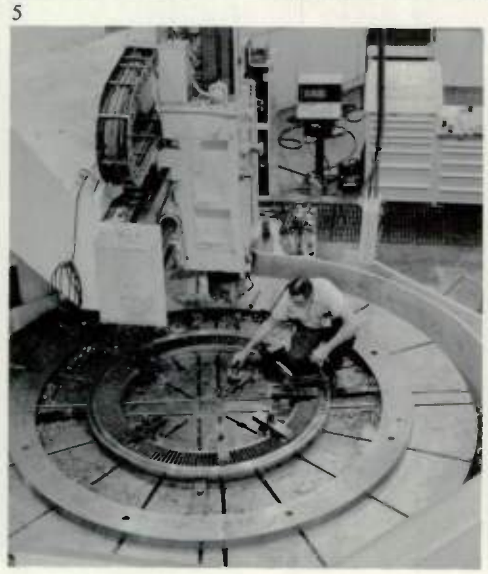

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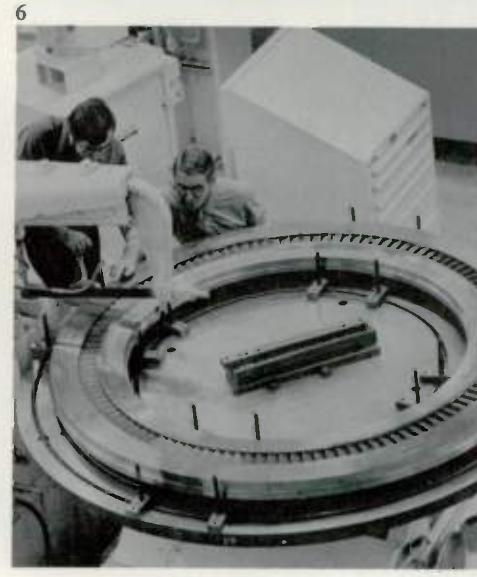

New Plant Increases Capacity for Manufacture of Turbine Components

To assure high quality in blades and other steam-turbine components, the dominant manufacturing philosophy in a new Westinghouse plant is to utilize the most recent developments in machine tools, fixtures, and processes. The Turbine Components Plant presently produces parallel-sided blades, tapered-twisted blades up to 44 inches in length, stationary blading, and other components such as nozzle blocks. Located near Winston-Salem, North Carolina, it operates primarily as a feeder for the main Steam Turbine Division Plant at Lester, Pennsylvania, and the Nuclear Steam Turbine Plant at Charlotte, North Carolina.

Numerically controlled machining centers are used extensively, performing multiple operations on the surfaces of a part with a single setup. Limiting the number of part setups in this way allows closer tolerances and improves repeatability. The plant's transfer lines also are designed to minimize the number of setups needed: blades are mounted in pallets and transferred from tool to tool without being taken out of the pallets.

The numerically controlled tools and machining centers are directed by a direct numerical control (DNC) system that improves the reliability and repeatability of operations, increases productivity, improves the efficiency of parts programmers, and provides real-time status information to plant management.

Parallel-sided blades are machined from bar stock (Fig. 1). Tapered-twisted blades start as precision forgings. Their roots are machined to final dimensions, erosion shields are brazed to their tips (Fig. 2), and they receive a final dimensional check (Fig. 3).

The stationary blades for a diaphragm ring are machined individually, and then a group of them are fitted together and gauged (Fig. 4). A computer collects cumulative tolerance data for the groups; if there is any error, the operator dials an adjustment into the numerical control to compensate for the error when finish-machining the next group of blades. The result is proper fitting of the several hundred blades that form each diaphragm ring. The blades for a complete ring are welded together, and inner and outer rims are machined on a vertical boring mill (Fig. 5).

Nozzle blocks are formed from solid steel by electric-discharge machining. Then they are cut into sections (Fig. 6).

An on-line computer system schedules production and monitors material flow. It keeps operations on the backlog of orders in the best sequence to help assure on-time delivery of each order.

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Front Cover: A truck for an electrically propelled transit car dominates this month's cover design by Tom Ruddy. Combined with it is a diagram of a thyristor chopper to suggest the trend toward use of solid-state control systems for propulsion and braking, a trend that is discussed in the article beginning on the following page.

Alternative Systems for Rapid-Transit Propulsion and Electrical Braking

B. J. Krings

The need for rapid transit is stimulating further development in the technology and equipment for propulsion and electrical braking. Although the traditional cam-controller equipment is being improved, control systems based on thyristors have some advantages over it.

The advent of solid-state thyristors with large power capabilities is providing several practical alternatives to the cam-controller equipment that has been almost universally used in rapid-transit cars. (Cam-controller equipment controls the voltage and current, and thus the speed and torque, of dc series motors by switching voltage-dropping resistors in and out of the circuit by means of cam switches.)

One of the alternative approaches is to supply dc power to series propulsion motors from a thyristor chopper, which controls acceleration by very rapidly turning the motor current on and off in a controlled pattern. The chopper also provides for either regenerative braking (regeneration of the car's stored energy into the dc supply) or dynamic braking (dissipation of the stored energy in a resistor).

A possible second alternative is use of the thyristor chopper to control voltage and current, but with shunt-wound dc motors instead of the traditional series dc motors.

A third approach is conversion of the dc supply power to ac by a thyristor inverter, with the three-phase output (variable in voltage and frequency) utilized by standard ac induction motors. The inverter also provides for regenerative or dynamic braking.

The thyristor approaches overcome two basic problems of cam-controller equipment: the need for continual maintenance on the cam switch contacts, and the power losses incurred when voltage is controlled by resistors. They also provide propulsion systems that are superior in smoothness of ride and ease of maintaining a given speed. The latter feature makes the thyristor systems much more adaptable for use with

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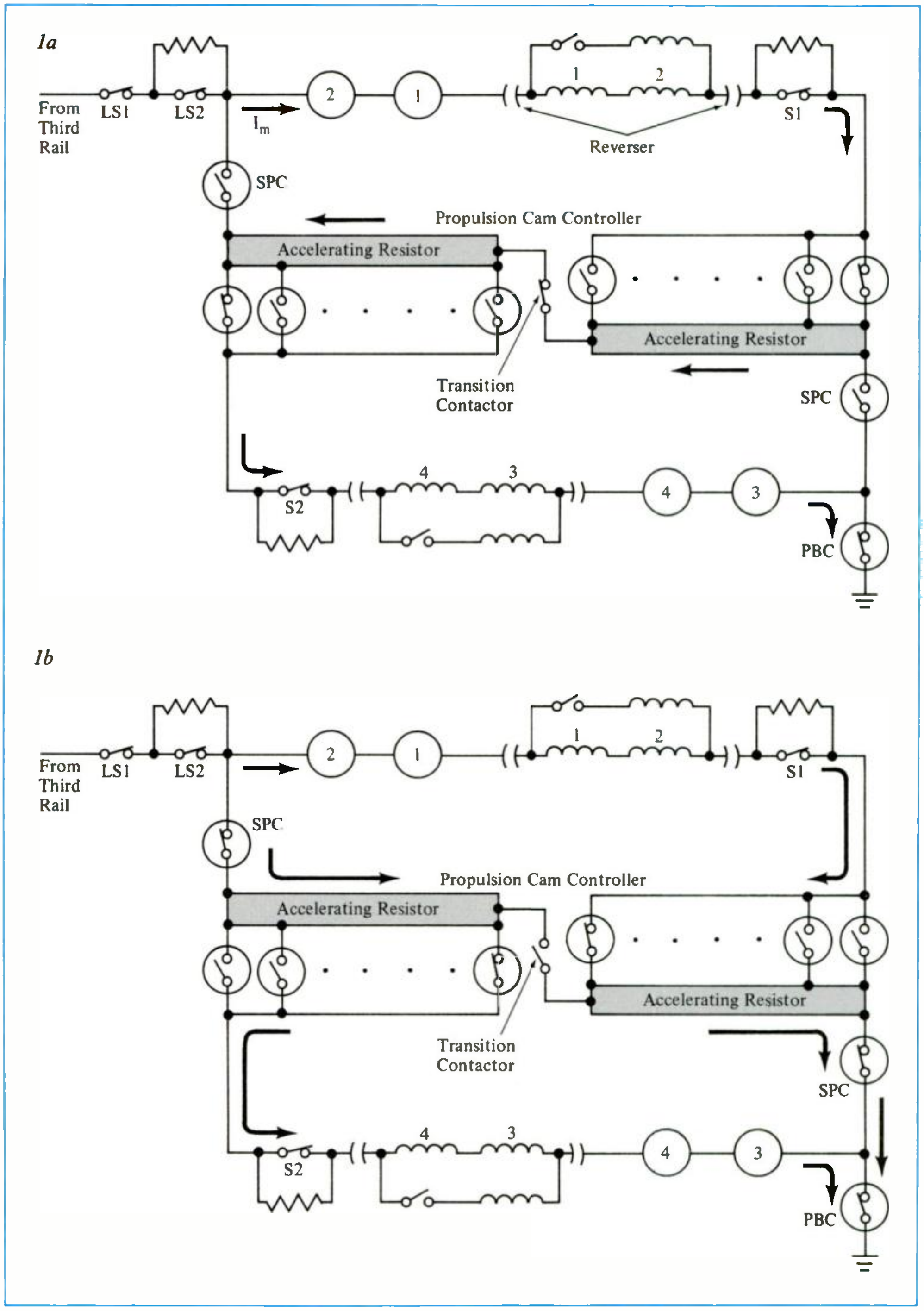


1—Cam-controller equipment is the traditional means for controlling motoring and electrical braking torque from the dc motors of rapid-transit cars. In these simplified schematics, arrows indicate flow of motor current (I_m)*. Cam-operated switches are indicated by circles. For accelerating (a), one set of cam-operated switches called the propulsion cam controller progressively shorts out an accelerating resistor to increase voltage and thereby increase current in the motor circuit. When all of the resistor has been shorted out, further acceleration is made possible by switches in a series-parallel controller* (SPC) *that split the resistor and motor circuit into two parallel circuits* (b)*. The cam controller again progressively shorts out the resistor in each circuit.*

automatic train control than is the cam-controller equipment.

Moreover, the thyristor systems make regenerative braking practical because, unlike cam-controller equipment, their responses are fast enough to continuously match regenerated voltage to line voltage. That matching prevents excursions in braking current (and thus torque) due to sudden transients in line voltage. The reduction in power consumption that results from regenerative braking can be significant, but another advantage makes regeneration even more important. Present standard cam-controller equipment employs dynamic braking; the energy stored in the train is dissipated as heat by resistors as the train decelerates, contributing greatly to temperature rise in the tunnels through which most rapid-transit systems operate for at least parts of their routes. Removing the heat by ventilation or air conditioning can be expensive, but failure to remove it can result in much rider discomfort and dissatisfaction. Regenerative braking minimizes heat input to the tunnels.

However, the performance improvements with thyristor converters are achieved at a cost in weight and complexity of the control equipment. Partly for that reason, and partly as the result of a "wait-and-see" attitude among many transit people, cam-controller equipment is still preferred by many. Nevertheless, there is much interest in thyristor equipment. Westinghouse chopper systems were purchased by Bay Area Rapid Transit (BART) for its 350 cars and by the São Paulo Metro, which is now under construction, for its 198 cars. Other transit people are requiring that cam-controller equipment be upgraded to more nearly provide the performance smoothness obtainable with thyristor equipment, and they are also buying small lots of thyristor equipment for evaluation on their transit systems.

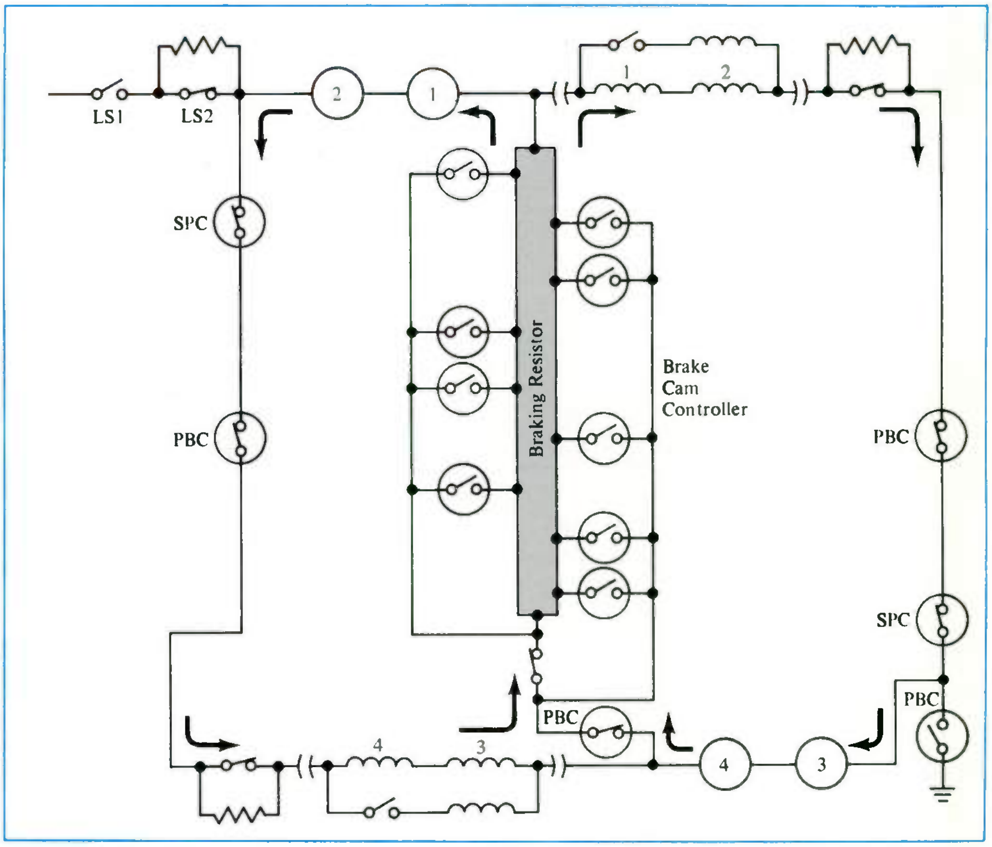
The main criteria for comparing propulsion systems are performance capability, initial cost, maintainability, reliability, and life-cycle cost. This article compares four alternative systems by those criteria, but first it describes them briefly starting with the traditional type.

Cam-Controller Equipment

The basic Westinghouse system has two controllers with cam-operated switches. One cam controller shorts out the accelerating resistors in steps; the other shorts out a braking resistor in steps. The camshafts of the controllers are pneumatically driven, with their movements controlled by a current-limiting relay system in such a manner as to maintain constant current in the motor circuits as the motor speed changes.

In the motoring mode, the four motors on a car are initially connected in series with the accelerating resistors (Fig. 1a). To accelerate, the propulsion cam controller progressively reduces the amount of resistance in series with the motors. When all of the accelerating resistor is shorted out, cam switches in a two-position controller called the series-parallel controller (SPC) make a transition in motor connections: they reconnect the motors with two in series and the two groups of two motors in parallel (Fig. 1b). The resistors are reinserted in series with the motors in each of the two parallel motor circuits, and the propulsion cam controller is again advanced to cut out all of the resistance.

To further increase car speed once all resistance is shorted in the parallel motor connection, the motor fields are weakened by paralleling them with suitable shunts. The shunt connection is made by contactors



2—For dynamic braking, the motors are disconnected from the power supply by line switch LS1, *and the switches in a power-brake changeover* (PBC) *reconnect them as generators across a braking resistor. The brake cam controller regulates the amount of resistance in the circuit and thus the amount of braking.*

that are energized after the propulsion cam controller has reached the end of its travel.

To reduce torque output from the motors for the purpose of maintaining a constant speed, individually operated contactors (*LS2*, *S1*, and *S2* in Fig. 1b) can be opened to insert resistors in series with the motors. They reduce the armature current and thus the output torque. The field shunting contactors are also used to modify output torque, when necessary, to hold a constant speed.

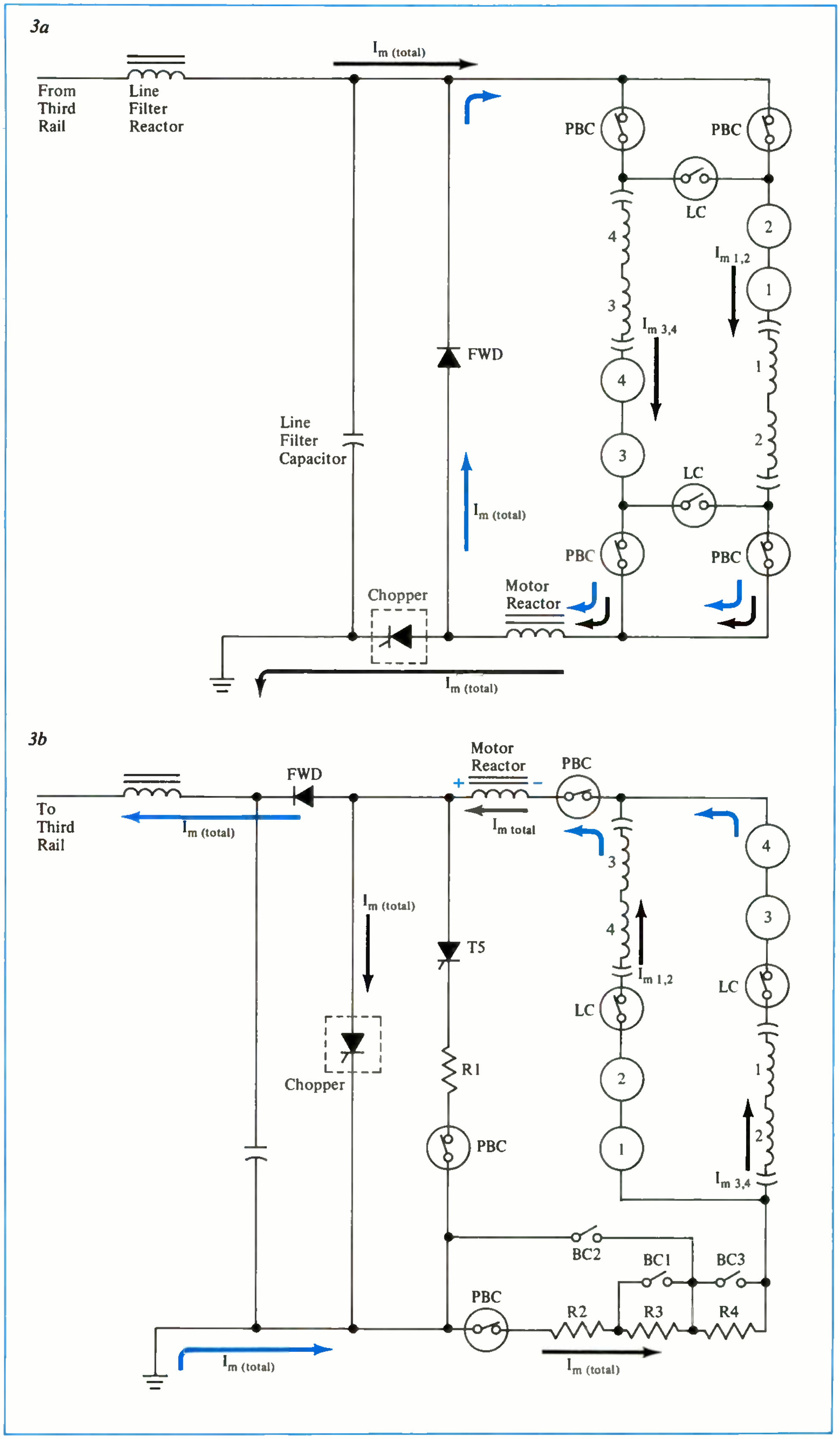
For dynamic braking, the motors are first disconnected from the dc power source. Then the cam switches of a two-position controller called the power-brake changeover (PBC) reconnect the motors as parallel generators across the braking resistor (Fig. 2). The motor armatures and fields are cross-connected to force load sharing between the motors (connected as parallel generators).

This advanced cam-controller equipment is included in 288 new cars being put into service by New York City Transit Authority.

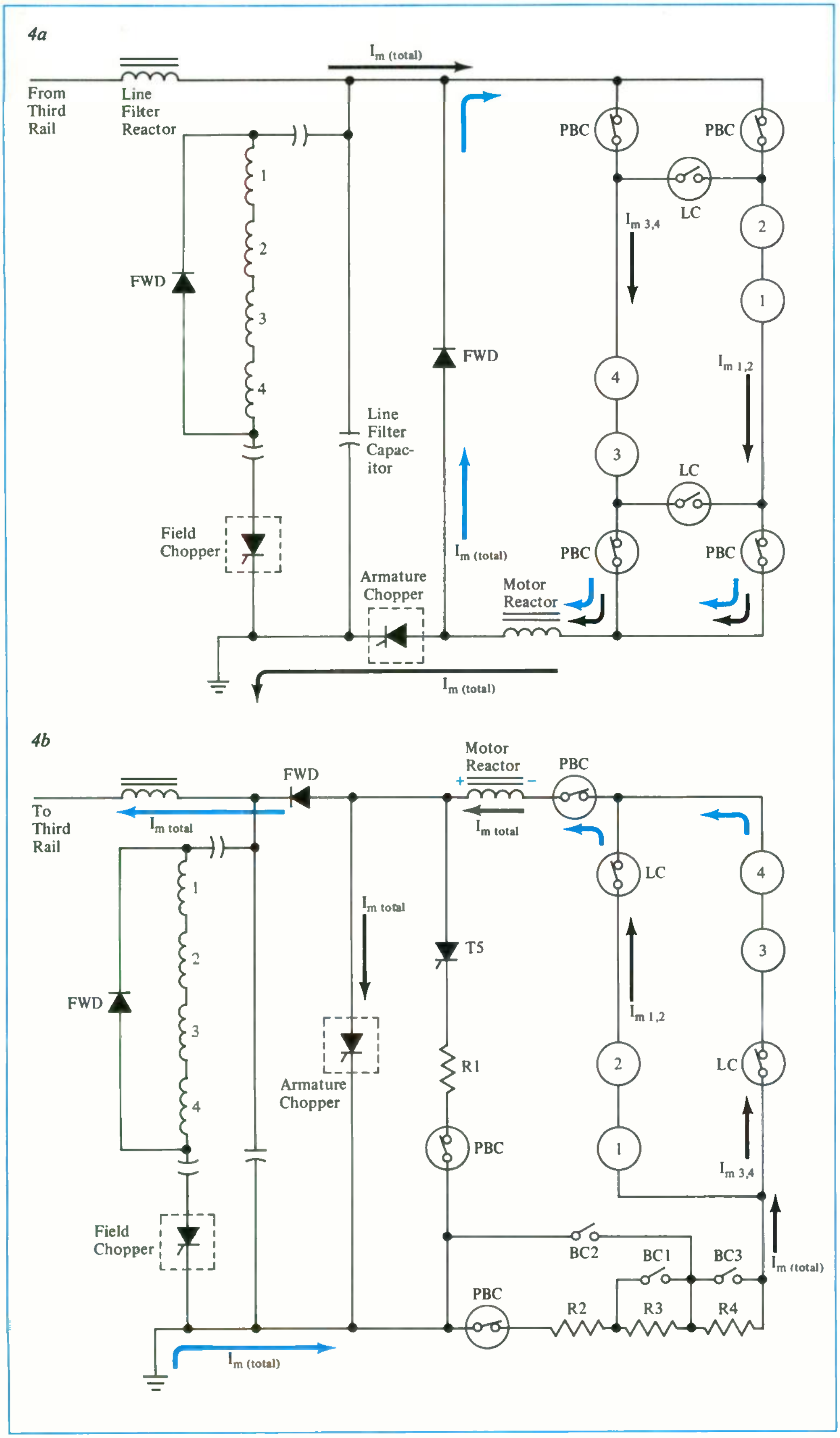
Chopper with Series Motors

The Westinghouse chopper system used in the BART and São Paulo Metro cars has four motors permanently connected with two in series and the two groups of two motors in parallel.

In the *motoring mode*, the chopper is used to regulate the current in the motor circuits (Fig. 3a). Turning the chopper on



3—One alternative to cam-controller equipment is this system, consisting of dc series motors and a thyristor chopper. In the motoring mode (a), *turning the chopper on completes the circuit and thereby builds up current in the motors as shown by the black arrows. When the chopper is turned off, energy stored in the motor reactor and the inductance of the motors maintains current flow (colored arrows) in the motor circuit via the free-wheeling diode* (FWD). *The ratio of chopper* off *time to* on *time determines the average current applied to the motors and thus determines torque. In the braking mode* (b), *switches in a power-brake changeover* (PBC) *and a loop controller* (LC) *reconnect the motors as generators. Their current output can either be returned to the supply, with the chopper again regulating the current and thus the braking effort, or dissipated in a resistor by turning on thyristor* T5.



builds up current in the motors by completing the circuit from the dc power supply positive through the motors to ground. When the chopper is turned off, the energy stored in the motor reactor and the inductance of the motors maintains current flow in the motor circuit via the loop formed by the free-wheeling diode. For a description of how the chopper works, see *Chopper Operation*, p. 38.

The average voltage applied to the motors is controlled by adjusting the ratio of chopper *off* time to *on* time. This adjustment is made by the chopper control logic to maintain the desired average motor current and, hence, motor torque. (The input to the logic is from the train operator or the automatic train operation equipment). When operating with full voltage applied to the motors, the chopper switches at the normal frequency of approximately 218 Hz with an *off* interval of about 6 percent of total cycle time.

For the *braking mode* of operation, the motors are reconnected by means of a power-brake changeover (PBC) as shown in Fig. 3b. The circuit is arranged for regenerative or dynamic braking with the motors as self-excited generators. The fields are cross-connected to force load division between the paralleled generators.

In regenerative braking, the function of the chopper is the same as its function in motoring: its on-off ratio is regulated to maintain the desired current. (The more current, the more braking.) With the chopper turned on, the current in the motors increases; when it is turned off, the current flowing in the chopper is forced into the line via the free-wheeling diode by the motor reactor.

The logic system for control of the chopper during braking also monitors the voltage across the line filter capacitor. It

4—A variation of the chopper system is this arrangement, in which shunt motors are used instead of series motors. The motoring mode (a) *and the braking mode* (b) *are essentially the same as in the other chopper system except that there is a second chopper to control motor field strength. Black arrows indicate armature current with the armature chopper on; colored arrows indicate armature current with that chopper off.*

Chopper Operation

A simplified power schematic with the chopper connected in the motoring mode is illustrated in Fig. A. The chopper is shown feeding two motor circuits, each of which could have one motor or several motors in series.

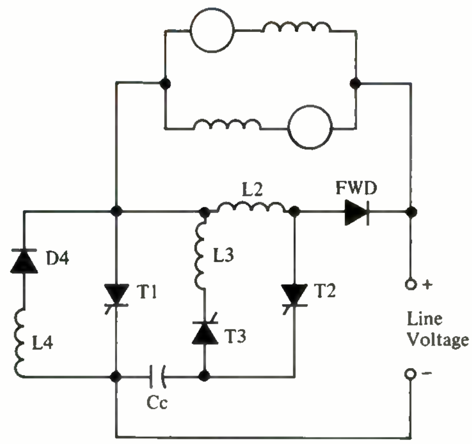
The first *off* pulse turns on the turn-off thyristor (*T2*), and the commutating capacitor (*Cc*) charges to the same level as the line voltage (Fig. B). [*Cc* would charge to twice line voltage due to its combination with the smoothing reactor (*L2*) if it were not for the free-wheeling diode (*FWD*).] When the voltage on *Cc* reaches line voltage level, the current through *Cc* and *T2* goes to zero and *T2* turns off.

An *on* pulse now occurs, simultaneously turning on the turn-on thyristor (*T1*) and the reversing loop thyristor (*T3*) as shown in Fig. C. The load is thus connected directly to the supply voltage, causing motor current to build up. Also, the voltage (*e*) on *Cc* begins to decay as current (*i*) flows through *T3*, the reversing loop reactor (*L3*), and *T1*. *T3* turns off when *i* has reached zero and the voltage on *Cc* has reversed completely. Current (i_L) is now flowing in the load only, and the circuit is ready for turn-off.

Turn-off is accomplished by turning *T2* on, as shown in Fig. D. The load current (i_L) now flows through *T2* and *Cc*. After a short delay due to *L2*, *T1* turns off and diode *D4* conducts, helping speed the charging of *Cc*. Reactor *L4* limits rate of rise of current in *D4*. *D4* stops conducting before *Cc* charges to line voltage. When *Cc* has charged to line voltage, *FWD* conducts i_L and *T2* turns off, leaving the circuit ready for another *on* pulse and the start of another cycle.

The basic action is exactly the same whether the chopper is regulating current for motoring or for braking.

A



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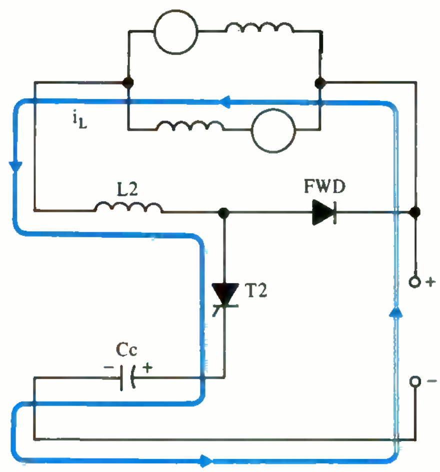

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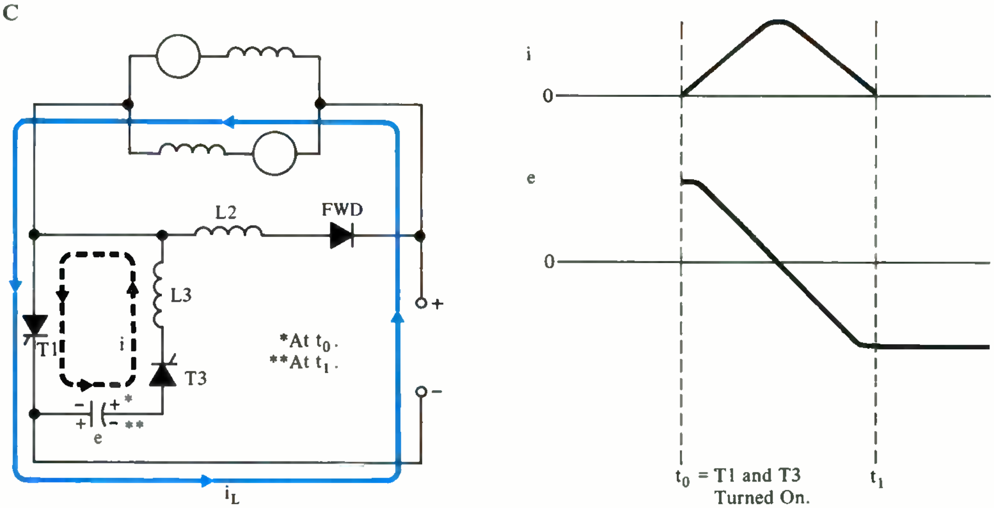

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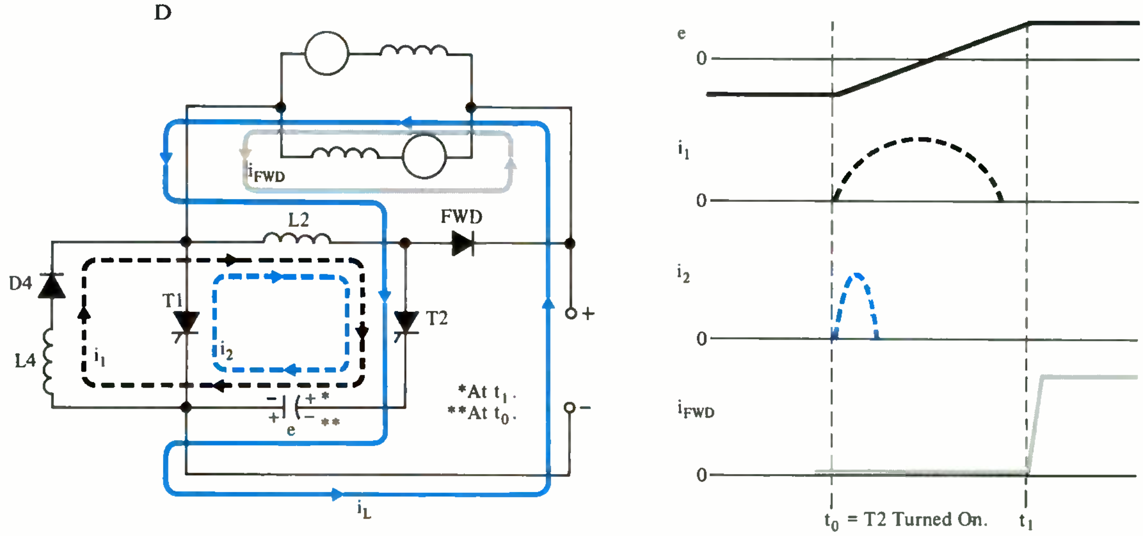


controls the chopper on-off ratio in such a manner as to prevent the capacitor voltage from ever exceeding line voltage, a condition that could result in increasing current during the chopper *off* time and loss of braking control. If capacitor voltage during regeneration reaches a preset limit, the logic removes regenerative braking by turning the chopper off and keeping it off; the remainder of the braking is achieved by friction brakes.

The dc series motor acting as a series generator inherently has a maximum generated voltage approximately twice line voltage. To provide for the maximum energy regeneration, resistors *R2*, *R3*, and *R4* are connected in series with the motors and the line by the power-brake changeover (Fig. 3b). The IR drop across the resistors opposes the generated voltage so that the voltage across the capacitor does not exceed line voltage. As speed is reduced during braking, the voltage of the series generators (motors) drops. When the *on-off* ratio of the chopper reaches the point where *off* time is a minimum in order to maintain the motor current at the desired average value, the logic system triggers pickup of one of the shorting contactors *BC1*, *BC2*, or *BC3*. That reduces the IR drop in series with the generators in order that the chopper can continue to maintain the same average braking current. The chopper shifts from a minimum *off* condition to a minimum *on* condition whenever a shorting contactor is picked up.

In train operation, regeneration into the power supply sometimes is not possible because of a dead third rail, loss of third-rail power in the car, or absence of load being taken from the third rail. In that event, the circuit consisting of thyristor *T5* and resistor *R1* (Fig. 3b) provides almost instantaneous shift from regeneration to dynamic braking. The logic that controls the braking current makes the decision at the time of each *on* pulse as to whether *T5* only will be turned on or the chopper will also be fired. If the logic determines that the power supply is not receptive to regenerated energy, the chopper is not turned on. Only *T5* is gated to divert the motor current through the resistor. At the time of the next fixed *on* pulse, the logic again determines the need to fire the chopper on the basis of the power supply receptivity. Only when the line again becomes receptive will the chopper be gated and permit the voltage generated to rise to the point where motor current again flows into the line.

Chopper with Shunt Motors[1]

In this circuit, armature voltage is controlled by a chopper connected in series with the motor reactor between the armature circuits and the ground return (Fig. 4a). The four motor fields are connected in series across the line. A separate chopper and free-wheeling diode are provided for controlling field strength after armature voltage reaches line voltage.

In the *motoring mode*, the basic armature chopper circuit and its function in controlling the output torque of the motors is the same as previously described for the series-motor system.

In the *braking mode*, the circuit is arranged for regenerative or dynamic braking (Fig. 4b). Field excitation is controlled by the field chopper. The armature chopper is connected so as to control braking current as in the other system.

Like the dc series motor, the dc shunt motor acting as a generator has a maximum generated voltage that is approximately twice line voltage. Dropping resistors (*R2*, *R3*, and *R4* in Fig. 4b) absorb the excess voltage to achieve maximum energy regeneration, as in the other system.

Two cars with this system have been built for the U. S. Department of Transportation by St. Louis Car Company on contract from the Boeing Company, the program manager. They are being tested at the DOT facility in Pueblo, Colorado. On completion of the test program this year, the cars will be demonstrated in a number of cities including New York, Boston, Chicago, Philadelphia, and Cleveland.

Inverter with AC Induction Motors

In this circuit, two inverters convert the fixed-voltage dc line input into a variable-voltage and variable-frequency three-phase ac output. This power is supplied to four ac induction motors (Fig. 5). Each inverter is controlled by a logic system that maintains a constant ratio of voltage to frequency for the three-phase power output to the motors. This mode of operation produces constant motor torque for acceleration. After maximum ac output voltage is reached at approximately 60 Hz, the output frequency only is increased to further increase the motor speed. In this region of operation, motor output horsepower remains constant.

Transition from the motoring mode to regenerative braking requires only a change in inverter frequency by the control logic. No reconnection of the power circuits is necessary.

The system as illustrated in Fig. 5 is being evaluated in three cars on the Cleveland Transit System.[2] It is capable only of regenerative braking; however, dynamic braking can be achieved by bringing out the neutral of the motor windings and inserting braking resistors in series with the windings.

Westinghouse is developing a similar system but with some circuit improvements that will improve performance. It has been proposed for use on the ACT (Advanced Concept Train) Program that is being administered by the Boeing Company for DOT.

Advantages and Disadvantages

Cam-Controller Equipment—This type has been thoroughly proved, debugged, and refined by many years of service in many transit systems. It has the lowest initial cost of the types compared here, and its control system is the lightest in weight. It needs no separate motor-driven blowers for equipment cooling, thus eliminating one source of audible noise. The simplicity of the circuits makes trouble-shooting relatively easy, so the few maintenance skills required can be achieved with minimum training. Reliability is excellent, although it depends on good maintenance because of the need for periodic replacement of switch contacts and motor brushes.

Disadvantages include more maintenance needs than the other systems have. Also, the ride is not as smooth as can be achieved with the other systems, the step current changes tend to make wheel slips and spins more prevalent, and acceleration resistor losses make power consumption per car mile somewhat higher than in the other systems. Moreover, only dynamic braking is practical, and the resulting resistor heat under the car during braking contributes to problems from equipment heating and tunnel heating. Finally, the equipment is not as adaptable to automatic control as are the other systems.

Thyristor Converter Systems—All of the thyristor systems provide smoother ride than does the cam-controller equipment. Because of the ease with which any motor or braking torque can be achieved, they are very adaptable to automatic speed control or complete automatic train control. Ability to regenerate energy to the dc supply greatly reduces heat output and provides at least the potential for savings in power cost. How large the savings are depends on such factors as train headways, number of trains, and auxiliary load on the cars. The expense of periodic maintenance replacement of power switch contacts is materially less because the thyristor systems have fewer contacts and because proper control of the converter virtually eliminates arcing on the contacts.

On the other hand, the thyristor systems have a higher initial cost. The present cost differential probably will be reduced eventually because of the difference in the stage of development of the systems as compared with cam-controller equipment. It is doubtful, though, that the cost will ever be reduced to the level of cam-controller equipment, because the thyristor systems all require addition of a line filter reactor and line filter capacitor; both chopper systems also require a motor reactor.

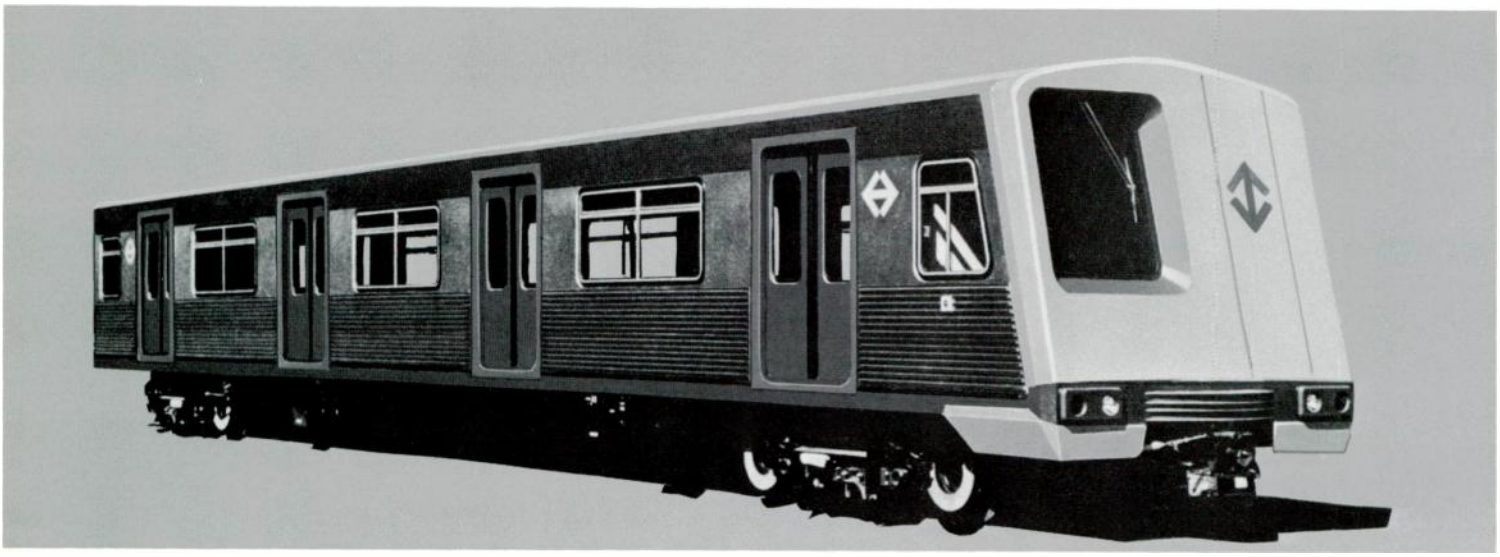
The filter components and motor reactor make the control packages for the chopper systems approximately 20 percent heavier than that for the cam-controller equipment. The inverter system's control package is about 18 percent heavier than that for the cam-controller equipment, since it does not have a motor reactor.

The thyristor systems generate more electrical noise than does cam-controller equipment, so they increase the possibility of signal interference with equipment for automatic train operation or cab signalling. They also require a separate motor-driven blower for cooling the thyristors and diodes, and blowers often cause audible noise problems.

From the maintenance viewpoint, the thyristor systems, and more specifically their control logic, are complex. They require more training of maintenance men and also more sophisticated instrumentation and test devices.

No final assessment of comparative reliability is yet possible because operating experience with the thyristor systems is much briefer than that with the cam-controller equipment and because the systems are still being refined. Analysis indicates that reliability equal to that of cam-controller equipment is possible, and evidence to date tends to confirm the analysis.

In the *chopper systems*, the inherent characteristics of the dc shunt motor make more energy available for regeneration to



Cars of the new São Paulo Metro in Brazil have a chopper system similar to that illustrated in Fig. 3. So do the cars of Bay Area Rapid Transit (BART) in the San Francisco area.

5—(Right) *Another alternative to cam-controller equipment is the inverter system, in which two inverters convert the dc supply power into three-phase ac power. The ac power is variable in voltage and frequency to vary the speed and torque of the four ac induction motors. Transition to regenerative braking requires only a change in inverter frequency.*

the power supply than is provided by the dc series motor. However, the total power saving is still a function of train headways, schedule speeds, and maximum speeds reached.

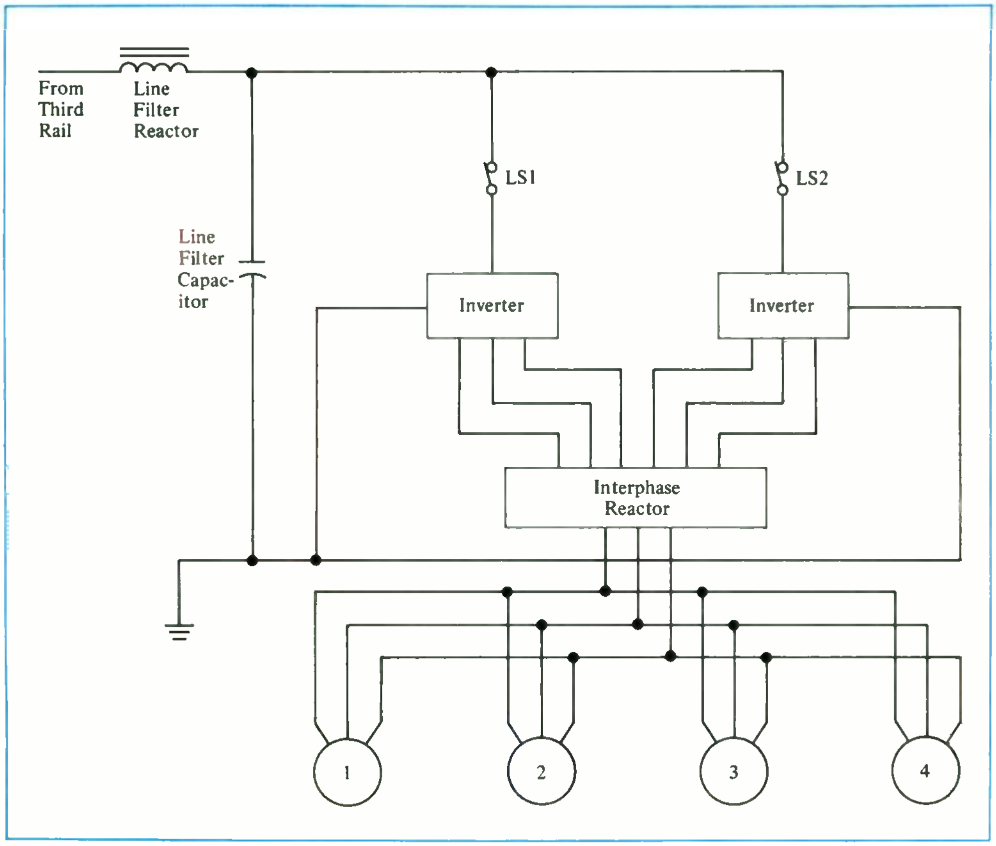
Torque produced by the shunt motor varies above base speed as an inverse function of motor speed, while that of the series motor reduces as an inverse function of the square of the speed. That difference in torque (and thus in acceleration characteristics) above base speed is an advantage for the shunt-motor system with respect to average speed on a given run.

Disadvantages of the shunt-motor system include a higher first cost than that of the series-motor chopper system, a result of the added field chopper and the greater cost of shunt motors because of the more complex windings. Maintenance requirements should be about the same as for the series-motor chopper system. Reliability probably would be slightly less because of the addition of the second chopper; also, reliability of the shunt motor is somewhat of an unknown in traction applications because of very limited experience. The shunt-motor system does not appear to have enough advantages to warrant expenditure of the time and expense required to gain enough motor reliability experience to justify a change from the time-proven series motor.

Another disadvantage is sensitivity to wheel size. Since the shunt-motor characteristic is flat (speed change from zero to maximum torque output is small), the shunt-motor system is much more sensitive to armature speed than is the series-motor system. Armature speed is set by the wheel diameter on a given axle at any given car speed, so the torque output at any axle is a function of wheel size. The problem could require maintenance procedures to match wheel sizes in a truck or car to prevent unequal duty on the motors. Another possible solution is use of a separate field chopper for each motor. That would enable proper load division in either motoring or braking, but it would increase system cost and adversely affect maintenance requirements and reliability.

The major advantage of the *inverter system* is use of simple ac induction motors with consequent elimination of commutators and brushes. Also, it requires no power contact devices. Those advantages reduce the cost of routine periodic maintenance. Preliminary analysis of the four systems discussed here, on the basis of a 20-year life cycle, indicates that the inverter system should have the lowest life-cycle cost. The overall system, with its lightweight ac motors, is also the lightest in weight of the four types. Finally, the Westinghouse inverter system can regenerate even more power than the dc shunt-motor system can.

However, the inverter gives this system the highest initial cost of the four and also the greatest complexity, especially in the phase-sequencing logic system. Because of the equipment complexity, the training required for maintenance personnel would have to be the greatest of all the systems described. Test equipment would also have to be more sophisticated and more expensive. Sensitivity of torque output and load sharing to wheel size is another problem.



Conclusion

All of the thyristor propulsion systems result in performance improvements over the present standard cam-controller equipment, although the improvements are achieved at a cost in weight and complexity of the control equipment. Thyristor systems are being applied increasingly to transportation vehicles of all kinds. Experience to date indicates that the trend will accelerate and that an eventual switchover to thyristor converters is inevitable in the transit industry. For the immediate future, the switchover will be made primarily with series motors for propulsion.

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Cast Resins Find Expanding Application in Transformer Bushing Insulation

C. L. Moore
E. E. Woods
P. W. Martincic

The electrical insulating integrity, high strength, and other physical properties of epoxy resins make them natural materials for many electrical applications. Improved resins and casting technology are enabling such materials to find increasing use as insulating components of transformer bushings.

Bushings, as used on transformers, consist of two basic components—a current-carrying conductor and a nonconductive member to support the conductor as it enters the transformer through a metal tank wall or cover. The supporting member must provide adequate insulation dielectric strength between the conductor and ground, adequate electrical creep resistance over its surface, and sufficient mechanical strength to sustain forces imposed on it by mounting bolts or plates, lead attachment, and vibration or shock loads. Such requirements are further compounded by the operating temperatures of the bushings, which can exceed 100 degrees C.

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While conventional bushing insulating materials such as porcelain, paper, and oil have been used satisfactorily to meet basic requirements, cast epoxy resins offer some major new advantages. For example, epoxy resin components can be manufactured to consistently close tolerances since they can be cast in a mold instead of wound or cut into shape. Casting also contributes to greater design flexibility, shorter customer lead times, and more economical production. Cast resins not only provide great strength for static and shock loading, but they are also highly resistant to shattering and deterioration. Other features of resin insulating materials are their higher radio interference inception voltages and lower corona thresholds. These advantages are complemented by the reduced sizes and weights of cast resin components.

Cast resins are formulated by first evaluating the desired characteristics in terms of flexural and tensile strength, heat distortion temperature, thermal weight loss, thermal expansion coefficient, thermal conductivity, thermal shock resistance, power factor, dielectric strength, track resistance, weathering weight loss, checking, chalking, fading, and arc resistance. The correct combination of properties is then obtained by manipulating four basic variables—resin types, curing agents, fillers, and coloring agents.[1,2]

Bushing Types

Cast resins have been used in two basic types of power transformer bushings. These are the lower voltage bushings (15 kV and below) commonly referred to as *solid* type bushings, and the higher voltage bushings (23 kV and above) identified as *condenser* bushings. The insulating member of a solid type bushing is of homogeneous material throughout, whereas a condenser bushing has conductive layers implanted within its insulation to distribute the dielectric stress throughout the insulation and over the bushing external surface.

The first use of epoxy resin for bushing

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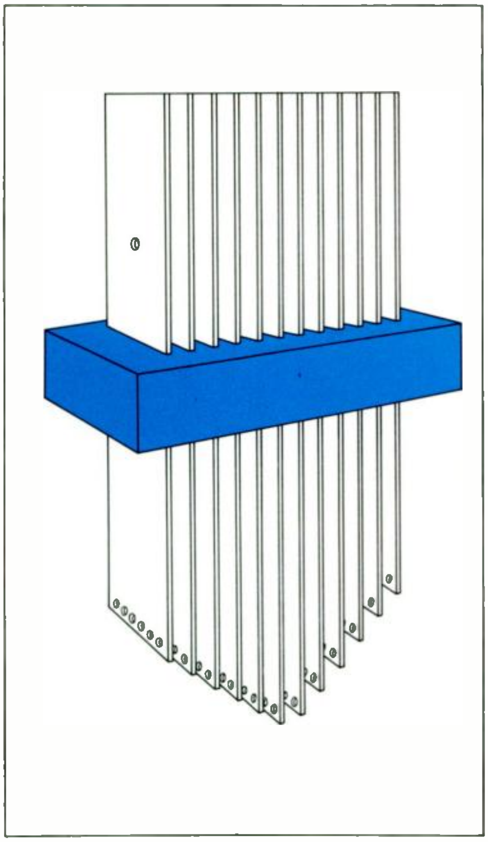

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1—The first application of cast resin as bushing insulation was for furnace transformers. The cast resin insulation (color) forms an impermeable seal between the adjacent plate conductors that enter the transformer tank.

2—The 15-kV cast resin wall-mounted bushing has proven so successful and economical that it is also standard for 5-kV and 8.7-kV applications.

3—These cast resin bushings can be welded to the transformer tank by the metal flange around their insulation, thus providing a completely leakproof seal. The 1.2-kV bushings are available in current ratings of (from left to right) 2000, 3000, and 4500 amperes.

4—The paper-, micarta-, and oil-insulated 34.5-kV condenser bushing (left) with its huge porcelain weathershed is being replaced by a cast resin version (right) that accepts either porcelain or resin weathersheds.

insulation was in plate type bushings for furnace transformers. A cast block of resin provided a reliable seal between the transformer tank and adjacent conductors as they entered the tank (Fig. 1). The seal reduced sludging of the transformer oil by eliminating the breathing of moisture and contaminated air into the unit, and it thereby reduced maintenance and extended the insulation life of the furnace transformer.

The evolution of the solid type epoxy bushing progressed from the furnace bushing through its smaller plate type counterpart to the development of a 15-kV wall-mounted bushing early in the 1960s. More than 500 different resin systems and numerous bushing design configurations were investigated in the development of that line of bushings (Fig. 2).[1] The final design has been verified by arc and track resistance tests, power arc tests, cantilever and torque tests, weatherability tests, and over 10,000 hours of dust- and salt-fog chamber testing while overexcited to 15 kV line-to-ground. The simplicity and economy of 15-kV epoxy bushings has enabled them to be standard equipment for use also on 5-kV and 8.7-kV applications.

Next in the progression of epoxy bushings came a replacement for the early epoxy plate type bushings, which were used on power centers, large distribution transformers, and small power transformers. The newer epoxy bushings, put into production in 1969, feature a metal flange around their insulation for welding onto the transformer tank to provide a hermetically sealed installation. These weldable bushings are rated 1.2 kV and are presently available in 2000-, 3000-, and 4500-ampere sizes (Fig. 3). A major advantage of casting the insulation around the conductor instead of inserting it onto the conductor is illustrated by the construction of those bushings. Both ends of the conductor are formed into flat spade terminals, thereby avoiding the expense of transition equipment to connect the otherwise round threaded conductors at the ends of the bushings to normally flat bus bars.

One of the more recent developments in the epoxy resin bushing line is the condenser bushing. Presently available is a 34.5-kV cast resin bushing (Fig. 4), and work is now being expanded to include 23-kV, 46-kV, and 69-kV versions in both 400-ampere and 1200-ampere current ratings.

Development work on these high-voltage condenser bushings is even more complicated than that on the low-voltage solid-type bushings because of the need to implant conductive elements. In high-voltage bushings 23 kV and above, a series of concentric conductive tubes are imbedded in the insulation around the bushing conductor. The size and positions of these tubes, relative to the conductor and to one another, provide a capacitance network throughout the insulation between the conductor and ground shield. This helps to evenly distribute the voltage stresses both radially and axially through the bushing.

Since the radial and axial positions of the condenser assembly tubes must be accurately maintained, a reliable skeleton structure is needed to support the tubes in the casting mold. The condenser skeleton must be sturdy enough to support as many

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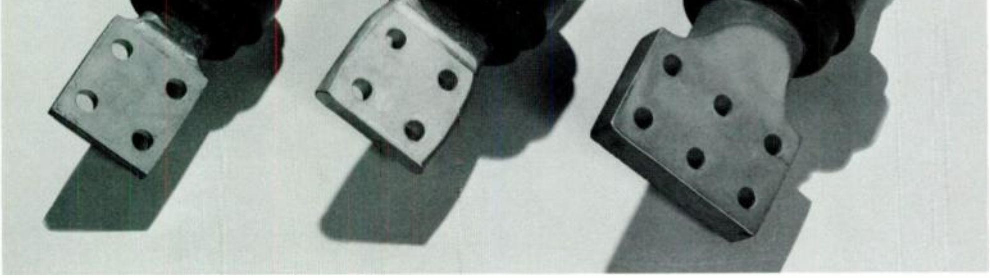

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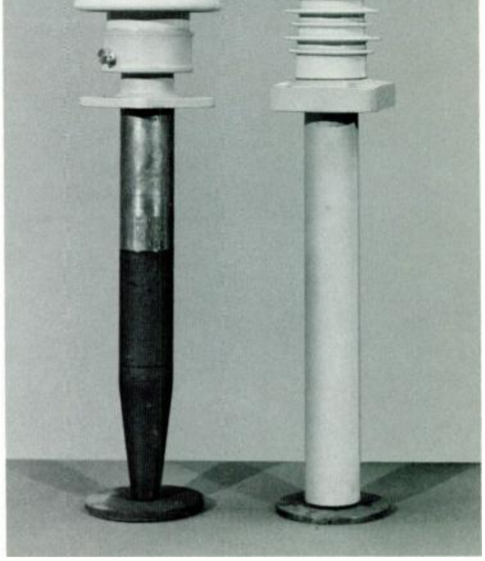

as 12 or more concentric tubes while being cast in resin and cured at high temperature. The condenser assembly of the 34.5-kV bushing employs thin aluminum foil for the conductive tubes, which are supported by a skeleton composed of a noncellulose material. Unlike cellulose skeletons, the new skeleton material is completely compatible with resin encapsulation. It presents a minimum barrier to the flow of resin and the escape of vapors during casting. This allows the condenser assembly to remain in complete unity with the resin during the thermal cycling of the curing process, thus preventing the formation of voids and interfaces. Voids or interfaces within the casting can cause corona at bushing operating voltages and thereby reduce the insulation capability of the bushing.

Another area in which cast resins are being applied is bushing weathersheds. On the air end of a condenser bushing (outside the transformer tank), a certain minimum creep distance is required between the bushing's exposed metal top parts at high voltage and its flange parts or transformer tank at ground potential. A weathershed provides the necessary minimum surface creep distance with its "peak-and-valley" design, which minimizes the overall height of the bushing. To date, almost all bushings have used porcelain weathersheds. However, development and test results are showing that the new weather and track resistant epoxy resins can replace porcelain as a weathershed material with major advantages of strength, shatter resistance, design flexibility, and cost.

The 34.5-kV cast resin condenser bushing can accept either the presently manufactured porcelain weathersheds or the newly developed track resistant epoxy sheds, depending on customer preference. The shed is attached to the bushing by simply slipping it over the top tapered end of the condenser casting. Next, a liquid elastomeric material is injected into the annular space between the bushing casting and weathershed. The material is then vulcanized into a sponge-like consistency. A major customer benefit of this method of shed attachment is that it enables field replacement of a damaged shed without removing the bushing from the transformer.

Testing of Resin Bushings

Although many tests such as electrical, physical, thermal, salt-fog, and dust-fog can be conducted "in-house," long outdoor exposure in all types of weather with bushings under operating conditions still remains the final test of a new design. Cast resin solid type bushings have been tested for long-term weatherability at various test sites since the early 1960s. These installations are located at both customer test sites and Westinghouse test facilities throughout the United States.

Twenty-five 15-kV cover-mounted epoxy bushings were shipped on transformers in April to September 1967 and were energized in February to July 1968. After some 2½ years service, all were in excellent condition. These bushings now have some 5½ years exposure to the elements and 4½ years of energized service with no service outages or detectable erosion.

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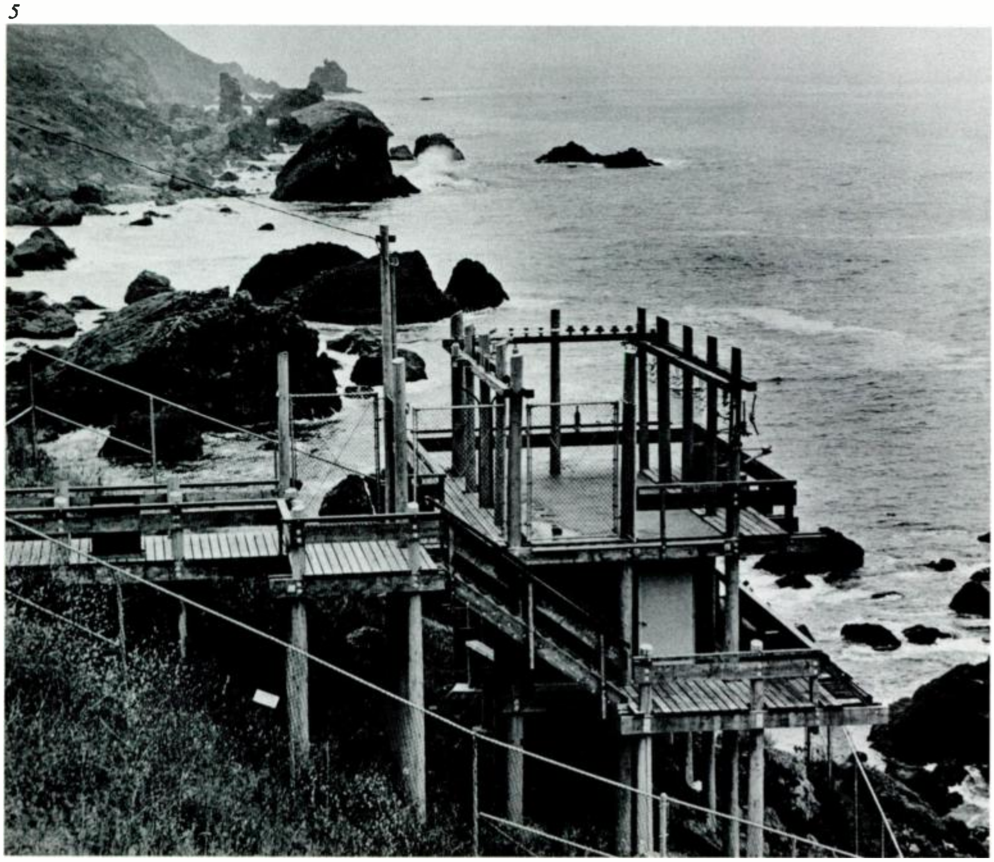

5—Cast resin bushings are tested for weatherability under the rigorous conditions of a coastal environment at Stinson Beach, California.

6—At the Westinghouse test facility in Glassport, Pennsylvania, 34.5-kV cast resin bushings are subjected to the weathering and electrical stresses of a typical field installation. A conventional porcelain weathershed is installed on the bushing on the right, while the bushing on the left is fitted with the newly developed cast resin weathershed.

7—Indoor test chambers at Sharon, Pennsylvania, subject energized cast resin bushings to controlled salt- and dust-fog atmospheres. The atmospheres are extremely severe in order to study the effects of many years of outdoor exposure in a much shorter time.

A number of 15-kV epoxy bushings have undergone severe testing at a beach location about 100 feet from the Gulf Coast waters at Galveston, Texas. Two groups of bushings were tested—original "as-cast" bushings and bushings that had been shot-blasted at the factory to produce a type of erosion acceleration. After 4½ years of exposure to the salty coastal environment and brilliant sunlight, the as-cast bushings have maintained their original surface, and the shot-blasted bushings have shown no erosion beyond their pre-eroded starting condition. Both bushing groups have remained clean and have encountered no flashovers.

As-cast and shot-blasted 15-kV epoxy bushings have also been tested at Stinson Beach, California, where the bushings are operated within the spray range of the surf (Fig. 5). The bushings are energized about 50 percent of the time to allow some contamination to build up on them between energized periods. Since testing began at the site in 1969, both groups of bushings have remained in excellent condition.

Weatherability tests have also been under way on the 34.5-kV epoxy condenser bushing with its epoxy weathershed since their development in early 1971. The bushing has been tested at Westinghouse outdoor test sites in Glassport, Pennsylvania (Fig. 6); Emeryville, California; Phoenix, Arizona; Hillside, New Jersey; Mulberry, Florida; and Houston, Texas. In addition, long-term salt- and dust-fog chamber tests have been in progress at the Sharon, Pennsylvania, plant with about 3800 hours logged to date (Fig. 7).

Continuing Work

The development and facilities program at Sharon continues to stay abreast of improved resin systems and processes and to apply them whenever opportunities are established. For example, although the resin system of the 15-kV bushing has been proven excellent, even more advanced resins with improved weatherability characteristics have been developed. One of them is used in the 34.5-kV condenser bushing and shed.

As epoxy resin bushing development progresses into other voltage classes and current ratings, casting facility capabilities will be expanded to meet the production demands of those classes and ratings. Also, new epoxy resin systems are being investigated as a means to minimize tooling requirements and increase production capabilities.

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[2]T. W. Dakin, G. A. Mullen, R. A. Kurz, and A. I. Keto, "A Study of Tracking and Erosion Behaviour of Electrically Stressed Epoxy Formulations," Westinghouse Research Laboratories, Pittsburgh, Pennsylvania, Jan. 1969.

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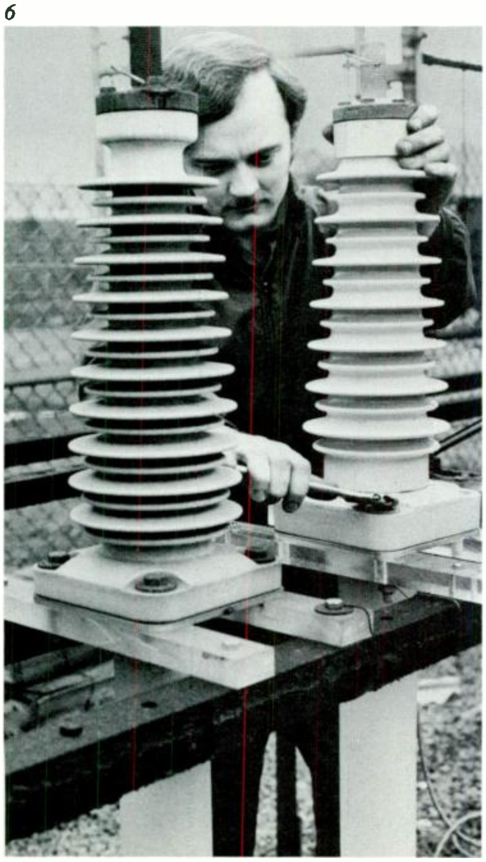

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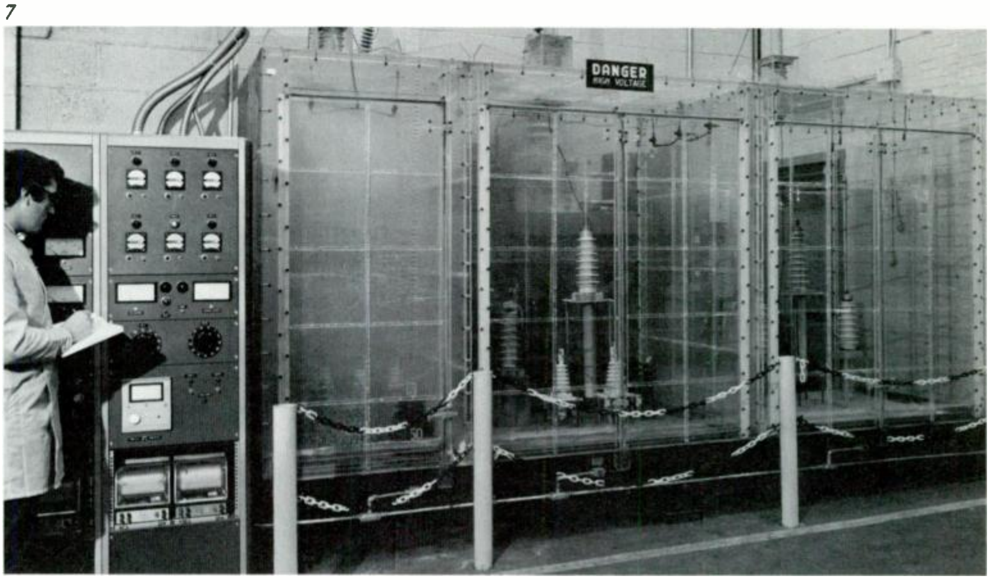

A Video Disc Television Display for Sonar

K. E. Wood

An improved sonar display uses a magnetic video disc and digital data processing to convert sequential sonar returns to a standard television picture format. The display simulates the movement of the side-look sonar over the ocean bottom. The same technique can be used in other applications where data must be sequentially displayed, with or without a permanent record.

Because seawater is almost opaque to electromagnetic propagation, high-resolution side-look sonar (SLS) has become one of the primary methods used for undersea searching and for large-area ocean bottom surveying.[1] Sonic energy can penetrate seawater effectively, but its speed of propagation is relatively slow—about 5000 ft/sec. Therefore, the time required for an echo signal from the sonar transmit pulse (about 65 milliseconds for a target 160 feet from the transmitter) dictates a sonar pulse repetition frequency (PRF) much lower than the human eye flicker frequency.

Since scan conversion to a more rapid refresh display for direct viewing adds complexity to the system, the conventional method for imaging slow-scan sonar data has been the paper recorder. Sonar returns (converted to time-varying voltages) are applied to wire helixes that rotate over voltage-sensitive paper. Although that method has been used extensively, the record it provides is generally unsatisfactory—mainly because the image is negative and its dynamic range is limited. Also, the paper transport often slips when exposed to the high-humidity conditions aboard ship, resulting in image distortion.

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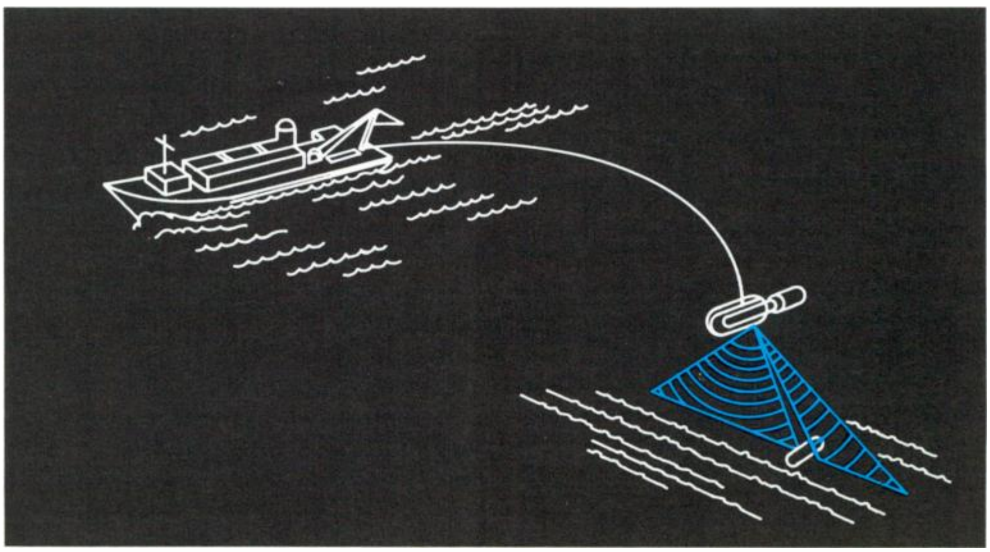
Another method for generating a sonar image without scan conversion is the cathode-ray tube (CRT) recorder, similar to the device used in side-look radar imaging. Here, sonar returns are written across the face of a fiber-optic CRT. The light pattern generated is used to expose a dry silver paper that is drawn across the face of the CRT. The image is fixed by heat to provide a high-quality permanent record about 14 seconds after the information is applied to the recorder.

While the CRT recorder does provide an excellent permanent record, there are many applications where it would be desirable to view the ocean bottom directly as it is traversed (as through a "moving window"). For example, it is often useful to make preliminary scans of an area before making permanent records. Or real-time viewing could be used for bottom navigation. But as previously mentioned, direct viewing requires some form of scan conversion of the slow sonar PRF to a more rapid refresh rate to permit viewing without annoying flicker. Electronic-tube scan converters have been used for this purpose, and Westinghouse has built several of these systems in the past. They produce a good quality picture, but they are bulky, expensive, and complex to operate. A better arrangement has now been made possible by combining television's magnetic video disc with digital techniques. This new combination uses digital pulse trains to accurately write the sonar echos, return by return, so that they can be stored in conventional TV frame format on the magnetic video disc. The information stored on the disc is read continuously onto a television monitor for comfortable viewing.

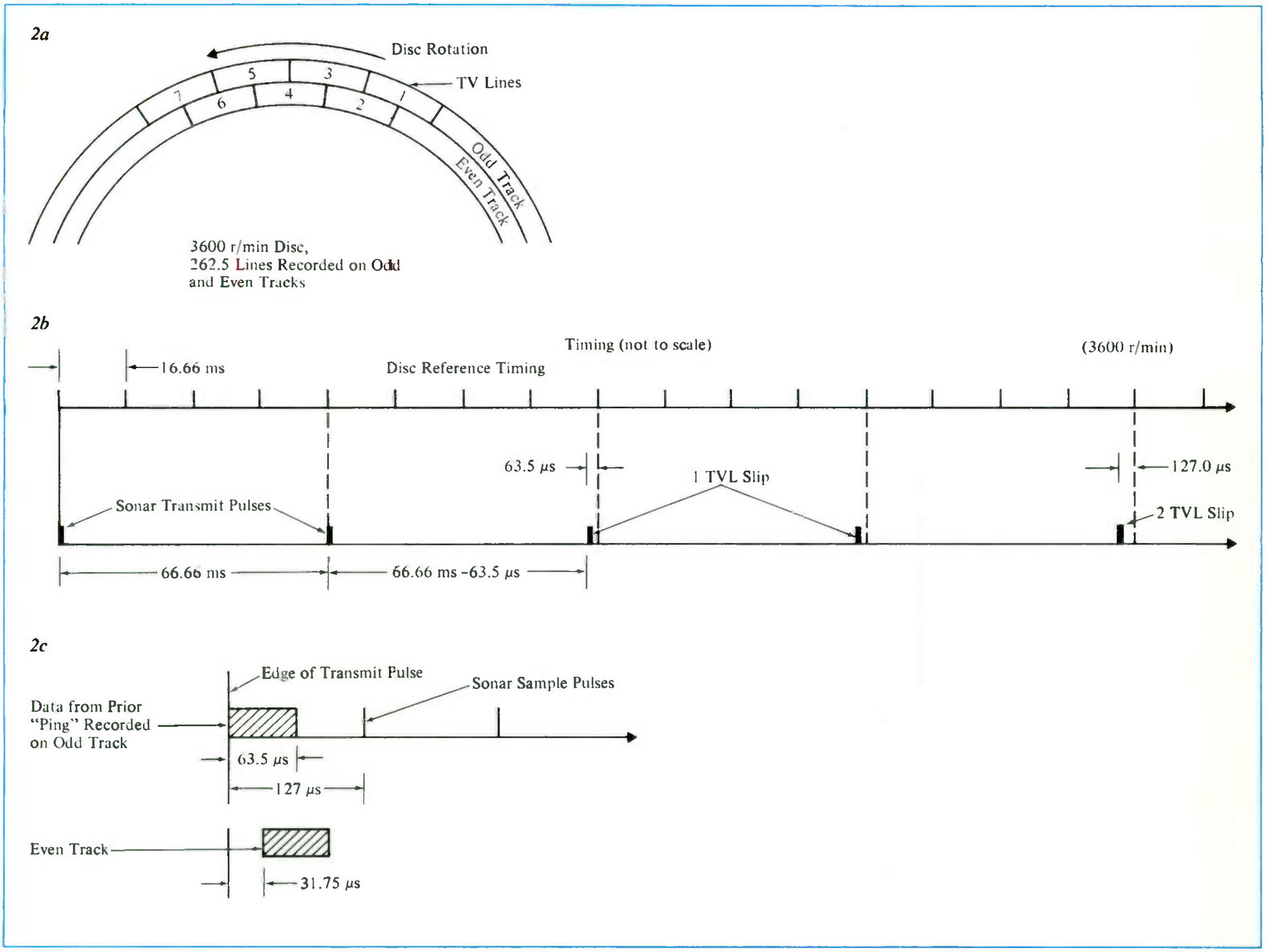
The Magnetic Video Disc

In the past five years, the magnetic video disc has been developed to a point where standard television pictures (4.2-MHz bandwidth) can be repeatedly written and erased over an extended period of time with little or no maintenance required on the system. The stop-motion and slow-motion effects used in television sportscasting, and many other special TV effects, use the magnetic video disc extensively. A standard 18-inch disc at 1800 r/min can store up to 20 seconds of TV viewing for recall. The data is recorded by heads that move radially across the disc. Slow-motion and stop-motion effects are generated by varying the radial movement of the read heads over the disc during replay.

The Westinghouse sonar scan converter uses fixed record and read heads (although moving heads could be added to provide



1—Port and starboard sonar transmitters and receivers can be mounted on the hull of a ship or carried in a towed underwater vehicle.[1] A fan-shaped sonic beam, canted downward, illuminates a narrow strip of bottom on either side of the vehicle. (Most sonar applications transmit only one beam per side although multiple beams can be used to increase the coverage rate.) Objects on the bottom and variations in bottom contour generate sonic echoes of varying amplitudes that are detected by the receiving transducer. Sonic shadows appear behind objects or terrain features and are helpful to the operator in evaluating size and shape. (This shadowgraphic effect is similar to the view that would be obtained if the bottom could be optically illuminated from the side and viewed from above.) In displaying the side-look sonar returns, the vertical dimension is directly proportional to ship speed. Thus, if the display is to have the same scale in orthogonal directions, the display aspect ratio must be adjusted to fit ship speed.



2—In the United States, the standard television picture (frame) contains 525 lines, completed in 1/30th second. To reduce flicker, each frame consists of two interlaced fields of 262.5 lines. Therefore, TV line frequency is 60 × 262.5 = 15.750 kHz, and the time required to scan one TV line is 63.5 microseconds. The two fields are interlaced by delaying the even field by one-half line (31.75 μsec) with respect to the vertical scan (accomplished with the half-line frequency of 31.5 kHz). For a detailed explanation of the signal format, see reference 2.

The method for recording a television frame on a 3600-r/min magnetic disc is shown in (a). *The odd and even field tracks are displaced one-half line to provide field interlace. Disc reference timing is shown graphically in* (b). *A disc rotation takes 16.6 milliseconds, and sonar transmit pulses are generated every four disc rotations (66.6 ms), with one TV line slip (63.5 μsec) every eight disc rotations, so that recorded TV lines precess around the disc.*

The sonar echo received between transmit pulses is sampled every 127 μsec (c) *to provide 512 samples, which are time-compressed to 63.5 μsec. Compressed line data from the previous sonar pulse is read onto the disc at the edge of the next transmit pulse (recorded data in this line position is erased just prior to the transmit pulse). As shown, data recorded on the even track is delayed by 31.75 μsec to provide field interlace when tracks are read to display.*

a recall capability) and a commercial 12-inch disc rotating at 3600 r/min, which can record and play back a video signal that is only 3 dB down at 6 MHz. This performance provides a data-recording capability much greater than required for the sonar display, but a smaller commercial disc is not available.

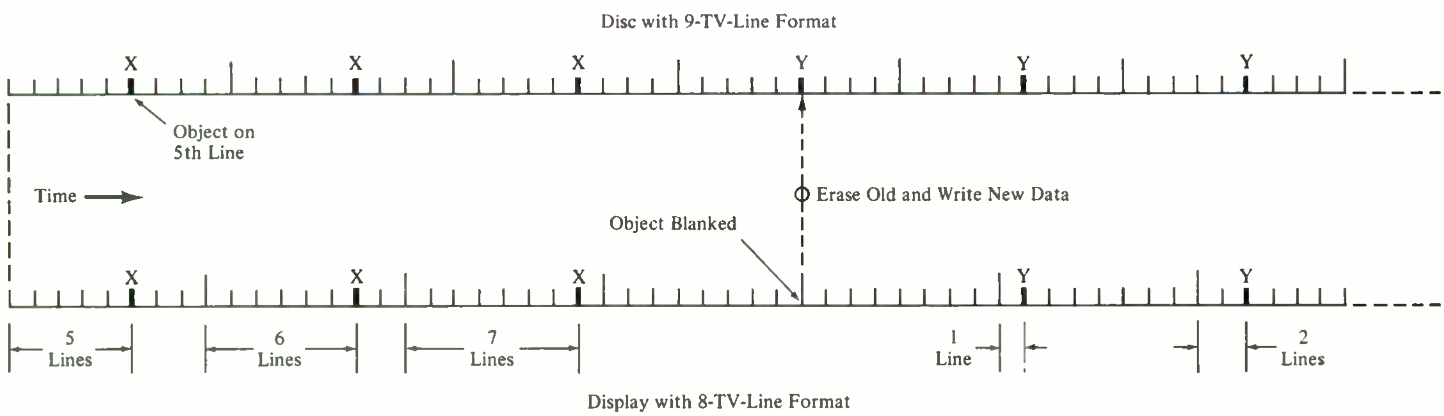
Video Disc Timing

At the 3600 r/min rate, one disc rotation corresponds to exactly one TV field (1/60 sec) of 262.5 TV lines. Since two interlaced fields are required to generate the standard 525-line TV picture, the odd and even fields are alternately written on the disc on separate tracks (Fig. 2a). Each set of sonar returns from a transmit pulse corresponds to one TV line, but since a TV line is written in only 63.5 μsec, the sonar return data must be time-compressed by about 1000 to 1.

Overall sonar system synchronization can be best accomplished by using the disc to control sonar transmit timing. Disc speed is accurately controlled by comparing a master sync track on the disc with a crystal oscillator reference and using the resulting error signal to control the dc motor turning the disc. A sonar transmit pulse is generated every fourth disc revolution (Fig. 2b), providing a nominal sonar transmit interval of 66.6 milliseconds. Between transmit pulses, each sonar echo signal is sampled 512 times (every 127 μsec) by an analog-to-digital converter, which converts each sample to a 5-bit digital value. The digital data is stored in a 512 × 5-bit register.

Time compression is accomplished by reading the digital data out of the register at the appropriate time after the register is full at a clock rate of 512 × 15.75 kHz = 8.064 MHz. The 5-bit digital words are converted back to an analog signal and read onto the disc such that the 512 samples now occupy one TV line (63.5 μsec).

If the sonar transmit-pulse interval were exactly four disc revolutions, each new line would be written over the preceding line on the disc. Therefore, to place the returns in the correct juxtaposition so that they will be recorded sequentially line-by-line around the disc track, the sonar transmit pulse interval is reduced slightly; for a one-beam-per-side system, the sonar PRF is advanced by one TV line (63.5 μsec) every eight disc rotations (Fig. 2b). Thus, data storage precesses around the disc, and every odd-numbered set of sonar returns (1, 3, 5, etc.) is read into adjacent locations on the odd track. To provide the interlaced picture with ½-line time delay between odd and even fields, the data from the even-numbered sonar returns is delayed by 31.75 μsec and recorded on the adjacent even track (Fig. 2c). In this fashion, the 63.5-μsec time advance per two sonar transmit pulses (eight disc revolutions) provides the correct timing to fill the odd and even field tracks, line-by-line, from the sequential sonar returns. Thus, the magnetic video disc and digital time compression make it possible to store and read out a standard 60-field-per-second TV picture even though new data is being added at the relatively slow sonar PRF of 15 scans per second.



3—The technique for developing the "moving window" display can be illustrated with a disc that has a nine-line format and a set of returns (x) *recorded on the fifth line. If the display has only eight TV lines between its field sync pulses, the recorded line* (x) *slips one line per disc rotation as shown and moves to the bottom of the display. When the recorded data* (x) *is due to return to the top of the display, a new input* (y) *is recorded on the fifth line of the disc to become the new top line of the eight-line display.*

Moving Window Timing

To simulate a "moving window" view of the ocean bottom, new data must always appear at the top of the TV display and previously stored lines must be shifted vertically downward. This vertical line shift is accomplished by moving the field-sync pulse with respect to the disc and the master timing unit that is generating the standard EIA sync format. Since EIA sync pulses are not written on the disc, the disc has no inherent field-sync position. Thus, as the display moves downward, a vertical flyback blank area does not appear.

One new line must be made available at the top of the display after every sonar transmit pulse (or four disc rotations). Therefore, the field-sync pulse is advanced by 63.5 μsec every four revolutions (four fields or two frames on the display) so that the resultant picture structure is 525/524 lines.

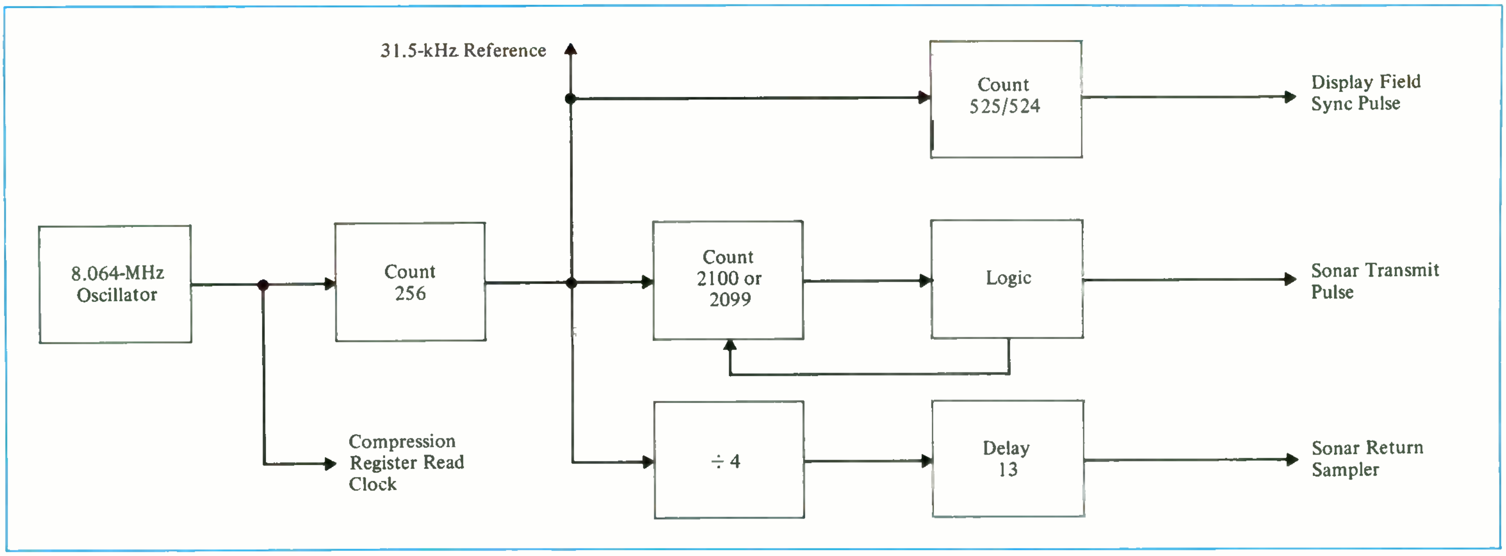
The mechanism for moving display lines downward is illustrated for a simplified 8-line format in Fig. 3. The digital data processing for generating the various sync pulses and 31.5-kHz reference frequency is shown in Fig. 4.

Video Disc Scan Converter Demonstrated

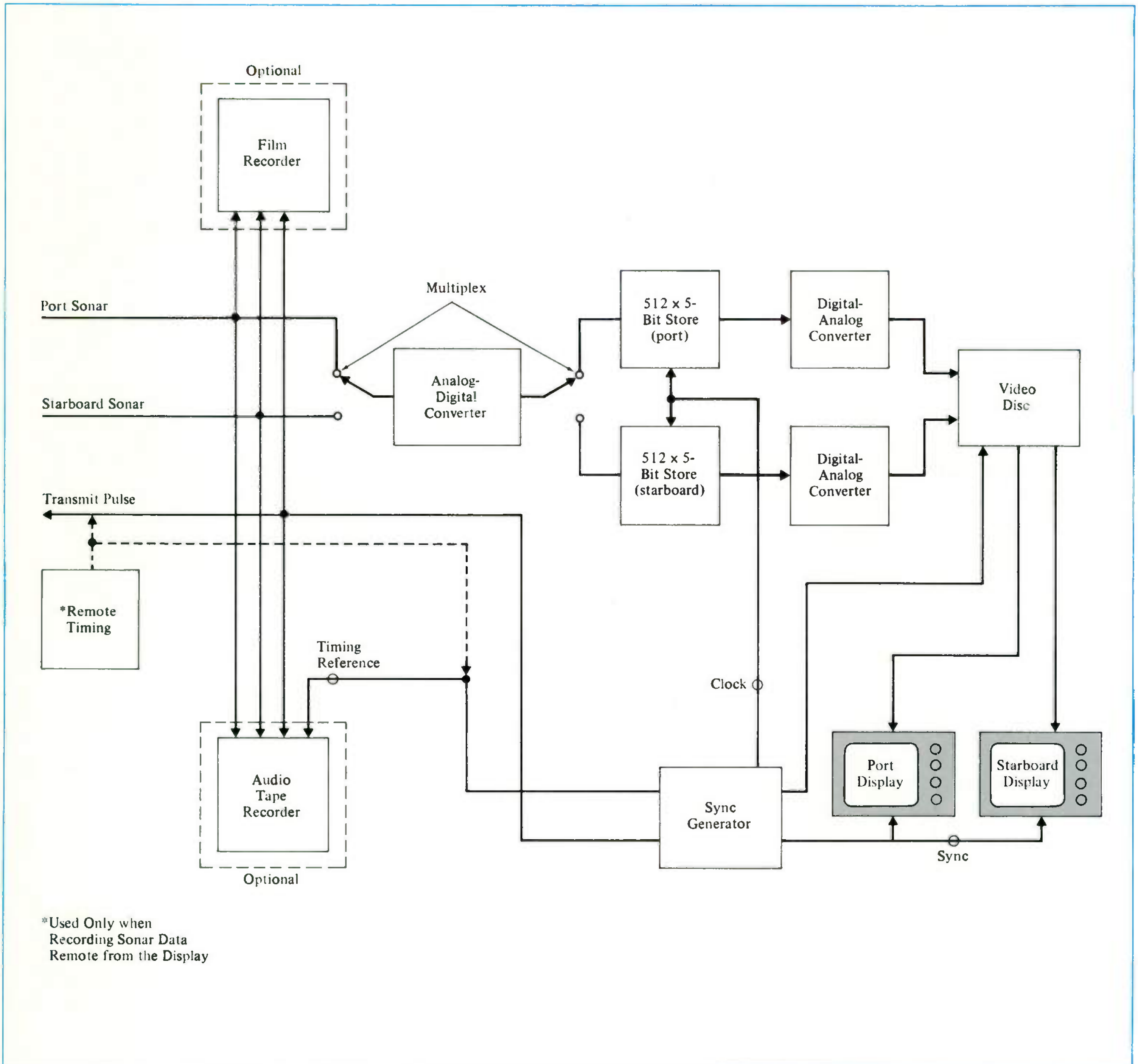
A block diagram for a port- and starboard-beam video disc scan converter is shown in Fig. 5. The data from the two sonar beams is multiplexed via the A/D converter to 512 × 5-bit random access memories, one for each beam. Successive sets of sonar returns from the starboard beam (the same process applies to the port beam) are written alternately onto odd and even tracks to form the two-field TV picture stored on the disc. All necessary sync signals to complete the composite EIA television signal are added by the sync generator. Since the whole writing process occurs within the time of one sonar sample pulse, the assembled picture can be displayed as it is written onto the disc.

A typical view taken from a starboard display is shown in Fig. 6a. For this picture, a Westinghouse L-15 sonar was towed about 30 feet above the bottom. The horizontal dimension of the picture is 160 feet and its vertical dimension is 100 feet. The image shows the deeply scoured bottom of Chesapeake Bay near the western end of the Chesapeake Bay Bridge. The extreme left-hand side of the picture corresponds to the time position of the sonar transmitter being towed, and the dead space immediately to the right of the left-hand edge corresponds to the height of the vehicle above the bottom. For this configuration, the height of objects above the bottom is approximately 1/5 the length of their shadows. Because the vertical scale of the display depends on the towing speed, a standard 3:4 aspect ratio of a television picture cannot necessarily be maintained if the speed is varied without giving some object distortion.

The breadboard scan converter built to demonstrate the video disc technique is shown in Fig. 6b. The unit above the display is the tape recorder, and the small drawer under the display is the digital data processor and sync generator. The lower three drawers contain the video disc and its servo control. In a prototype sys-



4—A master timing crystal oscillator provides the 8.064-MHz register readout clock. The pulse train is divided down by 256 to provide the 31.5-kHz reference for the TV sync generator and for disc master timing. It is further divided down by a counter that divides by 2100 or 2099 to provide the sonar transmit-pulse timing. A 525/524 counter from the 31.5-kHz reference provides the display field sync pulse for the moving window effect. The sonar sampling pulse is obtained from the 31.5-kHz clock divided by 4. This provides 525 sampling pulses, but the first 13 are inhibited because only 512 are used in the data-compression registers (and the first 10 percent of the sonar return interval contains no useful data).



5—Block diagram of a video disc scan converter illustrates the components that would be required for port and starboard sonar scan. Two optional elements that can be used for making permanent records from sonar data in parallel with the scan converter are an audio tape recorder and a CRT film recorder. If the tape recorder is used without the video disc scan converter, a remote timing track must be added to the tape for later synchronization with the video disc scan converter.

tem built for shipboard use, the video disc drawer could be substantially reduced in volume because the unit shown had the capability of recording 32 tracks, whereas only three tracks are needed for a starboard display. An advantage of the video disc system is that it can be expanded in capability with little additional hardware complexity. For example, adding a port capability to the starboard display converter increases the hardware by only about 10 percent.

Permanent records of the sonar data can be stored on the audio tape recorder, as shown in Fig. 5. The sonar data can be taped at the same time it is being converted to a video signal for display, or the tape recorder alone can be used with the sonar and the recorded sonar data subsequently fed into the display for viewing.

The sonar data for each beam is recorded separately on tape along with the sonar transmit pulse. Since the capstan reference available for speed control on some tape recorders does not have sufficient accuracy for this application, a master timing reference for playback is also recorded. The sync generator for accomplishing this is the remote timing unit indicated in Fig. 5. Typically, it would generate a reference frequency that is a submultiple of 31.5 kHz since this frequency is available for synchronization on the disc master sync track.

Other Applications

The video disc scan converter is not limited to sonar data processing. It is equally capable of processing slow scan television data and presenting the result at the standard TV field rate. It is also capable of presenting in TV format any slow continuously varying data. Since the disc output is compatible with the standard RS 170

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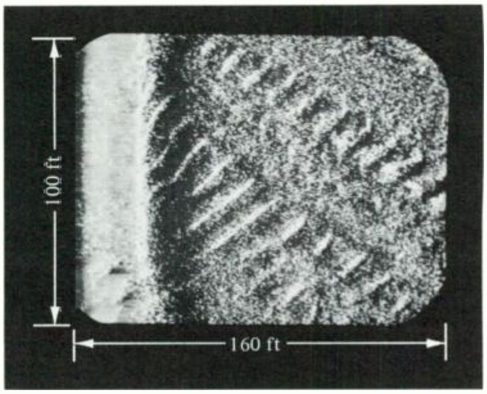

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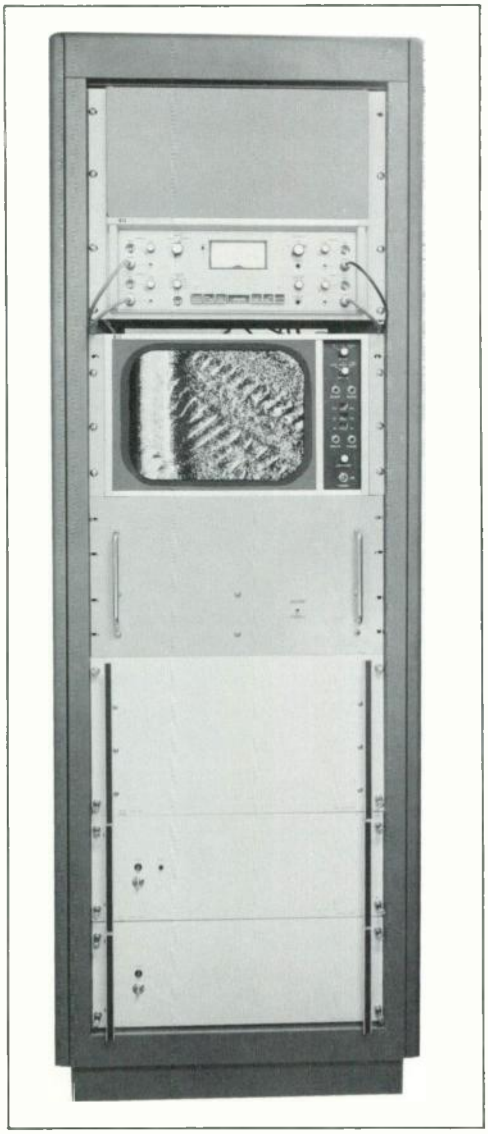

6—This bottom picture of Chesapeake Bay (a) *was developed from sonar data taped from a starboard scan with Westinghouse L-15 sonar. The picture is a photograph of the TV display provided by the breadboard model* (b) *that was built to demonstrate the use of a video disc scan converter for sonar display. A prototype for shipboard installation could be significantly reduced in size.*

sync structure, the video data can be recorded on a video tape recorder for playback at a later time.

The use of a magnetic video disc recorder in conjunction with a digital time compression system has enabled a considerable improvement to be made in the size, weight, and power dissipation required to convert sonar or other signals into a flickerless format for viewing.

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[2] J. H. Meacham, "Subminiature TV Camera," Westinghouse ENGINEER, March 1972, pp 39-43.

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Developing an Integrated Security Plan for Plant Protection

F. W. Romig

A variety of intrusion detection, alarming, and surveillance equipment is available for providing security functions. For any specific situation, a master plan should be developed to determine the mix of security equipment and procedures that will result in the most effective total system.

Although the ideal plant security plan would begin with site selection and proceed in parallel with the architect's building plans and the facility's configuration, this ideal is rarely achieved—except perhaps in some unique military installations. In the more usual industrial situation, other factors primarily dictate site selection. In fact, plant security is often given little consideration until after an intrusion or loss has occurred.

However, there is a growing awareness of the desirability of a carefully developed security program. It should begin with an analysis of the security threat combined with an evaluation of the ultimate loss or damage that could occur should the projected threat materialize. Although an absolute security system for handling any threat would be ideal, economics require that the degree of security be tempered by the severity of the potential hazard, damage, or loss. Thus, a realistic security plan basically attempts to make access difficult enough to discourage the intruder's attempt; but if he persists, then the plan should provide at least to some extent for the intruder's apprehension.

The first step in the development of a security plan—evaluating the actual security threat—is also the most difficult because the nature of the threat may be obscure. It could range from petty theft or vandalism to destructive sabotage or even armed assault. Even though none of these possibilities may ever materialize, some estimate of potential threat is required before the damage or loss can be assessed so that the security plan will be a cost-effective tradeoff between the security goal and investment cost.

Any good security plan must be a blend of many elements. It must begin with prosecurity attitudes and procedures, such as employe training and personnel identification systems. The physical elements may include plant equipment alarms and control systems, various interior security monitors, a perimeter security system with gate controls, and closed-circuit TV surveillance. Other elements could include a plant security guard force and/or a cooperative arrangement with local, county, or state law enforcement agencies. But the best mix of, and the relative emphasis on, these various elements can only be determined after a careful analysis of the existing situation and the potential security threat including an evaluation of the magnitude of the hazards or losses that could occur.

Most of this article is directed at just one security element, external perimeter security, which detects (and should discourage) an intrusion. Of the various security elements, this one is usually the most

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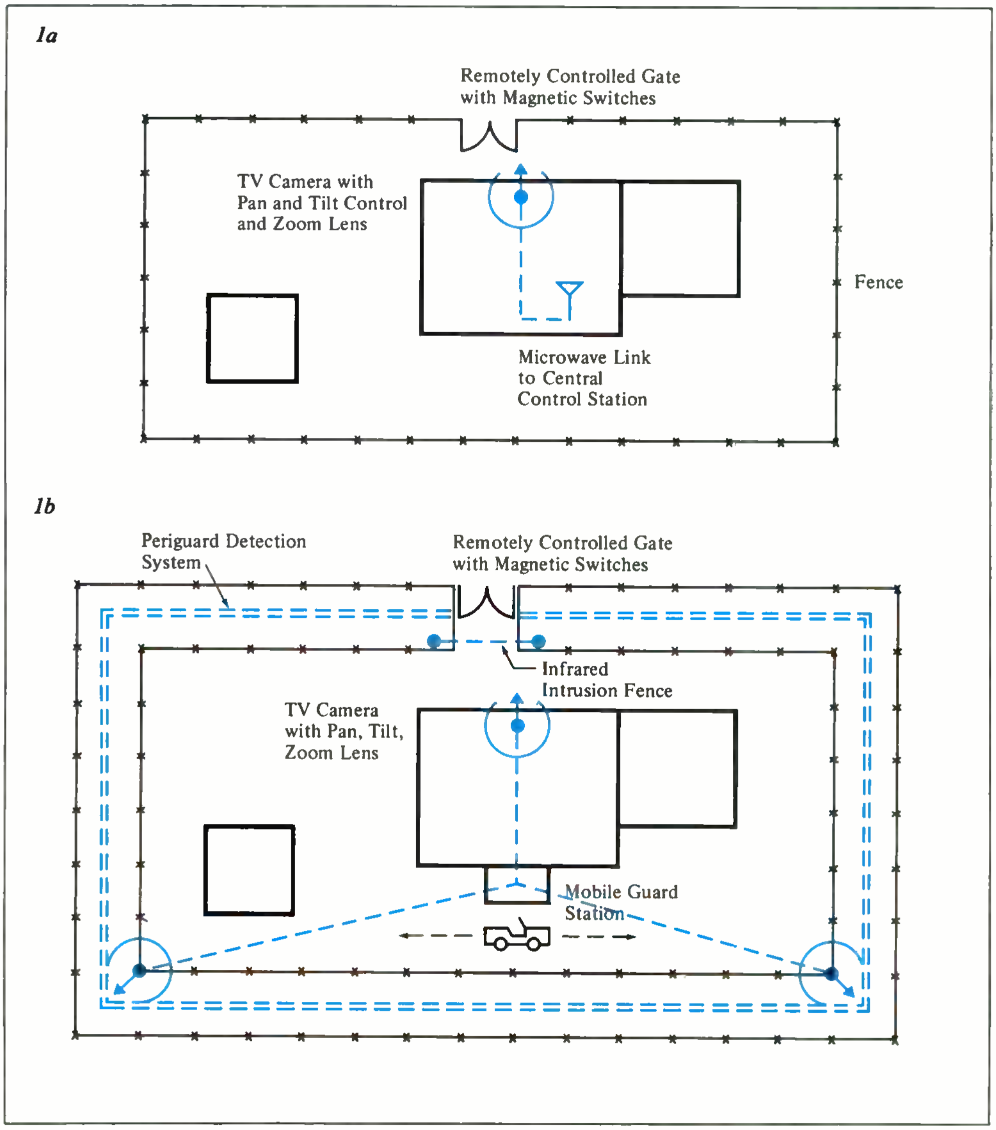

1—Perimeter systems can be designed to provide any desired level of security. A minimum system for remote applications (a) *would consist of a fence and a remotely controlled TV camera, located so that it can view the remotely controlled gate and also provide area surveillance. A much greater level of security is obtained* (b) *with a double fence and an underground Periguard detection system and/or aboveground infrared intrusion detection. Closed-circuit TV cameras provide area and gate surveillance to a control center, from which a mobile guard can be dispatched.*

difficult to apply, the least understood, and the least discussed. However, the other elements of security must not be overlooked in the total plan. For example, internal plant security is needed to locate intruders or other potential dangers within a protected or specified area. And even the best perimeter and internal security systems can be easily bypassed if the personnel identification system does not screen out unauthorized personnel. Similarly, the effectiveness of any internal or external security system is limited if plant guards or local enforcement agencies are not available to respond quickly to an intrusion or alarm. Furthermore, personnel must be carefully trained to respond in the proper fashion to an alarm. Thus, the elements chosen must be carefully blended to form a realistic security system that can function effectively to provide the desired level of protection.

The approach of Westinghouse Electronic Protection Systems is to develop a total plan that can provide some specified level of protection, with additional options that can increase the security level (and investment). This gives the user the option of selecting a protection level that he feels commensurate with his needs.

Perimeter Security Systems

A good perimeter security system consists of several interrelated functions:

Predisturbance surveillance senses a security threat before it occurs—if properly designed, it may help deter the intruder;

A *barrier with gate control* restricts entry to authorized persons and warns unauthorized persons that they are trespassing;

A *detection system* should instantly and accurately pinpoint any intrusion of the barrier;

Postdisturbance surveillance can quickly determine what caused the detection system to alarm, and it can evaluate the threat;

And finally, a *response* is required to neutralize the security threat.

Although most perimeter security systems have the above elements, the relative emphasis and effectiveness of each can vary considerably. Military installations have all these functions, accomplished with sophisticated detection and surveillance equipment and manned by highly trained personnel. Industrial or commercial installations, on the other hand, where threat and loss are not so clearly defined, apply varying degrees of emphasis and sophistication in accomplishing the various security functions.

Since it is not possible to illustrate any specific perimeter security installation—to do so would violate the security of that installation—a hypothetical utility/industrial remote plant site is described (Fig. 1).

Predisturbance Surveillance

Measures for performing the predisturbance surveillance function can range from something as simple as warning signs posted at regular intervals around the perimeter to discourage intrusion, to a closed-circuit television network for monitoring the complete installation.

Predisturbance surveillance by plant guards is limited to whatever the guards at each post can hear and see, along with whatever intelligence reports they might obtain from on-site employes and off-site

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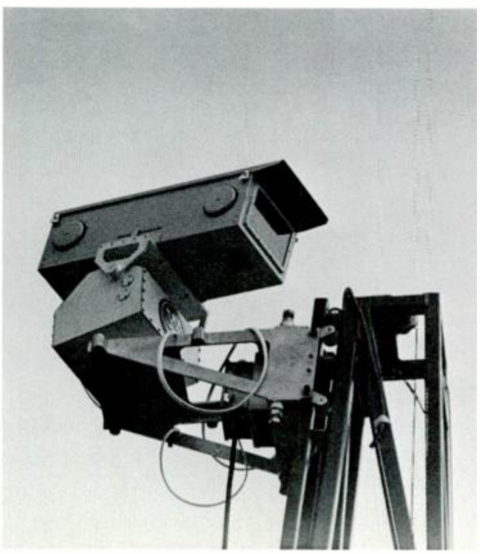
2b



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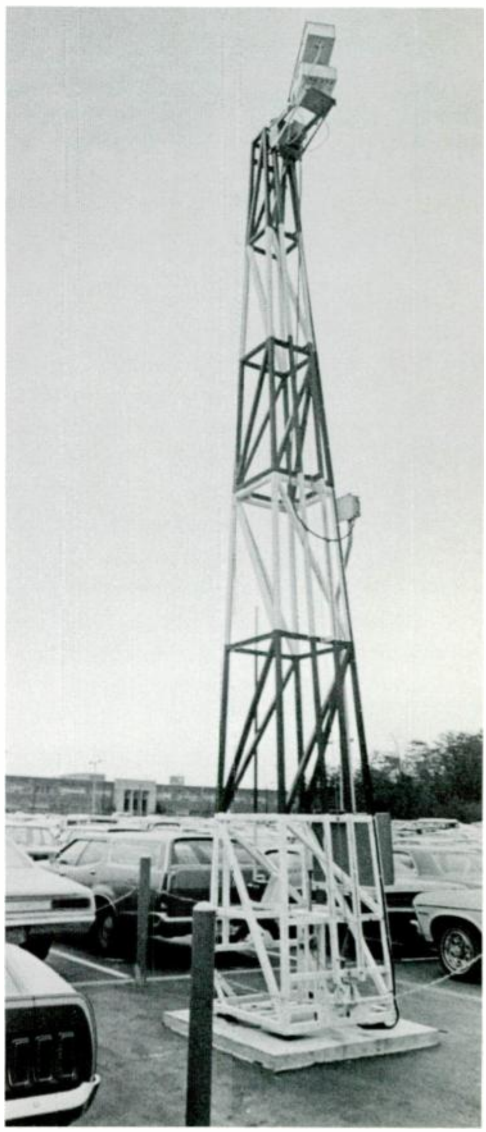


2—Sensitive TV cameras in weatherproof housings are remotely controlled by a central operator. Cameras can be roof mounted (a) *or, where necessary, mounted on towers* (b) *to provide the desired field of view. This tower* (c) *is designed to facilitate routine service on the camera. Servicemen can lower camera, perform necessary service such as lens cleaning or maintenance, and return camera to viewing position in a matter of minutes.*

neighbors. Thus, the principal advantage of closed-circuit TV is that a guard with many cameras can "patrol" large areas much more effectively than a large guard force on foot. Although a man viewing a TV screen is not an efficient detector over long viewing periods, such a system is very effective for regular surveillance checks of an area, which would at least provide notice of any significant changes such as parked vehicles.

The most economic TV system for both pre- and postdisturbance surveillance consists of a low-light-level camera mounted on a platform and remotely panned and tilted, either automatically or under the remote operator's control. A more elaborate version could use many cameras solidly mounted to cover specific areas. Sensitive TV cameras can provide a viewable picture throughout a range of scene illumination levels from bright sunlight to starlight (25,000 foot candles to 10^{-4} foot candle). Thus, even on dark overcast nights, a relatively low level of perimeter lighting will permit TV cameras to provide clear pictures.

Perimeter Barriers

In its simplest form, the perimeter barrier may be no more than a woven-wire fence with a padlocked gate. However, since padlocks are relatively insecure against a determined intruder, a more effective gate control system should include some form of visitor identification. One effective method for remote gate control is television surveillance. Although a camera in fixed position at the gate is the most obvious arrangement, it may be more economic to utilize a camera from the predisturbance surveillance system. By strategically positioning the camera so that it can be focused on the gate when required, the gate control camera can also be used for other surveillance work. Visitors merely signal their intention by pushbutton or telephone to the central operator, who then views the gate; if all is satisfactory, the control operator releases a magnetic lock that allows the visitor to enter. The gate is then closed and locked until the visitor signals to exit, at which time the remote viewer again focuses the TV camera on the gate. Any attempt to open the gate without approval initiates an alarm so that the operator can view the situation on the TV monitor.

For more positive identification of personnel entering or leaving, the remote viewer can zoom in to compare the visitor's face with a prerecorded picture that has been "stored" on a magnetic disc memory. Facial characteristics appear in sufficient detail to enable the viewer to readily identify a particular individual by comparing the TV camera image with the stored image.

Camera systems capable of performing this type of high quality surveillance have been developed, partly as a spin-off from the Westinghouse space camera program and from other low-light-level military systems. One Westinghouse camera system now offered (Fig. 2) includes a heavy-duty pan and tilt unit with direct-drive gearmotors to move the camera in azimuth and elevation, a zoom lens, and a remote junction box with enough conductors to control the various camera functions. An emergency spotlight can also be mounted with the camera to illuminate its field of view for personnel identification.

Detection Systems

Predisturbance surveillance systems, perimeter barriers, and gate control systems are made readily visible with the hope that they will discourage the potential intruder. On the other hand, detection systems that sense a violation of the barrier should be hidden from view, camouflaged, or else designed so that any attempt on the intruder's part to disable the system will automatically trigger an alarm. The detection system is usually designed to function inside the barrier so that it will not be accidentally triggered. If it is desirable to give the postdisturbance surveillance system time to operate, or to gain time for preventive response, a second barrier that is more difficult to scale is placed inside the detection system.

Although the TV monitors used for predisturbance surveillance can provide some degree of intrusion detection, a TV watchguard looking for infrequent intruders may very easily miss them, or if a panning camera is used, the intruder may be able to move across the barrier when the camera is viewing another area. Therefore, a more effective detection system is some form of above- or below-ground sensor permanently installed to protect the perimeter.

The basic perimeter detection system consists of an above- or below-ground sensor placed between an inner and outer barrier (Fig. 1b). If a choice exists between above- and below-ground sensors, and only one sensor system can be afforded, the detector with the least chance of being defeated should be chosen. Usually, a buried sensor such as the Westinghouse Periguard System (Fig. 3) is more difficult to defeat because it is invisible, and even if the intruder suspects it is there, he must raise

3—(Above) *The Westinghouse Periguard system consists of a pair of fluid-filled hoses buried along parallel paths several feet apart. As an intruder approaches, a larger pressure change is generated in the hose nearer the intruder. Piezoelectric crystals in the buried detector sense the pressure differential between hoses and trigger an alarm.*

4—(Right) *A typical infrared intrusion fence is mounted in a standard housing. A single transmitter activates several receivers, so an interruption in the beam to any receiver triggers an alarm.*

himself off the ground by some means, thereby increasing his exposure and the chances of his detection. However, where underground sensors are not applicable (such as in rock or coral), then some above-ground sensor must be used.

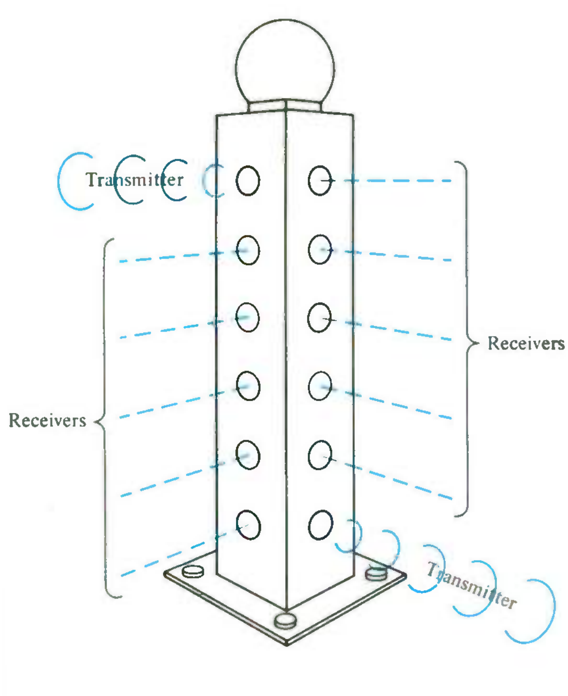
Of the two types of above-ground interrupting-beam systems, laser and infrared, the infrared system is the easier to apply because infrared produces a wide beam of about 15 feet in diameter at the receiver end (Fig. 4). Not only does this configuration eliminate alignment and vibration problems, but infrared energy also penetrates extreme weather conditions better than laser beams and is invisible.

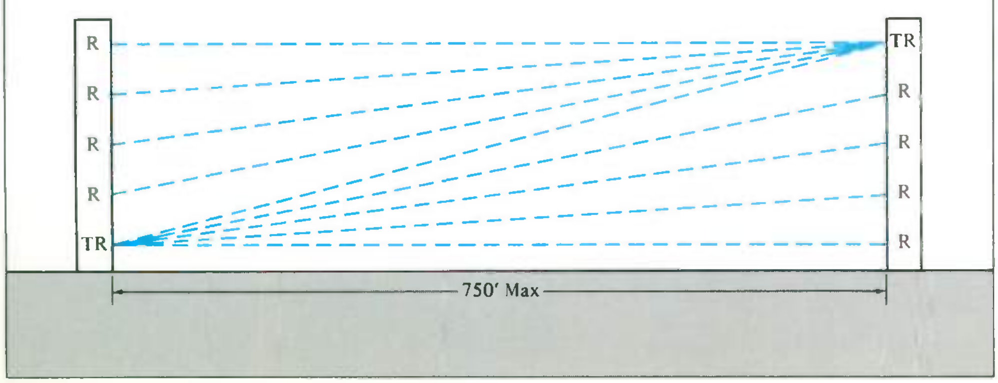
Area Detection Systems—The maximum security requirements of military installations have led to the development of another type of intrusion detection, which can be classified more accurately as large-area detection rather than purely perimeter detection, even though the results are similar.

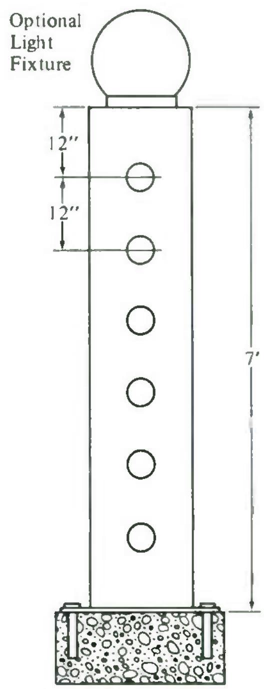
Of the tried and proven methods of large area detection, radar is the most effective technique. Several sophisticated all-weather radar systems have been developed for boundary security of military installations. For example, one recently developed military radar uses advanced digital signal processing to detect moving objects (moving target indication, or MTI). For permanent installations, the radar antennas are usually tower mounted in strategic locations for viewing the perimeter (Fig. 5).

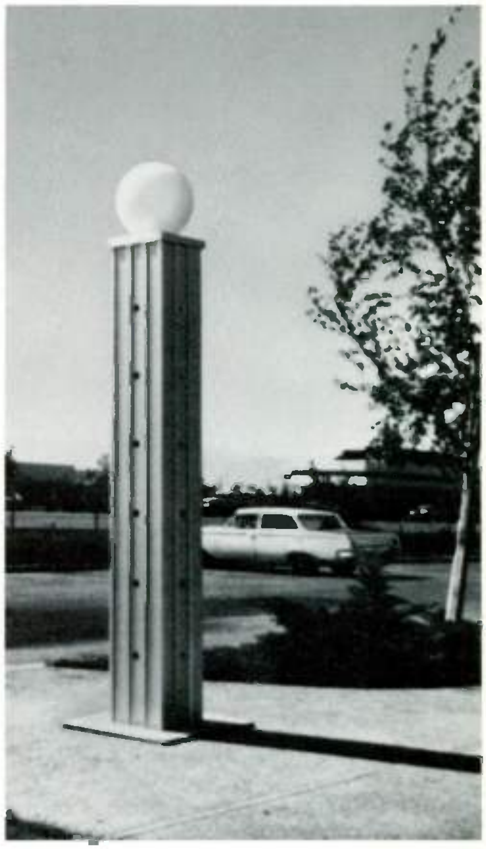
Another military radar system developed for intrusion detection is designated a *dual-beam* MTI. This radar is even more specifically designed for boundary work in that it establishes a range gate and only detects personnel or objects that move through this boundary.

The disadvantages of radar systems are that they occupy considerable space, plant or maintenance personnel can easily wander into the large sensitive areas causing unnecessary alarms, and for the industrial application, radar is relatively expensive. Thus, this form of intrusion detection is









primarily applicable where the loss potential is extremely high.

Another large-area detection system that has better potential for nonmilitary applications consists of a TV camera and a magnetic disc recorder. A TV image of the area being protected is stored on the disc for comparison with the continuous output from the camera. The quality of video storage with today's magnetic discs is so good that very small pictorial differences can be detected by comparison of signal waveforms. The comparison pictures stored on the disc can be updated arbitrarily or can be automatically updated to allow for lighting changes and for scene changes. For example, if a truck or aircraft is moved into the area for parking, the comparison picture can be updated to include the new content so that only changes with respect to this new condition will be detected.

This type of TV system has the further advantage that a "frozen" picture of the cause of any scene change can be stored for future reference. This makes pictures of the intrusion available for use in identification and apprehension. Furthermore, if the intrusion is not a threat, the TV picture will quickly reveal the situation to the operator (postdisturbance surveillance) so that an unnecessary alarm is avoided.

Postdisturbance Surveillance

After a detection system has alarmed and located an intrusion, a postdisturbance surveillance system is needed to quickly identify the nature of the intrusion. Since even the best detection systems can be accidentally triggered by on-site personnel or by animals, birds, or even extreme weather, it is desirable to be able to quickly determine whether the alarm is genuine and requires an immediate response and, if so, to identify the intention of the intruder. Unless there are on-site security guards who can quickly reach the alarmed section of the perimeter, some sort of day-night closed-circuit television can effectively provide this function. In a well-designed security system, the same cameras used for predisturbance surveillance can logically be used here. When an alarm occurs, the control operator can quickly swing the TV camera to the alarm zone. In multiple-camera systems, cameras can be permanently focused on each protected section and automatically switched to display the alarm situation.

Response

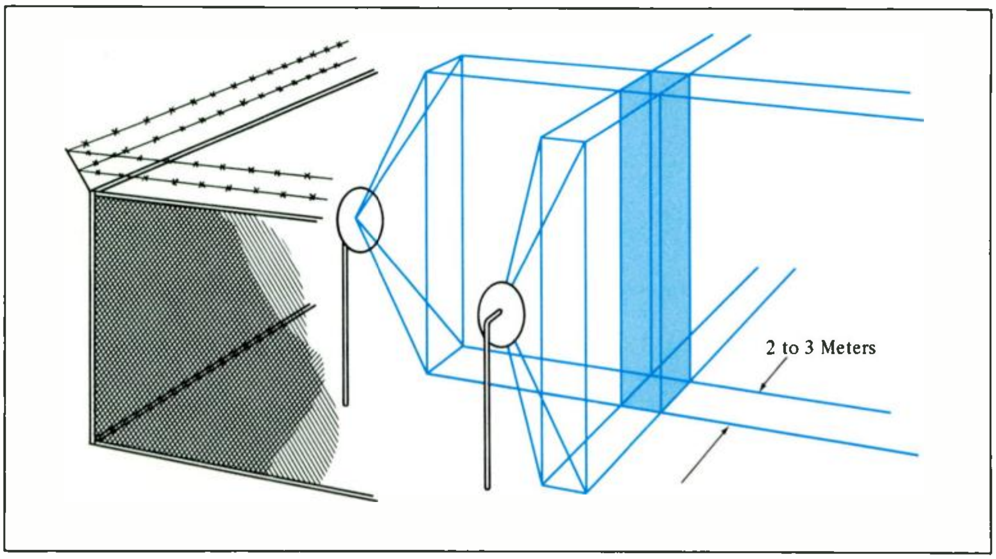
The final link in any perimeter security system is the response that is dispatched to neutralize the detected threat. The magnitude and speed of response obviously will depend on the seriousness and potential damage of the threat. Furthermore, the maximum speed of response, particularly for remote unmanned sites, may determine the practical level of surveillance and detection. For example, if an intruder can scale the barrier, enter the facility, and leave in 5 minutes, but a response cannot be generated in less than 20 minutes, a sophisticated electronic surveillance and detection system may not be the most logical security arrangement.

The user must consider whether the response force should be company supervisory employes, contract guard personnel, local law enforcement officers, or some other group. Also, various levels of response may be considered. At the highest security level, an armed security force would be dispatched immediately. At a lower level, the intruder might be monitored and followed with a panning TV camera. A video recording would be made so that law enforcement agencies could use this information for identifying and convicting the intruder. At the lowest level of urgency, a loudspeaker or alarm system could be used to attempt to discourage the intruder from completing his mission.

In summary, the perimeter security system should be designed to achieve an effective mix of interrelated security functions that will provide the desired level of overall protection.

Internal Plant Protection

Internal plant protection plans are designed to track the intruder when an intrusion has been detected by the perimeter system, or to detect an intrusion by someone already in the plant—either because he was not



5—(Left) *Radar is one of the most effective perimeter detection systems because it covers a relatively wide area and is therefore very difficult to penetrate.*

6—(Right) *Closed-circuit TV surveillance permits a single operator to monitor a complete installation. The display should be designed so that an alarm directs the viewer's attention to the alarmed area, permitting him to view the situation and take necessary action.*

subjected to surveillance by the perimeter system or because the plant has no perimeter system. Thus, internal protection systems have much in common whether they be for protecting plants within a perimeter security system or for open plants or public buildings.

The detection systems may include key-operated tour stations for security patrols, door and gate contacts to warn of unauthorized entry, infrared beams that signal the crossing of some barrier, or TV cameras to help identify the nature of an alarm. Fire and smoke detectors, and equipment malfunction detectors, are also tied into the alarm system to warn of those types of threats.

In large installations, there may be hundreds of detection and alarm points; the internal protection plan then requires sophisticated coordination so that the overall system can be effectively monitored. This function can be accomplished most effectively with a computer, programmed to continually survey all detection and alarm points and warn of any irregularity. For example, the computer would signal an alarm when a key station is not activated at the proper time or in the correct sequence. The computer can automatically activate TV cameras in the alarm area and switch the picture to a central monitor. An effective internal protection system must also provide the central control operator with the continuous location of all security personnel so that they can be quickly dispatched to answer alarms of break-in, fire, or equipment malfunction.

Developing a Total Security Plan

The total security plan should integrate all elements of security to meet any estimated or projected threat, internal or external. This requires an integrated approach so that there will be no weak links in the overall system. Several factors should be kept in mind in the development of the total security system.

When on-site personnel are available, they should be used effectively, but usually not for the predisturbance surveillance or the detection functions where electronic devices can perform more reliably.

If on-site personnel are not required for other functions, an all-electronic system may be the most cost-effective system over the long run. For example, a minimum type security system for a remote installation (such as a pumping station or electric utility substation) might include a television camera, some form of barrier and gate control with intrusion detection, and a microwave link to a central control station. If the cost of this system is balanced against the cost of maintaining a 24-hour guard station at the site, it is quite possible that the all-electronic surveillance system can pay for itself in just a few years—and do the job just as effectively as an on-site guard.

At the central control station, the security display equipment should be designed so that alarms are readily recognized and quickly identified. If possible, the display system should not require continuous TV viewing because an operator can only view a television screen effectively for short intervals. However, the system should require some sort of continuing activity by the operator to avoid boredom so that he is alert if an emergency does occur.

The security system should be organized so that a response can be immediately activated, whether it be some sort of alarm to warn the intruder away or the dispatch of a security patrol. Operating personnel should be alerted to the potential threat so that they can be prepared to protect the rest of the system (pipeline, transmission line, etc.) from the effect of the threat. A careful analysis of the total security requirements, balanced against the most effective (and affordable) mix of protective techniques, yields a cost-effective security plan that provides the desired level of protection.

Correctional Security

Although security has been discussed here from the industrial/commercial point of view where the concern is intrusion, the same security elements and functions apply to the detention application where security means preventing escape.

Today's correctional goals include the creation of a physical environment that is most conducive to reorientation, adjustment, and socialization of the offender or patient. Certainly, high concrete walls with guard towers manned by sharpshooters do not contribute to this objective. On the other hand, a carefully planned perimeter system using electronic surveillance and detection techniques can provide a relatively "soft" internal exposure and still maintain "hard" security. The same techniques used for intrusion detection can provide instant warning of an escape attempt and provide sufficient time for a mobile guard force to intercept the escapee.

And finally, high prison walls with multiple guard towers are not only awesome but expensive. Modern perimeter security systems should provide savings in operational costs over the years—savings that can be better spent for doctors, teachers, and social workers.

High-Quality Magnet Wire Produced Quickly and Efficiently

Both copper and aluminum magnet wire, bare or with a variety of insulations, are made in great quantities in a new production facility.

As the use of electricity increases, so does the demand for copper and aluminum magnet wire. In fact, the wire market's growth curve closely follows the curve of growth in demand for electric power. To help meet that increasing demand for magnet wire, both inside and outside Westinghouse, the Westinghouse Wire Division has opened a new plant near Abingdon, Virginia.

The plant makes bare and insulated copper and aluminum wire in all the common sizes and in round, square, and rectangular shapes. It is a fully integrated plant, so the Wire Division has become the country's only major producer of magnet wire with its entire manufacturing operation under one roof. The plant replaces outmoded facilities at Buffalo, New York. Ample room for expansion on the site will enable the Division to keep up with future demands for wire for motors, generators, transformers, coils, and other devices.

The modern facility has a flow-through production system (Fig. 1). Aluminum rods and bulk copper enter at one end of the plant, and finished reels of magnet wire exit at the other. The plant produces wire in sizes ranging from 0.0025 inch (49 gauge) up to sizes required for power transformers and large generators—0.289-inch round wire and 0.150- by 0.625-inch rectangular wire or even larger.

The plant is unique in that all of its copper magnet wire is made from rod produced right in the plant by the CMCR (continuous melting, casting, and rolling) process. This rod is especially well suited for making magnet wire because of its unusual homogeneity and fine grain structure, which give it surface and physical properties superior to those of copper rod made by the conventional batch process. The uniform high quality greatly reduces wire breaking in the drawing and coating processes, facilitating economical production of very long lengths of superior wire. In addition, the vastly increased rod length available from the continuous process essen-

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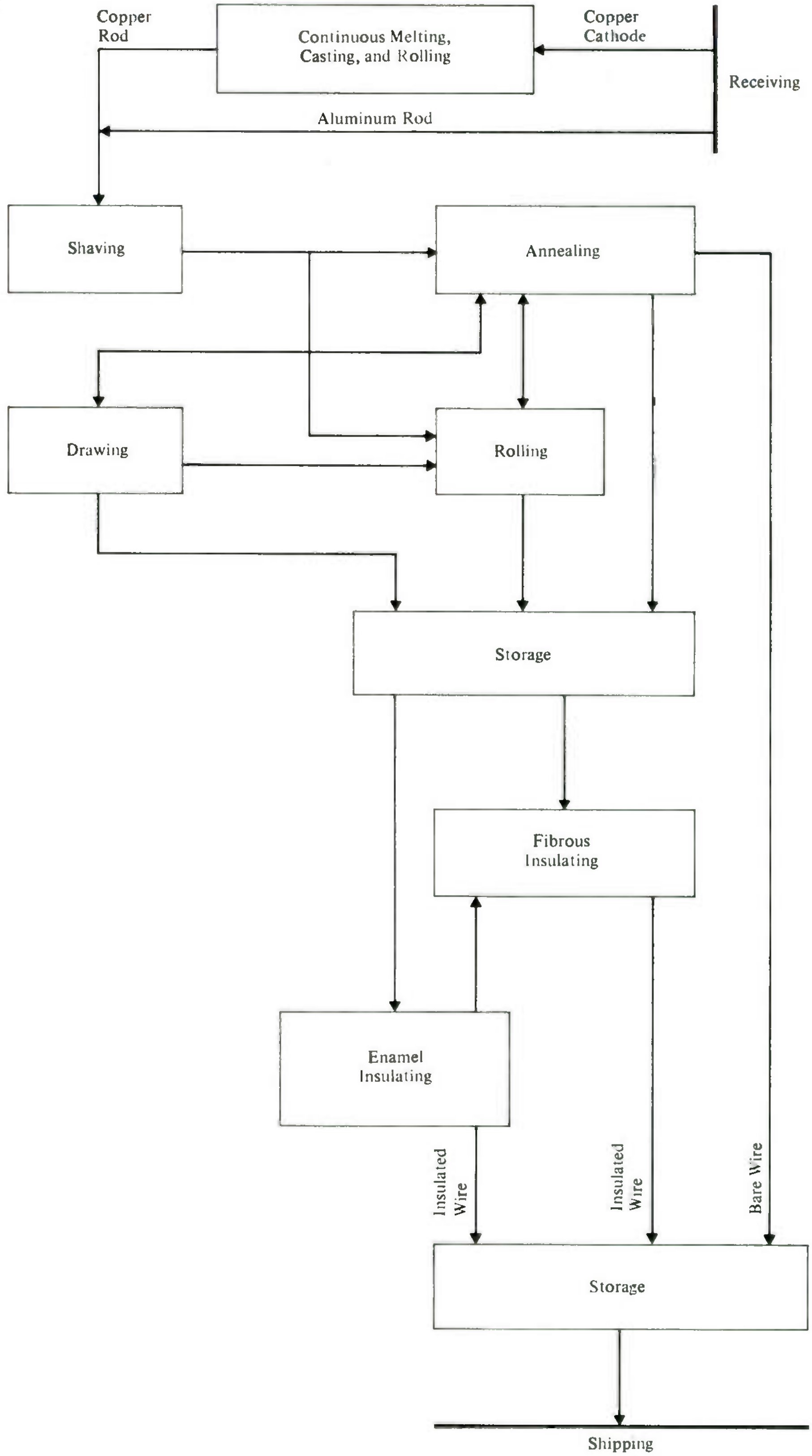

tially eliminates the need for welds, removing another common source of breaking in the drawing and coating processes.

CMCR Process

An earlier version of the Westinghouse CMCR process that went into production in Buffalo in 1966 was the first of its kind.[1] It was a revolutionary change, because production of copper rod for wire drawing had not changed basically in nearly 100 years. The traditional batch process involved casting bars at one location and transporting them to another location to be reheated and rolled into rod.

In the Westinghouse CMCR process, refined copper in the form of electrolytic cathode plates is melted in a modified cupola furnace. The molten copper is then transferred to a holding furnace, which serves as a buffer to maintain the exact flow rate needed for casting. It flows from there to a tundish, from which it is metered into a trough in the rim of a 6-foot rotating vertical wheel. A steel belt meets the wheel and closes off the top of the trough, forming a continuous moving mold as the wheel rotates. Water sprays cool both wheel and belt so that a solid 2¼- by 1½-inch bar emerges as the wheel and belt part company on the opposite side (Fig. 2). Rolls guide the bar up out of the casting wheel in an arc that is flattened into horizontal movement through a bar conditioner and into a 12-stand hot mill (Fig. 3). There the bar is rolled into continuous half-inch rod. At the end of the process, the rod is collected in baskets in 25,000-pound coils, each about 7 miles long (Fig. 4).

The CMCR process was developed by Westinghouse in conjunction with Southwire Company. Southwire made much of the equipment and created the basic process design; Westinghouse adapted it to production of rod for magnet wire, making several significant contributions that improved product quality, extended equipment life, and eliminated a pollution problem.

For example, to improve the quality of the cast bar before rolling, Westinghouse developed the bar conditioner and inserted

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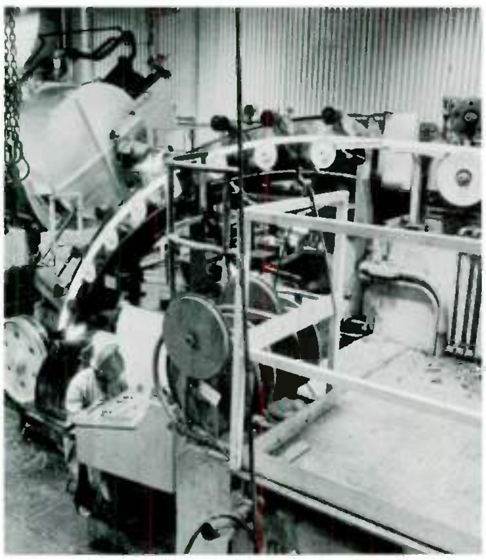

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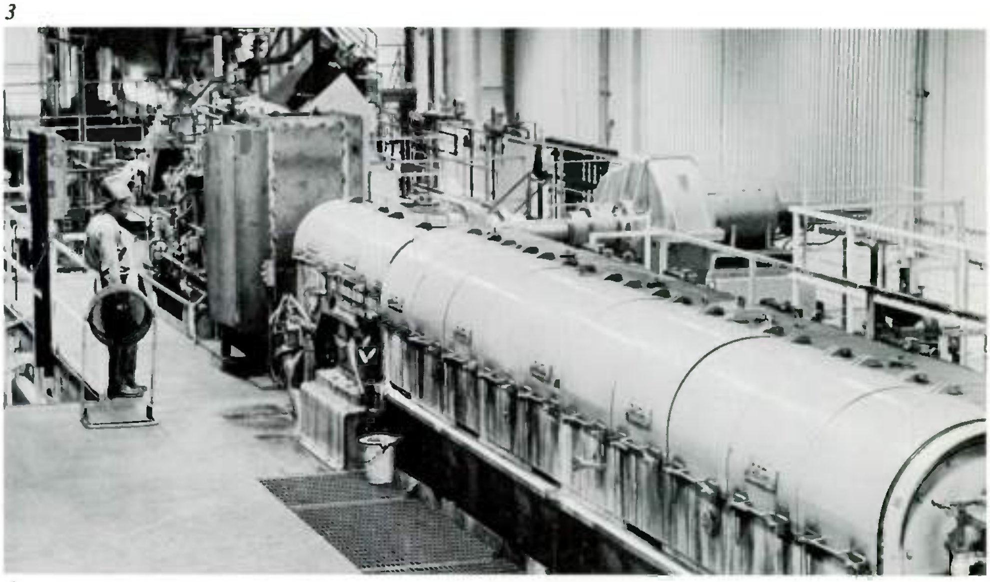

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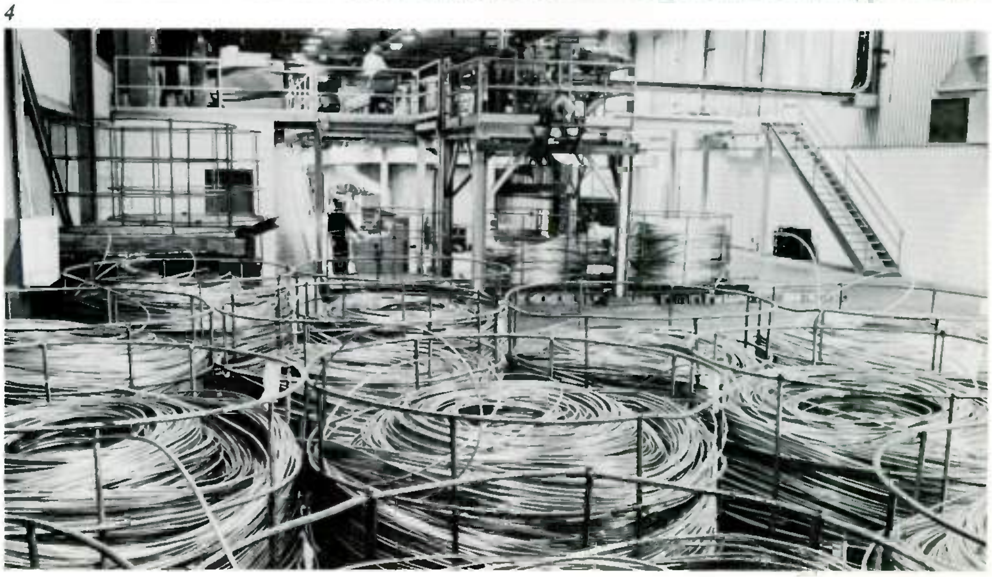


1—With its entire operation under one roof, the new wire plant has an orderly production flow from raw material to finished wire.

2—Copper to feed the CMCR (continuous melting, casting, and rolling) process is melted and metered into a trough in the rim of a casting wheel. The copper solidifies and emerges as the orange-hot bar seen arcing out of the wheel on its way to be rolled.

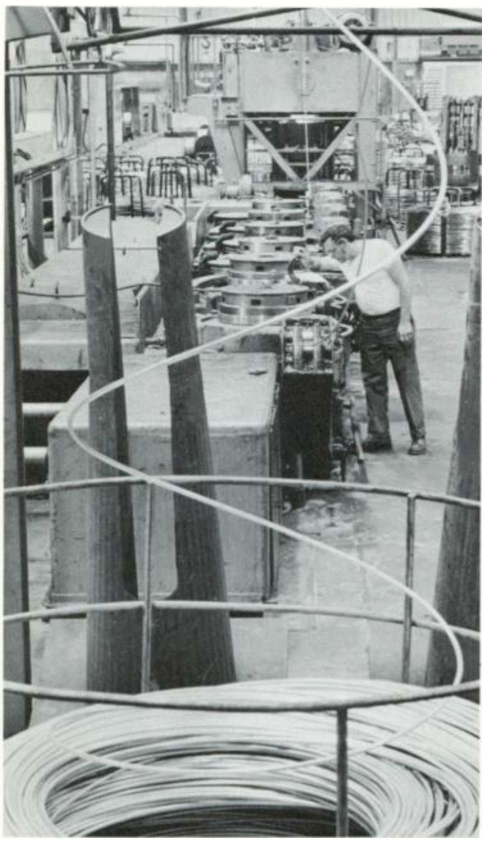
3—Now out of sight, the continuous copper bar moves through a bar conditioner (the rectangular structure) and into a 12-stand hot rolling mill to be rolled into rod.

4—At the end of the CMCR process, each of these baskets collects about 7 miles of continuous half-inch copper rod.

it in the process between the casting and rolling sections. The conditioner removes flash that forms on the bar where the belt meets the casting wheel, keeping the flash from being rolled onto the surface of the rod and perhaps later causing breaks in the wire insulation.

The potential pollution problem was from acid wastes in the standard pickling process used to remove scale and oxides from the cast bar. Westinghouse initiated development of a nonacid process that removes oxides continuously as the cast bar is cooled and rolled.

A dc electrical drive and control system was developed by the Westinghouse Industrial Systems Division. It is now used on most of the dozen continuous copper-casting systems currently in use around the world.



5—Shavers such as this one cut the skin off CMCR rod and perform a preliminary draw to prepare it for final wire drawing or rolling. Aluminum rod is also shaved and drawn.

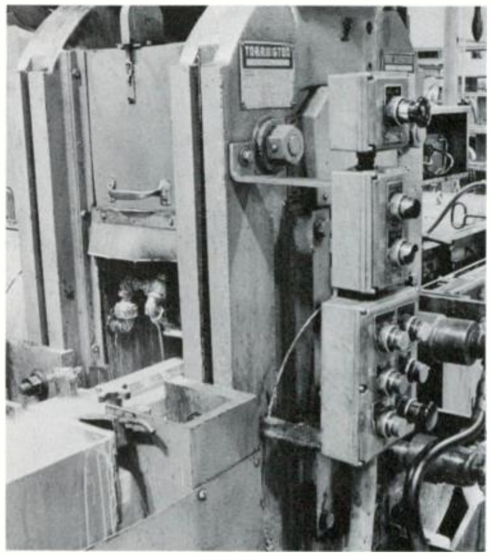
From the CMCR machine, fork-lift trucks move the baskets of rod to a shaver (Fig. 5). All of the plant's rod, both copper and aluminum, is shaved by running it through dies that cut off the skin to remove remaining oxides and any other surface imperfections. (The brittle oxides could cause the surface to flake and peel during drawing, leading to flaws in the enamel insulation coating.) The shaved rod is collected in 4000-pound coils.

Next, the rod is processed in one of 20 wire-drawing systems or in one of four cold-rolling mills that produce rectangular or square wire (Fig. 6). Annealing furnaces are used to soften the wire as necessary after shaving or between successive drafts in the drawing and rolling machines. Drawing dies are made in an in-house die shop to ensure good quality control and maintenance as well as quick reaction to special orders that require new dies.

Lubrication System

The passage of rod and wire at high speeds through the shaving, drawing, and rolling processes causes friction heat. This heat is minimized and removed by use of a cooling lubricant commonly called "lube-coolant." The lubricity also increases die life, the cooling inhibits heat-induced oxidation on the wire, and the flow of lube-coolant keeps the wire clean.

A relatively low-cost, low-fat, water-soluble oil is used for copper, but aluminum requires a more expensive oil-based lube-coolant to avoid galling of the wire and poor die life. The two types cannot be mixed, and yet all machines in the new plant were designed to process both aluminum and copper wire to allow complete



6—(Top) *This flattening mill is one of four mills used to produce rectangular and square wire.*

7—(Bottom) *Large wire sizes are being fed here into gas-heated recirculating enameling towers.*

production flexibility whatever the future demand levels for the two kinds of wire. Therefore, complete dual circulation systems were installed for all the wire processing equipment. Color coding of the pipe connections prevents errors in connecting the appropriate circulation system to a given machine.

The large quantity of lube-coolants required makes recycling essential, both to save on the cost of the lube-coolants and to avoid any waste disposal problem. However, before used lube-coolant is recycled back into the supply tanks for reuse, it is thoroughly purified by a filtration system. Filtration keeps the lube-coolants continuously clean and also reduces the need to dispose of them after use.

Insulating Processes

Five of the plant's large gas-heated recirculating enameling towers are devoted to the larger wire sizes (Fig. 7). In addition to the 14 large towers (Fig. 8), 50 smaller gas and electric towers process smaller wire sizes. For very fine wire, there are two high-speed enameling machines.

Not all of the plant's output is enamel insulated, for a considerable amount of magnet wire still requires fibrous coatings —glass-fiber, Glascron (a combination of dacron and glass fibers), cotton, or paper. Although those older coatings result in bulkier electrical equipment, they remain in demand for turbine generators and for equipment used in mines, quarries, aerospace vehicles, and other rugged applications where dust, abrasion, or moisture can sometimes cause problems with the thinner film insulations.

To keep fumes from the enameling process out of the atmosphere, a vent system delivers them to rooftop incineration equipment. The result is essentially 100-percent breakdown of waste gases, including high-temperature polymers.

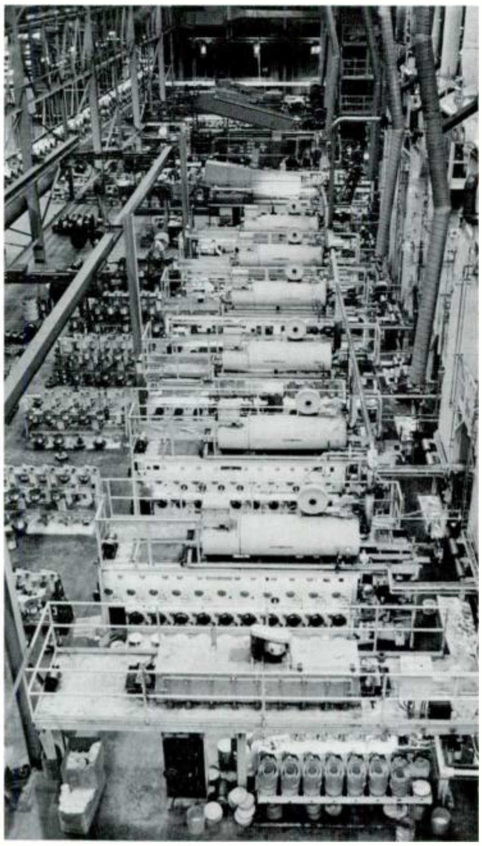
Finished reels of wire are stored and retrieved by a stacker crane system (Fig. 9). A smaller system is used for in-process storage of bare wire.

Order Entry

All orders are logged into a central Westinghouse computer by way of a terminal at the plant. Automatic printouts notify customers weekly of the status of their orders, and invoicing is also handled automatically. In addition, the computer data are used by the manufacturing and marketing departments to increase the efficiency of their operations.

This combination of modern technology in order handling, material handling, and manufacturing results in fast and efficient production of high-quality wire.

REFERENCE:
[1]R. E. Fromson and D. R. James, "Continuous Casting and Rolling Process Makes Superior Copper Rod for Wire Drawing," *Westinghouse ENGINEER*, May 1967, pp. 77-81.



8—The plant has 14 large gas-heated recirculating enameling towers such as those seen on the right, plus 50 smaller towers. A conveyor system for storing and circulating containers is visible at upper left. Dozens of reels of magnet wire feed simultaneously into the plant's many enameling towers.

9—Stacker cranes store and retrieve finished reels of wire. The blur in the center here is the crane cab moving quickly upward to retrieve a reel for shipment.

Technology in Progress

Improved Weapon Detector Reduces False Alarms

A weapon detector of an improved type is capable of making a rapid head to toe three-dimensional search of airline passengers, ignoring harmless metal objects such as buckles, keys, and cigarette lighters but signaling when a passenger is concealing a weapon. One hundred of the units have been built and installed at eight major airports under a contract from the Federal Aviation Administration to the Westinghouse Electronic Systems Support Division.

The new detector is an active device, which means that it sets up its own electromagnetic fields. In contrast, conventional magnetometers are passive devices; they sense disturbances in the earth's magnetic field caused by metal objects but are not selective enough to discriminate between a weapon and objects commonly carried on the person. False alarms mean inconvenience, longer waits for passengers, and increased screening costs for airlines.

The Westinghouse detector generates two electromagnetic fields at different frequencies, one high and one low, in three planes within a portal that passengers pass through. No matter where or how a weapon is carried, it is detected. The console of the detector has data processing circuitry that analyzes disturbances in the fields with a high degree of accuracy, providing the selectivity that cuts down on false alarms.

The Westinghouse detector and other units were extensively tested at Chicago's O'Hare International Airport and Washington's National Airport. Units are now in service at Houston, Denver, Kansas City, Seattle, Dallas, San Antonio, Minneapolis-St. Paul, and Dulles International Airport near Washington.

Weapon detectors at Dulles International Airport are of an improved walk-through type. The units are also in use at a number of other airports.

Medium AC Motors Designed for Especially Quiet Operation

A new line of especially quiet medium ac motors is alleviating one of today's major industrial problems—airborne noise. The Quiet-Line totally enclosed fan-cooled motors have sound levels from 5 to 12 dBA below those of standard industrial motors in general use. Although they range up to 200 hp in size, none produce more than 80 dBA sound pressure at 3 feet.

Permissible noise levels are included in the stringent regulations that now cover virtually every area of industrial safety and health. In simplified terms, the present regulations set a sound pressure level of 90 dBA as the maximum permissible noise exposure for a worker in a continuous 8-hour period. (The dBA is a unit of sound-wave power or pressure measured on the "A" scale, which is the scale that most closely approximates the frequency response of the human ear.)

Closeup view of the motor nameplate shows how sound pressure and sound power outputs are specified for each motor.

While the noise output of standard Westinghouse motors falls within the regulations, the new line provides a safety margin to increase the probability that overall noise level from a machine or at a particular factory location will be within acceptable limits. A motor itself is only one of many possible noise sources, and noises can reinforce each other; two sources, each below the 90-dBA limit, can combine to produce more than 90 dBA.

The Quiet-Line motors were developed by the Westinghouse Medium AC Motor and Gearing Division and the Research Laboratories. Both mechanical and aerodynamic noise factors were explored and tested. Among the steps taken were use of stronger parts to minimize vibration, selection of bearings, and changes in the contours of brackets and frame and in the size of fan intake and exhaust openings. Special attention was given to the size, shape, and placement of frame fins, and the blower was optimized in such key variables as diameter, blade shape, tip clearance, and number of blades.

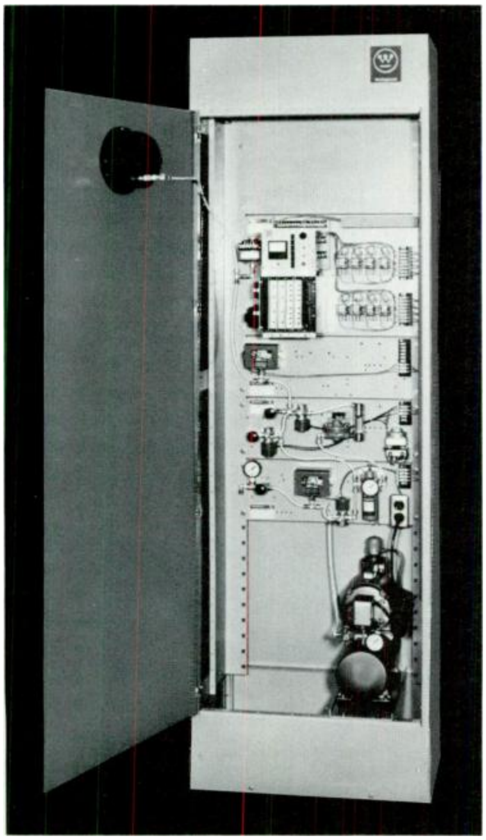
The motors are made in both the "T" and "U" combinations of rating and frame. All sizes can be had in explosion-proof enclosures.

Varaflow Director Controls Pumps for Waste and Water Plants

Waste and water treatment systems depend on reliable pumping, often at unattended locations and often with the requirement that several pumps operate either individually or together and in a range of speeds. To provide such reliability and flexibility, a pumping control system has been developed by the Westinghouse General Control Division.

The Varaflow Pump Director is a modular system of sensors, logic, and sequencing control designed to direct the operation of a complete pumping system. It controls pump sequence and speed according to a programmed schedule. Construction is modular to permit economical matching of features to specific applications.

In operation, the Varaflow Pump Director continuously monitors the liquid level of a "wet well" (see diagram). It provides output signals to motor controls, which are normally included as part of the total pumping system. Selection of the particular type of motor control depends on the economics of each application. For flexibility, the Varaflow Pump Director is designed to interface directly with a wide variety of speed controls including secondary resistor/reactor wound-rotor control, primary thyristor variable-voltage control for wound-rotor and high-slip squirrel-cage motors, and adjustable-frequency control for use with standard NEMA B motors.



In a typical system, liquid level in the wet well is monitored by a bubbler, which directs a constant air flow down a tube. The pressure required to force air down the tube is proportional to the level of the liquid, and a transducer converts it to a proportional dc electrical output. The user sets a zero-offset adjustment to make 0 volts output correspond to a specific pressure (water level) of his choice.

An on-off programmer converts the transducer signal to programmed digital signals to start and stop pumps, actuate alarms, or control other on/off functions. The programmer modules are solid state and arranged on plug-in cards; each has independent and adjustable pick-up and drop-out points.

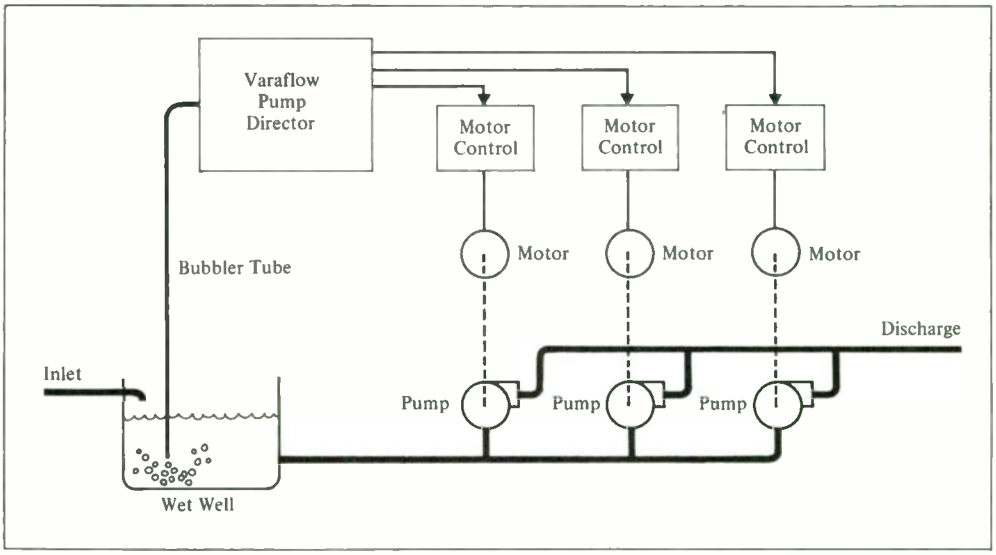
Solid-state speed programmers convert the pressure transducer signal to programmed dc command signals that direct each variable-speed pump control in the system. These modules are also on plug-in cards, and each has adjustable zero point and span over the entire pressure transducer range. Cards can be added to enable the director to control additional pumps if the system is expanded.

An alternator takes the signals from each speed programmer and each on-off programmer and directs them to the proper pump control according to the predetermined sequence. Optional modules provide for such functions as automatic insertion of standby pumps in the event of pump failure and sequence restarting after interruption of power.

Pressure switches can be provided to convert the pressure signal from the bubbler to digital signals for such uses as indicating wet-well level. Where pump speed control is not required, the pressure switches also provide on-off control for the pump motors. A metering and test panel provides for field adjustment and routine checking of the entire Pump Director.

Besides its uses in waste and water treatment systems, the Varaflow Pump Director can be used for liquid level control in industrial processes, constant-pressure water systems, or wherever multiple pumps are to be controlled in a coordinated system.

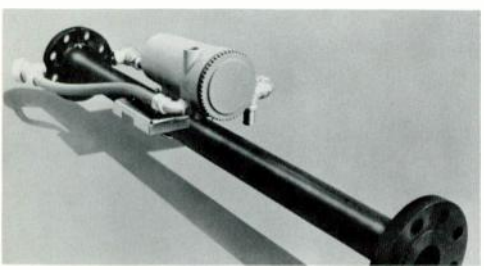
Varaflow Pump Director controls pumping systems of various types and sizes. For small simple installations, it can be housed in a wall-mounted cabinet instead of the floor type shown. The diagram illustrates the Pump Director's place in a typical pumping system.



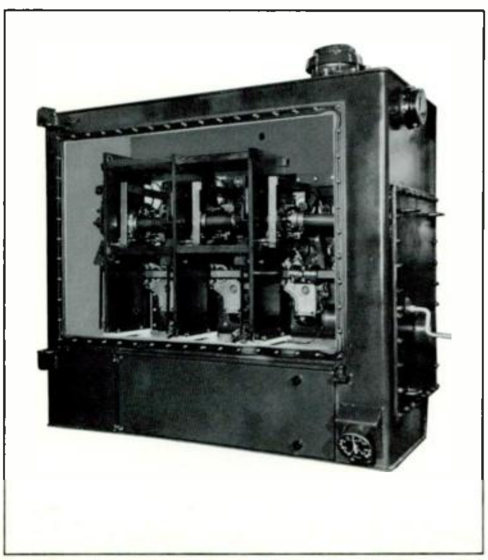
Products and Services

Servochrome ribbon indicator is a servo-powered display that is highly readable from close up or at a distance. Its vivid red and white ribbon gives precise readings for temperature, pressure, flow, or any other variable transmitted by dc signals. The ribbon is positioned by a high-torque subminiature motor. A multiturn feedback potentiometer and an integrated circuit amplifier provide high dc gain with the optimum frequency response needed to minimize overshoot. Scales are available in a variety of vertical or horizontal formats; special scales can be made to order. *Westinghouse Computer and Instrumentation Division, 200 Beta Drive, Pittsburgh, Pennsylvania 15238.*

Vortex ultrasonic flowmeter measures liquid flow and generates proportional signals (digital and analog) suitable for recording, totalizing, and/or control. Maximum flow velocity is 30 ft/s, which corresponds to flow rates of 80, 300, and 700 gal/min for 1-, 2-, and 3-inch meters respectively. Pressure and temperature rating are 550 psig at 350 degrees F. The meter is all solid state, has no moving parts, is inherently linear, and has a low permanent pressure loss. It operates on the principle of ultrasonic detection of vortex shedding. A cylindrical stainless-steel strut in the flow stream creates vortices downstream that modulate the amplitude of an ultrasonic signal beamed through the fluid. A solid-state amplifier-transmitter monitors the modulations and provides both a pulse frequency and an analog output (4 to 20 mA dc). Flow measurement is unaffected by variations in density, temperature, or conductivity of the fluid. *Westinghouse Computer and Instrumentation Division, P.O. Box 402, Orrville, Ohio 44667.*



Vortex Ultrasonic Flowmeter



Vacutap Load Tap Changer

Forced-cooling analysis computer program determines the effectiveness of various cooling methods for any new or existing installations of underground pipe-type cable. It decides how much heat can be removed by conduction from the cable pipe or return pipe and how much must be removed externally, and it also determines pressure drops and inlet and outlet temperature levels to facilitate specification of mechanical equipment. *Westinghouse Power Systems, Advanced Systems Technology, East Pittsburgh, Pennsylvania 15112.*

Vacutap load tap changers have been extended to cover current ratings of 1500 and 2000 amperes at 69 kV. The new ratings have heavier current-carrying parts than the earlier 1000-ampere type, and all mechanical parts are designed for heavy-duty service. Sight windows permit visual inspection of wear on interrupter contacts without removing the unit from service. Use of vacuum interrupters minimizes oil contamination and reduces maintenance since arcing occurs in a vacuum chamber instead of in oil. *Westinghouse Sharon Transformer Division, 469 Sharpsville Avenue, Sharon, Pennsylvania 16146.*

Tape reader economically extends the use of many computer systems to include translation capability for WR-1C, WR-2C, WR-4C, and similar recorder tapes. The WLT-28 tape reader performs pulse-counting functions and presents interrupt signals to the computer from the time interval circuit. Data transfer is made under program control from the computer and is initiated by a subroutine call from the interrupt signal. The tape reader is especially desirable when time is available on existing computer systems of adequate capacity to perform the translation function. *Westinghouse Meter Division, Box 9533, Raleigh, North Carolina 27603.*

"Westinghouse High Intensity Discharge Lamps," A-8452, is a brochure that gives technical information on lamps (mercury, metal halide, and Ceramalux), auxiliaries, and applications. Subjects covered include lamp construction, types, identification, performance, and spectral characteristics. A section on troubleshooting and maintenance gives possible trouble symptoms with their causes and corrections. *Westinghouse Fluorescent and Vapor Lamp Division, 1 Westinghouse Plaza, Bloomfield, New Jersey 07003.*

About the Authors

B. J. Krings joined Westinghouse on the graduate student training program after graduating from Penn State University in 1942 with a BSEE degree. His first work assignment was in design and development of transportation control at the former Transportation and Generator Division. In 1954, he moved to the Bettis Atomic Power Laboratory as an apparatus engineer in nuclear plant instrumentation and control. Krings transferred to the Plant Apparatus Department in 1959 as Supervisory Engineer of a group working on nuclear instrumentation and water-level control for steam generators. He then moved to the Research Laboratories to work in the Electric Power Systems group, mainly on development of thyristor circuits for elevators.

Krings has been in the Transportation Division since 1965. His first responsibility there was design and development of the propulsion and dynamic-braking equipment for the Metroliner rail cars. During the car design phase for the BART system in 1969 and 1970, Krings was the Systems Engineer for the car project and was responsible for the interfacing of all of the Westinghouse-supplied systems. He was also responsible for coordinating all of the interfaces with Rohr Corporation, the car builder. Since 1971, he has been attached to the Propulsion Sales activity as a Systems Engineer responsible for the technical content of proposals for all propulsion system negotiations.

Curtis L. Moore graduated from Purdue University with a BSEE in 1942, and he added an MSEE degree from the University of Pittsburgh in 1954. He earned a Business Management Certificate in 1957 from Pennsylvania State University.

Moore began his Westinghouse career on the graduate student training program in 1946, and he was soon doing design work on large core-form transformers and rectifier transformers at the Sharon Transformer Division. In 1956, he was appointed Supervisory Engineer in charge of long range major development of transformers. Since 1958, Moore has been Section Manager of various functions involving advanced development, computers, external development, and core-form development. He is currently Section Manager, Special Apparatus Development, where his responsibilities include transformer tanks, coolers, bushings, and accessories.

Included among Moore's engineering contributions are the pioneering of power transformer design with digital computers, development of gas-vapor transformers, application of aluminum for transformer windings, optimization of cooling and tank design, improved magnetic materials and core structures, and development of epoxy transformer bushings. He has five patents to his credit.

Edmund E. Woods received his formal education in England, where he earned the National Certificate in Mechanical, Marine, and Electrical Engineering at Gateshead Technical College. His early professional experience included service as Assistant Works Manager for the Bushing Company. After coming to the United States in 1962, he worked for Permali, Inc., where he became Manager of the Epoxy Resin Division.

Woods began work at Westinghouse in 1965 as a Materials Engineer for the Sharon Transformer Division. He was promoted the following year to Senior Materials Engineer, working on development of cast epoxy insulation, and to his current position as Manager, Solid Insulation Development Section, in 1968. He is responsible for new developments of all types of electrical insulation for use in power and distribution transformers. Woods has contributed to the development of epoxy resins for use in instrument transformers, high-voltage stress-controlled bushings, and high-voltage condenser bushings for use on power transformers.

Paul W. Martincic earned his BS degree in Aeronautical Engineering in 1954 at Pennsylvania State University. His first job was with Goodyear Aircraft Corporation, working on the design of aircraft radar equipment.

Martincic joined Westinghouse in 1956 at the Bettis Atomic Power Division, where he worked as a design engineer on the development of reactor cores for attack type and Polaris type nuclear submarines. He later worked for General American Transportation Company, in charge of a group responsible for setting up a computerized engineering design system. In 1966, he rejoined Westinghouse at the Sharon Transformer Division as a development engineer in the cast epoxy distribution transformer project.

He is currently a Senior Design Engineer in the Special Apparatus Development Section, responsible for projects such as designing bushings and other resin components for transformers and developing advanced resin casting molds and techniques. His past design contributions include high-voltage SIEF cast coils, equipment for winding foil coil transformers, and cast resin high-voltage condenser bushings.

Kenneth E. Wood is an Advisory Engineer in the Westinghouse Ocean Research and Engineering Center, Annapolis, Maryland. He graduated from Hendon Technical College, London, in 1951 and joined the British Aircraft Corporation, where he designed radar circuitry. His next assignment was as a project engineer for the design of a large analog computer to study aircraft flutter problems.

In late 1955, Wood joined the Westinghouse Defense and Space Center as an engineer in a computer group that designed an early transistorized missile radar control system. In 1961 he was appointed Supervisor of a group designing solid-state circuitry and memories for the AN/SPG59 ship radar. After a short assignment in an electro-optics group, he was transferred to the Oceanic Division to design acoustic transponder and tracking systems.

Wood was appointed to his present position in 1968 and is now concerned with the design of all phases of ocean electronic equipment, including the power and data transmission system over the mooring line of the National Data Buoy project and scan conversion systems to improve the viewing of data from underwater sensors. He currently has five patents and has six under file.

Fred W. Romig joined Westinghouse in 1970 as a sales engineer for the Speciality Electronics Division, where he was responsible for security systems training, market planning, and technical sales support for direct and distributor sales. He worked with such products as intrusion detectors, alarm consoles, and closed circuit television. He came on the job well prepared, since he had spent the previous four years as a protection systems sales engineer for Honeywell, Inc., working with fire and security alarms and with detection and transmission systems for large commercial and industrial complexes.

When responsibility for industrial and military security systems was transferred to the Electronic Systems Support Division, Romig transferred also. He is now a security consultant responsible for developing perimeter integrated security systems in the correctional/rehabilitation, industrial, and public utility fields, as described in his article in this issue.

Romig obtained a BS in Business Administration from Youngstown University while majoring in industrial merchandising. He has a liberal arts background from Bethany College.

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Copper rod is shaved before being drawn or rolled into magnet wire. (See page 58.) Shaving removes oxides and surface imperfections that could degrade the quality of the finished wire.