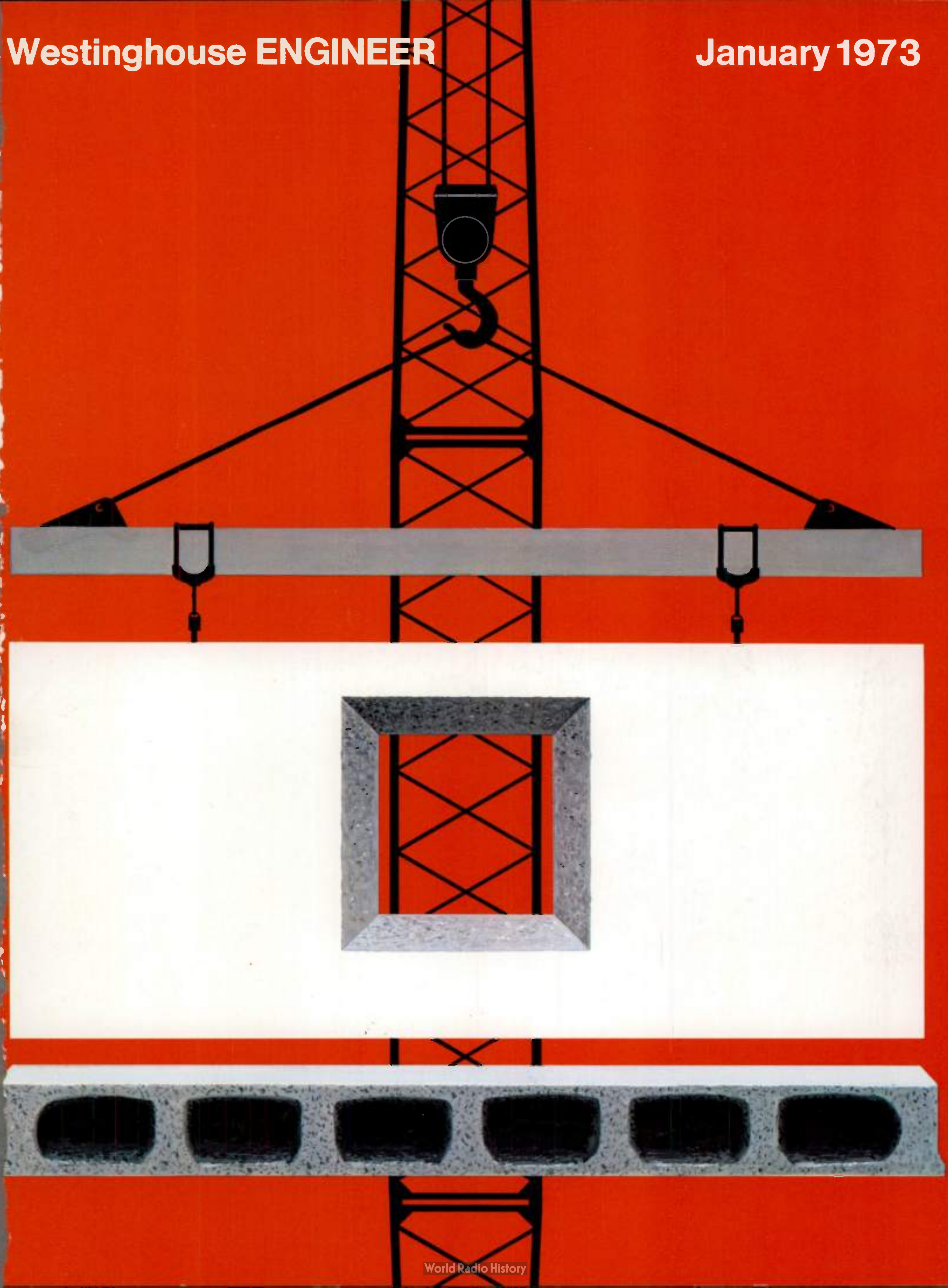
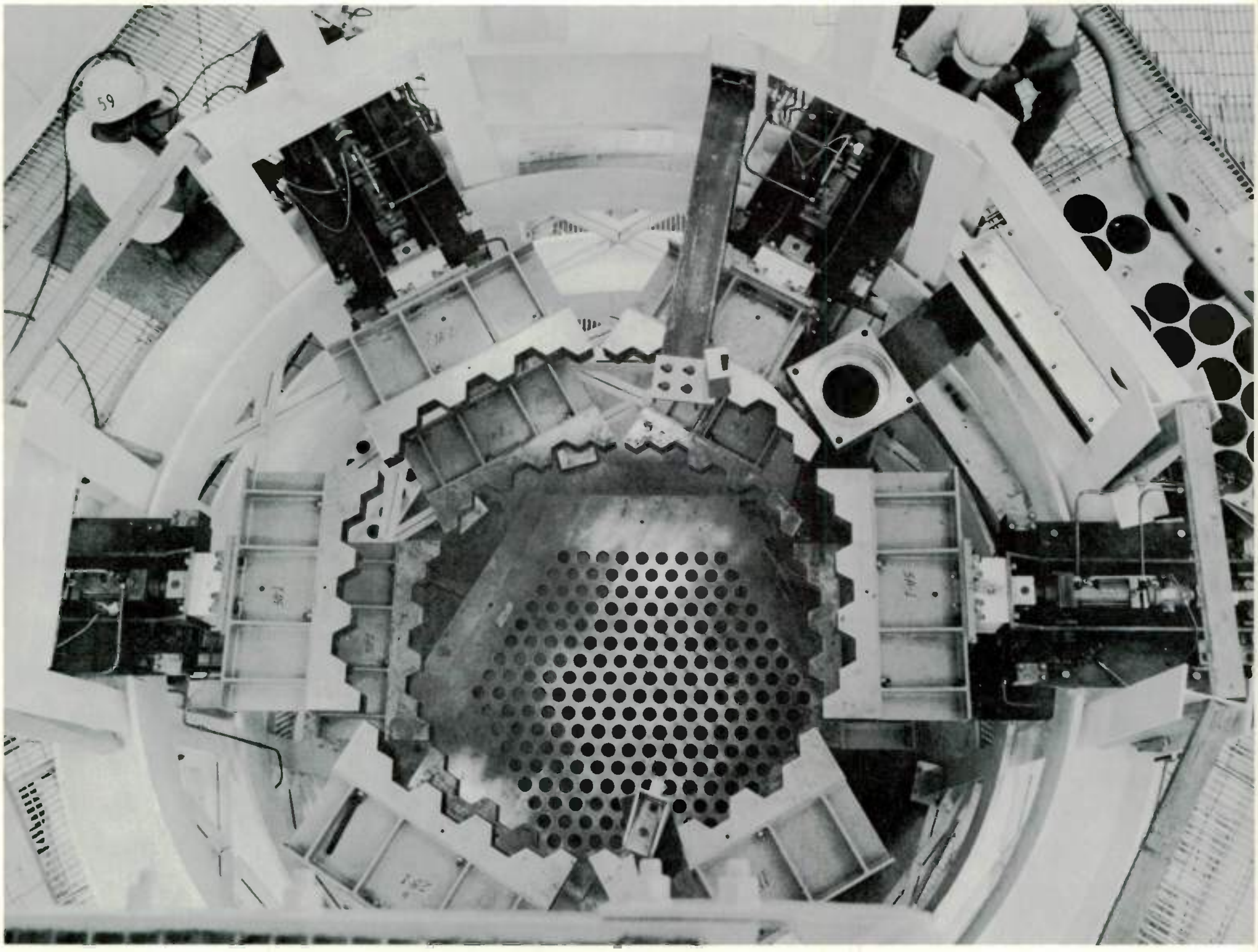
Westinghouse ENGINEER January 1973





Core Mechanical Mockup for FFTF

A full-scale core mechanical mockup for the Fast Flux Test Facility (FFTF) has been installed in the high-temperature sodium facility at the Hanford Engineering Development Laboratory. It will enable engineers to test operation of the in-vessel handling machine, insertion and removal of instrument trees, and methods of holding fuel bundles in the core region of the FFTF. Results of the tests will be applied in component design and engineering for the nation's liquid-metal fast breeder reactor programs. The Hanford Engineering Development Laboratory is operated by Westinghouse Hanford Company for the U. S. Atomic Energy Commission.

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Front Cover: Industrialized building systems using precast concrete components provide solid economic benefits for multistory residential construction. The Bison system manufactured by Blakeslee, the subject of this month's cover design by Tom Ruddy, is described in the article that begins on the following page.

Back Cover: Environmental monitoring equipment is being installed on the National Oceanic and Atmospheric Administration's first National Data Buoy, which was placed on station some 225 miles south of Gulfport, Mississippi, in mid-1972. The buoy transmits meteorological and oceanographic information automatically to a shore receiving station. Its environmental sensing equipment is described in the article that begins on page 18.

A Systems Approach to Multistory Residential Housing

Robert B. Curtis

Although multistory residential buildings have been constructed from precast concrete components for many years in Europe, this type of residential construction is just beginning to appear in the United States, stimulated primarily by its economic advantages. However, as the U.S. housing market becomes aware of the interesting shapes and finishes achievable with concrete, economic acceptance will be further strengthened by aesthetic acceptance.

The application of industrialized building systems to multistory residential construction provides three solid benefits—elimination of repetitive detail design, more economical mass-produced components, and reduced construction time.

Creative architecture and innovative housing concepts are possible with a flexible building system just as they are with the older construction methods, but the architect must work within a different framework of constraints. Rather than designing to accommodate the limitations of conventional structural materials, components, and connections—which are relatively standardized even for one-of-a-kind buildings—the architect plans with the modular flexibility of the building system. This approach can eliminate much of the repetitive detail design effort traditionally required for each and every building and permit the architect to concentrate on the more challenging problems of accommodating the needs of people.

The economic problems of housing can only be solved by reducing material and component costs and by improving the productivity of the construction process. So far as high-rise residential building is concerned, those benefits can be realized with industrialized building systems using precast concrete components. Concrete is readily available and relatively inexpensive. It is an excellent building material because it can be made strong, fireproof, and soundproof. Small field crews can erect high-rise buildings with a precast component system in less time than traditional building methods require, which reduces construction costs. Shorter erection time also contributes appreciable savings in interim financing cost because the overall on-site construction period can be significantly shortened. The Bison system as manufactured by Blakeslee demonstrates the achievment of those various benefits.

Bison plus Span-Deck

The Blakeslee precast concrete system is an Americanized version of the English-designed Bison building system, which is suitable for constructing buildings over 30 stories high. The Bison system was developed in England by Concrete Limited. Blakeslee is one of three United States firms licensed to manufacture and sell it. Although Bison buildings are just beginning to appear in the United States, the English firm has had more than a decade of experience in Great Britain, so the integrity of the system has already been well demonstrated.

Basically, a Bison building consists of prestressed concrete floor spans supported

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Robert B. Curtis is Vice President and General Manager, Prestress Division, C. W. Blakeslee & Sons, Inc. (a subsidiary of Westinghouse Electric Corporation), New Haven, Connecticut.

WATERBURY, Connecticut—Mall View Apartments, the Northeast's first Bison building, was completed in early 1972. It is a five-story 86-unit HUD turnkey housing development for the elderly. Using the Bison wall frame system, Blakeslee erected the basic structure of precast concrete components in just 7 weeks. Total time from groundbreaking to building dedication was 6 months.

BRIDGEPORT, Connecticut—Park Towers, a 10-story 109-unit apartment building, provides semi-luxury housing for its occupants. Along with many other advantages, the building developer chose the Blakeslee precast building system because it permitted him to deal with just one major subcontractor for the manufacture and erection of the basic building shell.

1—(Right) *A Blakeslee building is erected on a poured concrete foundation and ground slab. End and internal cross walls support floor slabs. Concrete facing panel walls to the front and rear elevations (and corridor walls if required on higher structures) provide lateral rigidity.*

by precast concrete end and interior cross walls (Fig. 1). Precast front and rear exterior walls (and when necessary, interior corridor walls) provide lateral rigidity. All walls are supported by the usual poured-concrete foundation.

The floor planks used by Blakeslee are Blakeslee Span-Deck units, originally developed to provide fireproof sound-resistant floors for office buildings, motels, apartments, schools, and parking garages. They have been adapted for use with the Bison wall frame system.

Planning Grid

The basic modular grid to which a Bison floor plan must conform is set by floor plank dimensions. A plank's width can be either 4 or 8 feet, and its prestressed construction permits it to span distances up to 39 feet. Since the Bison wall framing system is designed to adapt to one-foot intervals in span length, floor plank lengths can be any desired whole-foot multiple up to the maximum 39-foot span. These dimensional requirements establish the basic one-foot by four-foot grid for floor areas (bays) between supporting walls.

For interior planning, the architect works with overall bay dimensions. Since maximum Span-Deck plank span is 39 feet, each bay can have any whole-foot width up to 39 feet and any depth that is a multiple of four feet. Interior room-dividing walls within a bay are not load-bearing, so they can be any form of usual construction. Nailing inserts can be cast in the concrete wall panels so that field attachments can be made to accommodate the other trade's interior walls. The excellent dimensional accuracy of precast components makes it possible to prefabricate and field assemble to precise tolerances.

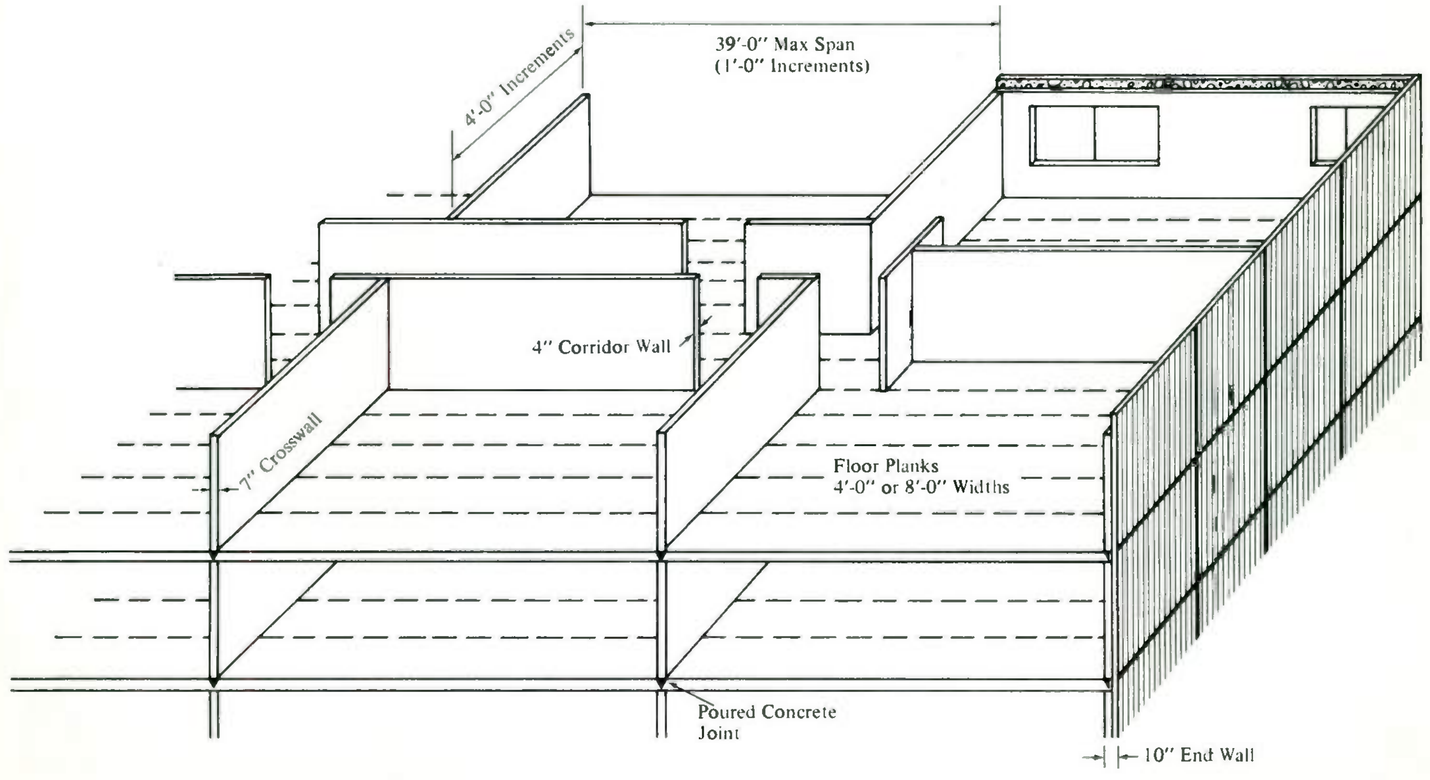
Building System Components

Although the architect designs within the one-by-four-foot grid and to certain other component dimensions, he has considerable freedom to develop a building of unique layout and appearance. The Bison system provides this design flexibility because wall-panel casting is set up for each building so that panel layout can conform to the architect's design. The following are the major precast components of the system and their dimensional constraints.

Exterior Wall Panels—All exterior wall panels are of sandwich construction—an inside 5-inch layer of structural concrete (load bearing), a 1-inch layer of rigid insulation, and a 4-inch exterior facing layer of concrete. The sandwich is held together with stainless steel shear connectors. Window frames (unglazed), window subframes, sill frames, and openings for air-conditioning sleeves are cast in the panels at the factory. Exterior caulking around cast-in frames and sleeves is also done during panel manufacture.

The standard external finish can be any workable combination of exposed aggregate, formed vertical rib, split vertical rib, or flat finish. In addition, other architectural finishes can be developed but they require coordination between Blakeslee and the architect so that costs can be established.

The method of fastening and waterproofing joints between exterior wall panels



is indicated in Fig. 2. The poured-in-place fastening system and the joint waterproofing technique have evolved from extensive experience with the Bison Wall Frame System in Great Britain.

Exterior wall panels are 9 feet 1 inch high. End (load-bearing) wall panels can by any length up to 20 feet; front and rear (non-load-bearing) wall panels can be any length up to 24 feet.

Balconies and their supporting walls can be precast to the architect's specifications in accordance with the building system's dimensional requirements and standard connection details. Parapet panels for railings around balconies and roofs are also solid cast concrete, with an exterior finish to match or complement other exterior wall panel finishes.

Interior Wall Panels—Interior panels for load-bearing cross walls are of solid precast concrete, 7 inches thick. Connection details for fastening load-bearing crosswalls to exterior walls and to floor planks are illustrated in Fig. 3. After structurally connecting the wall and floor components with poured-on-site concrete, the interior wall surfaces of both exterior and interior panels are ready for painting with textured paint. Interior cross-wall panels are 8 feet high and can be manufactured in any length up to 32 feet.

A 4-inch-thick interior panel can be provided for constructing corridor walls. Precast concrete corridor walls are used primarily in higher buildings where wind loading is greater and additional lateral rigidity is required.

Stairwell wall panels and elevator-shaft wall panels are precast concrete, usually 7 inches thick. Stairs and landings are also precast concrete units and include a nonskid stair nosing. Elevator machine-room wall panels and floor and roof planks are precast concrete.

Large openings (40 square inches or more) in any of the various interior wall panels are usually cast during panel manufacture.

Span-Deck Floor Plank—Floors and roofs of Bison buildings are built of hollow-

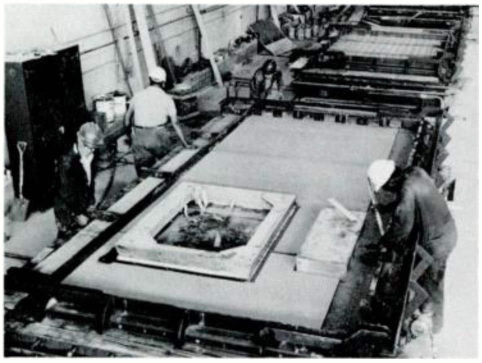
The Story of a Blakeslee Building

Construction of a factory-made building begins with the manufacture of Bison wall panels. The various exterior panels (A) are manufactured in hydraulically operated tilt tables. After the exterior layer of concrete is poured, insulation panels and window subframe are placed in the wall-panel mold and the interior layer of concrete is poured and finished. The 7-inch solid concrete interior wall panels (B) are manufactured in vertical battery molds, in which steel reinforcing and blockouts have been placed prior to pouring.

Hollow-core Span-Deck flooring (C) is cast in 500-foot-long beds and cut to module length. The various precast components are stored at the plant for curing (D) and are trucked to the site as needed.

Building erection begins (E) on a poured foundation. Wall panels are placed, leveled, and secured with poured-in-place concrete joints between panels. Erection proceeds floor-by-floor as panels are lifted into place by crane. As building erection proceeds, window openings are glazed so that interior work can proceed a few floors below the erection level.

This building in Providence, Rhode Island, (F) was erected in only 5 months by use of the Blakeslee industrialized system. If older construction methods had been used, erection would have taken another 3 months, and erection costs would have been at least 10 percent greater.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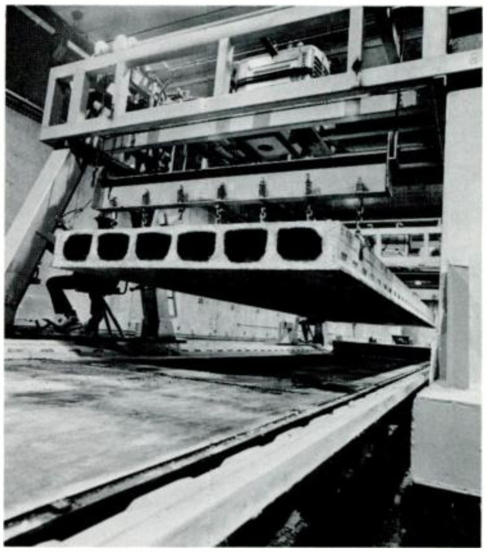
C



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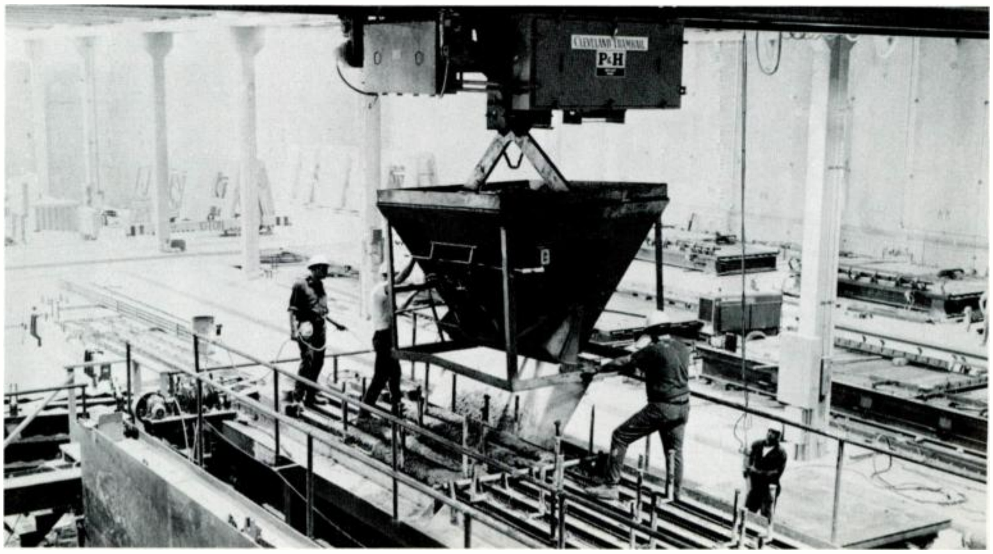


cored prestressed concrete plank, 4 or 8 feet wide and 12 inches thick. Span-Deck plank is continuously cast and cut to the desired whole-foot-length module. When installed, the top surface is sufficiently flat that pad and carpet can be applied directly to the concrete. Tile or other flooring material requires additional floor preparaation. The underside of the plank is the ceiling for the room below, and it accepts textured paint with no surface preparation other than caulking and pointing.

Blockouts in floor and roof plank for mechanical or plumbing chases can be cast during manufacture if the opening has an area of at least 120 square inches and a minimum dimension of 10 inches. Smaller openings are most economically drilled after the plank is in place.

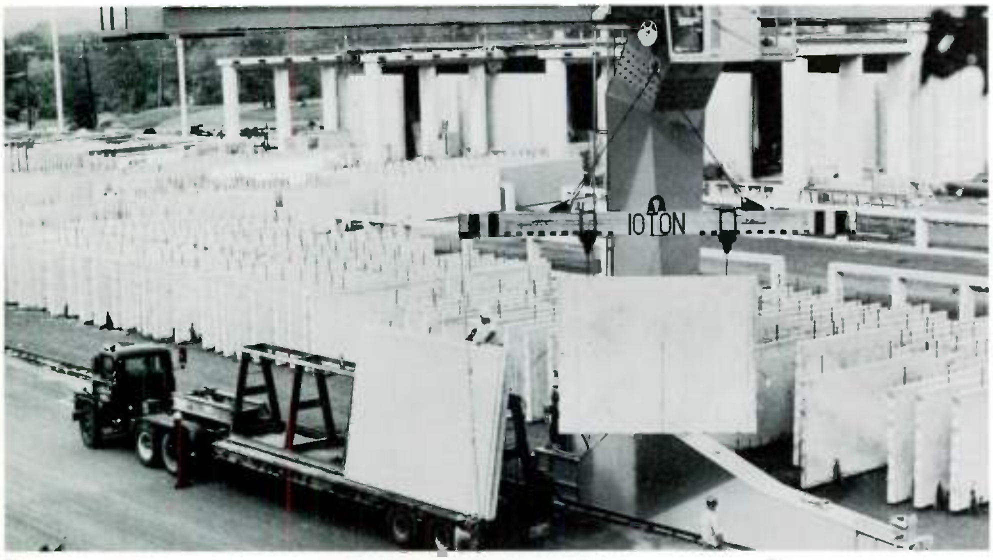
Building Erection

One of the major advantages of a precast building system is the speed with which the structure can be put together. All the various precast components—outside and inside walls, stairways, floor planks, etc.—are accumulated and cured at the factory so that, once erection begins, components can be trucked to the building site as required with no delays.

Erection begins on a poured concrete foundation, which is built to the configuration defined by the wall layout. With a precast component system, accuracy in squareness and elevation of the building foundation is extremely critical. The Bison system allows a tolerance of ±½ inch in building squareness measured across diagonals, and a tolerance of ±½ inch per 100 feet in overall length or width. All load-bearing surfaces must be on a true line and level within ±⅛ inch in 4 feet of length. The first floor is normally cast on grade, and it is poured prior to the start of wall erection.

Building erection is done by a Blakeslee crew, using appropriate cranes to accommodate building height. No scaffolding is required. As each floor is completed, other building materials such as windows, doors, baths, fixtures, cabinets, partitions, or other

D



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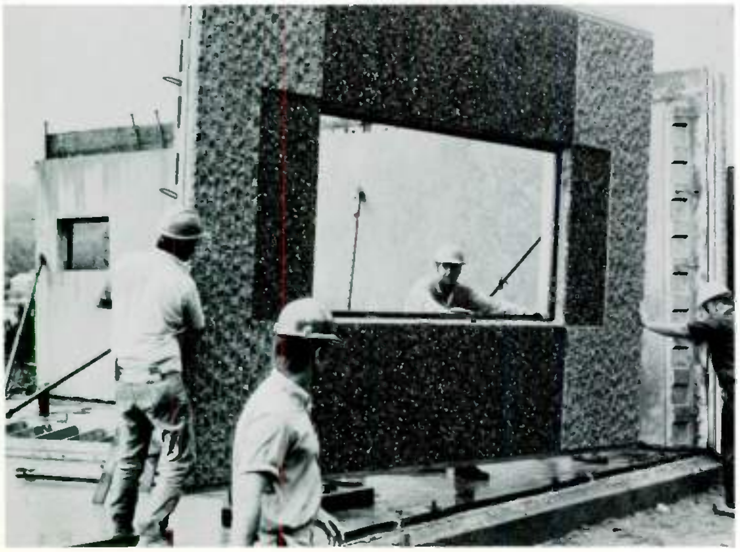

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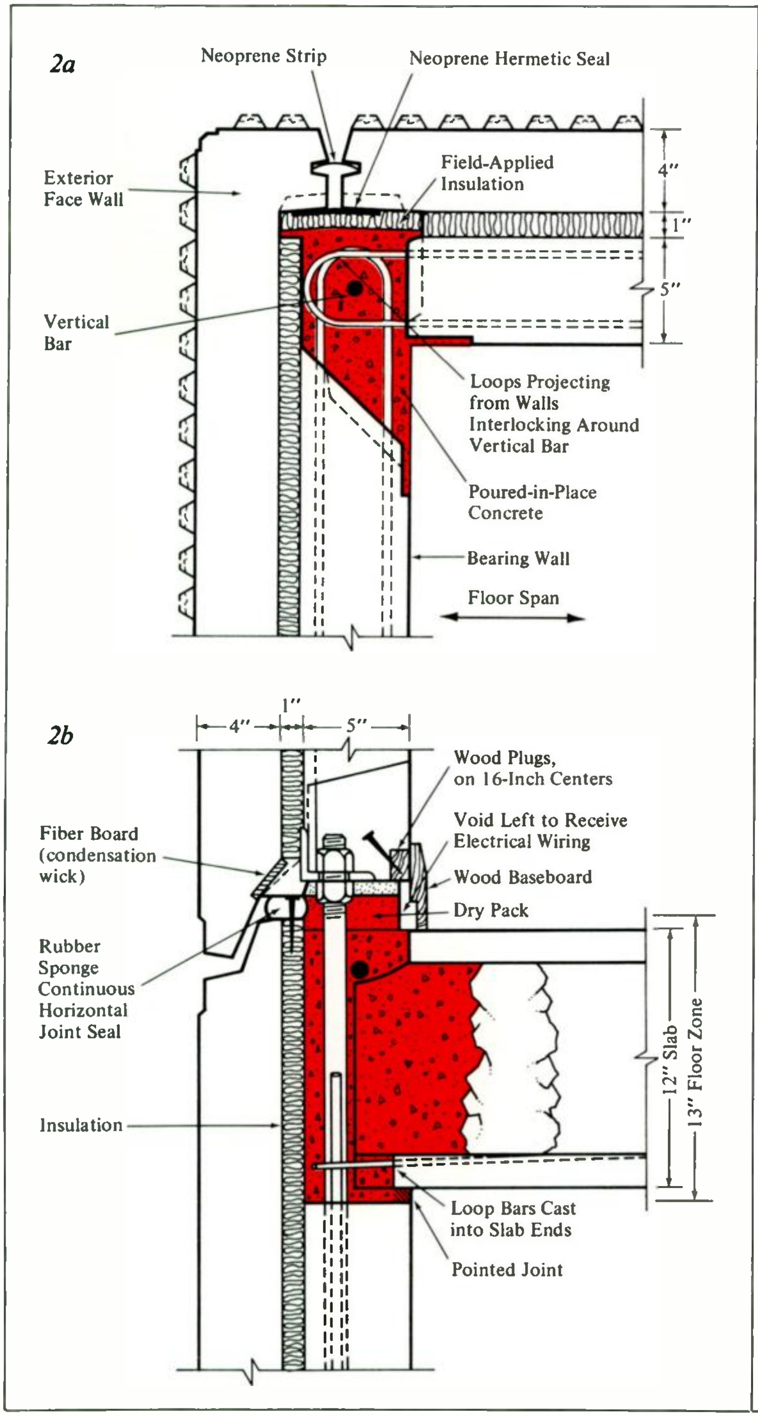
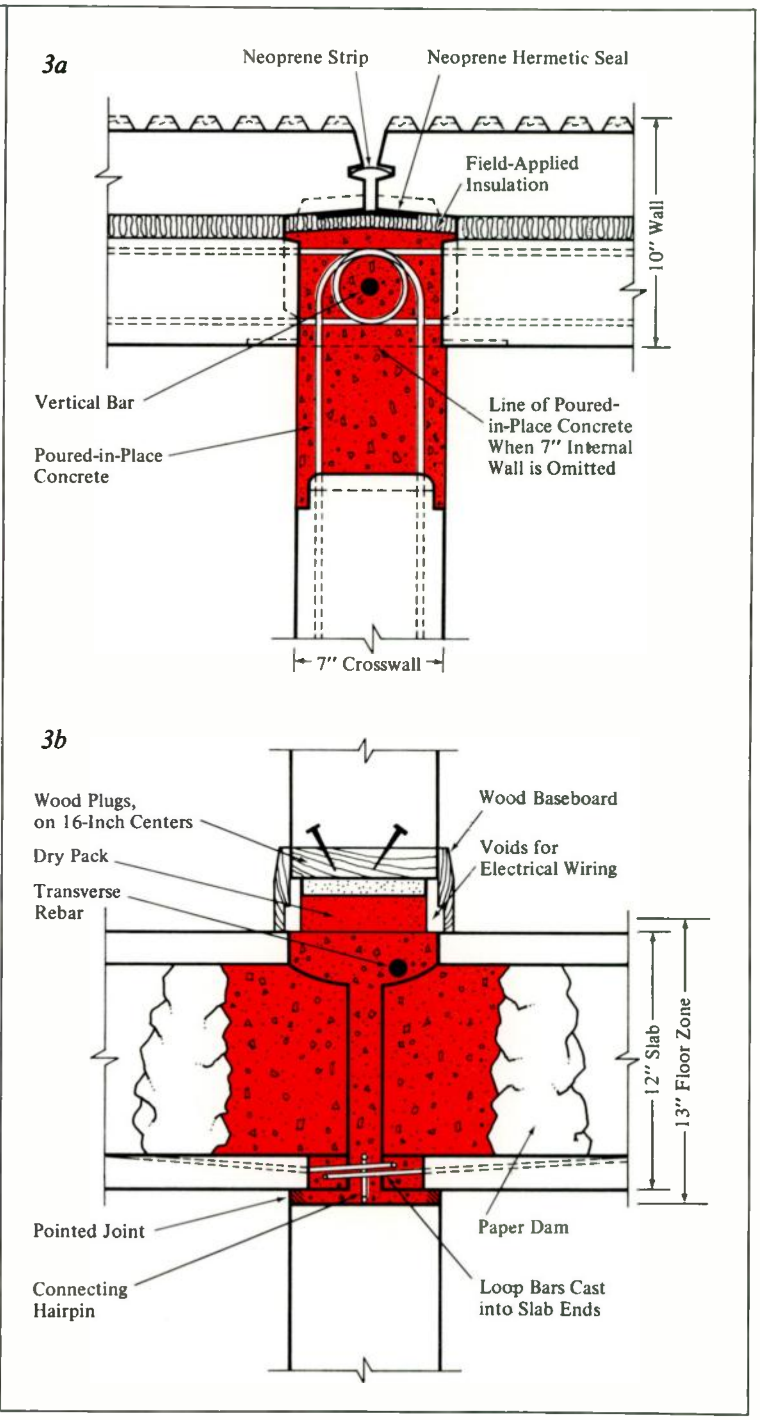


2—The joints between exterior panels are poured-in-place concrete. Looped projecting steel from wall panels interlock around vertical reinforcing bar. Neoprene strips are fastened to the back of the exterior vertical joint with adhesive, and the joint is filled with concrete. A corner joint between exterior bearing and non-bearing walls (a) *illustrates the connection detail in plan view. A section view* (b) *illustrates the method of fastening floor slabs to load-bearing exterior end walls.*



3—Plan view of vertical joint (a) *between interior and exterior walls shows waterproofing and connection detail; section view* (b) *illustrates the method of fastening floor planks to interior load-bearing walls.*

prefabricated components can be lifted into place.

Windows are glazed from the inside on each floor after the walls are erected, and other openings without windows are protected against the weather. Temporary heat is usually applied to help the building dry as quickly as possible and to permit other inside finishing work to proceed with minimum delay. Since the Blakeslee building system permits each floor to be enclosed as the building rises, much inside work can be accomplished as the building is being erected.

Speed of erection is such that completion time is much less than required by older building methods, and the problems of drying out are mostly removed. For example, only six months after ground was broken for an 85-unit housing project for the elderly in Waterbury, Connecticut, the building was occupied.

Future for Concrete Residential Buildings

The economic advantages of precast concrete building systems—elimination of detail design, more economical components, and reduced construction time—stimulated introduction of the Bison system to the United States. In only one year, Blakeslee has demonstrated those advantages for high-rise residential buildings.

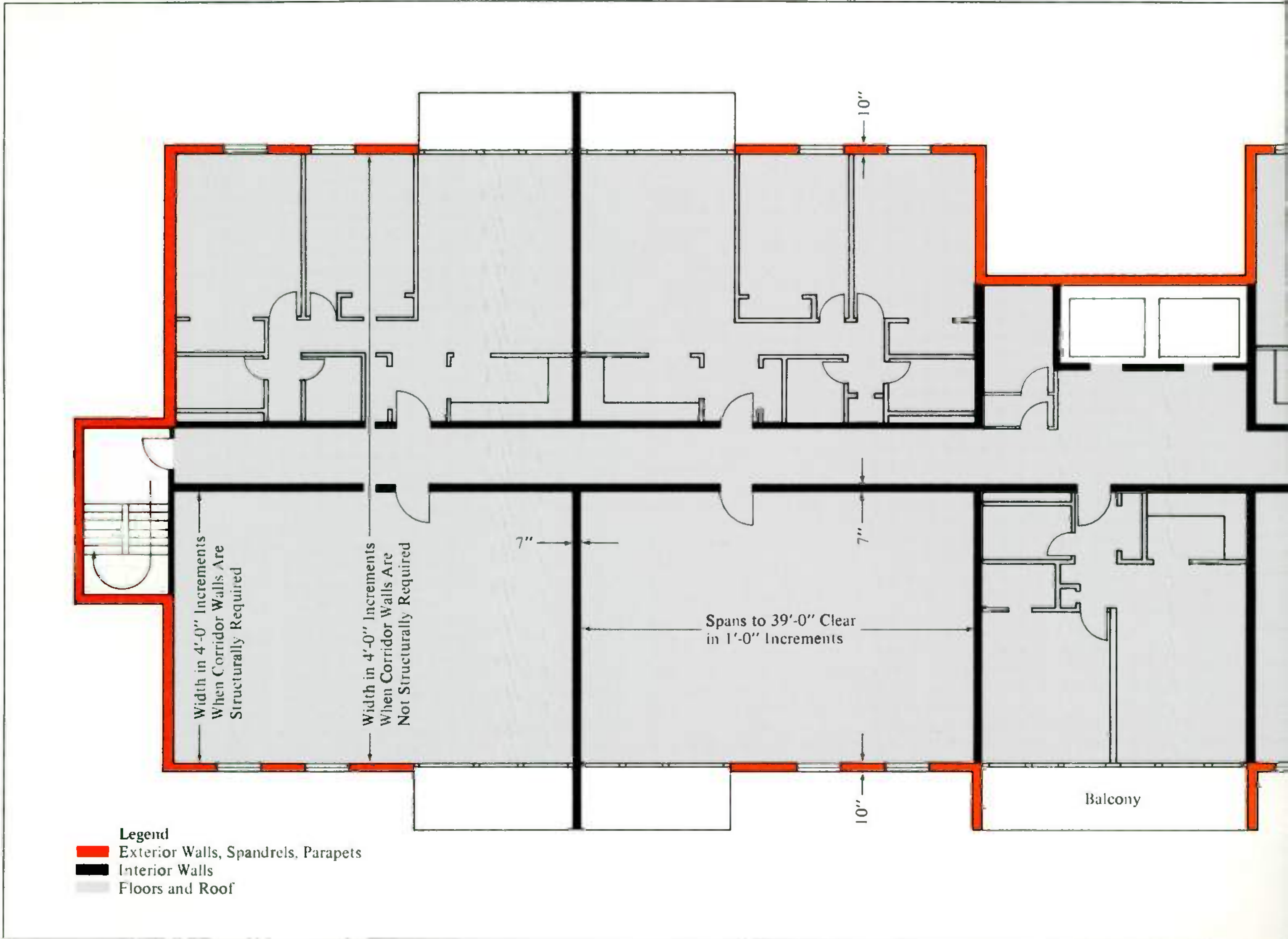
As architects gain familiarity with the building system concept and its potential, another advantage assumes major proportions—a precast concrete building need not look like the usual brick-and-mortar residential structure. Rather, the variety of finishes and structural shapes that can be so economically achieved with precast concrete is beginning to be appreciated and applied. Precast concrete construction has been used for commercial and industrial

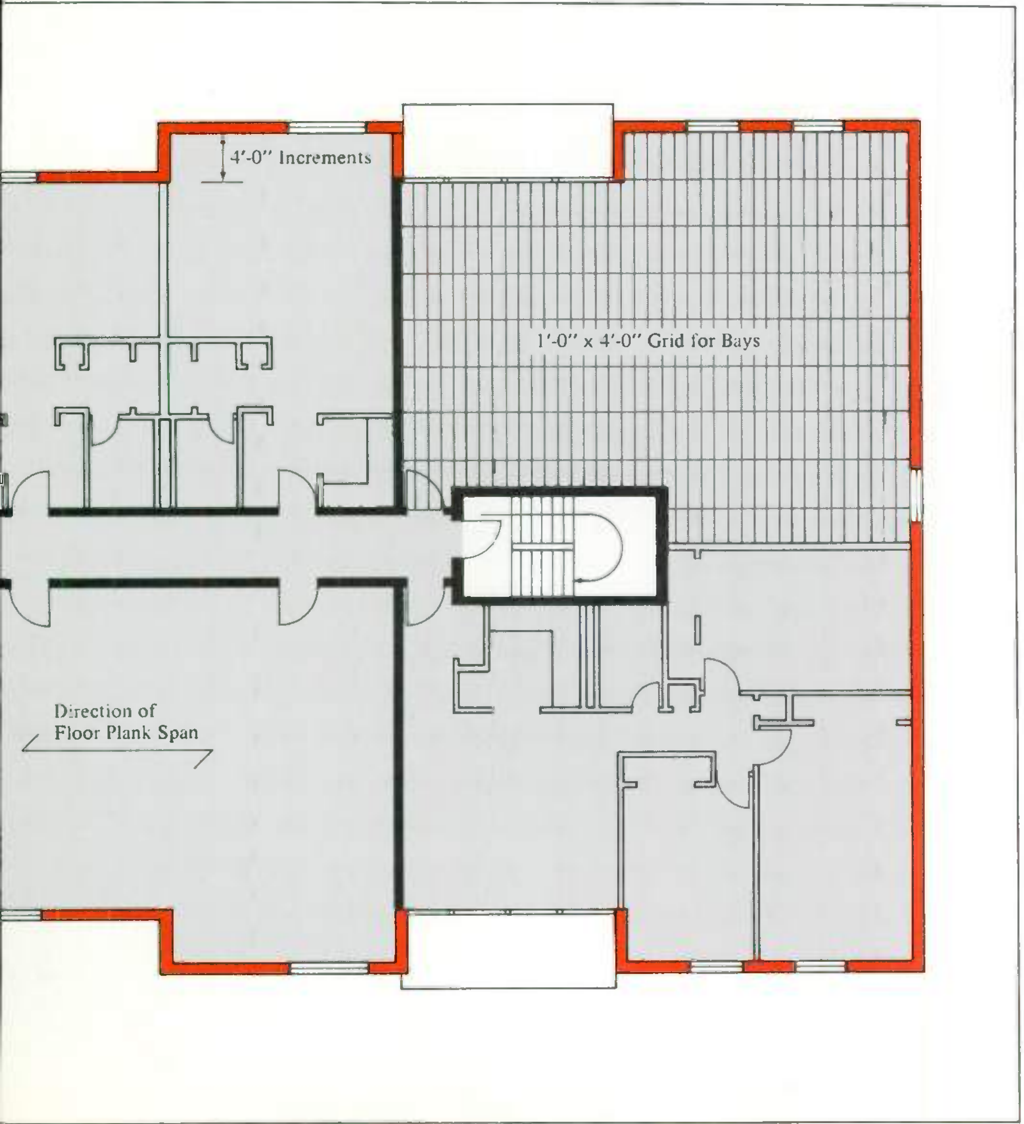
PROVIDENCE, Rhode Island—One of two 16-story Bison buildings for elderly housing is shown during erection. The photograph illustrates the floor-by-floor assembly of a Bison building, which permits interior work to proceed a few floors below the erection level.

VERNON, Connecticut—(Left) *The shell for this six-story 85-unit apartment building was completed in 6 weeks. The precast concrete components were manufactured at Blakeslee's Branford, Connecticut, plant, trucked to the site, and erected with an 85-ton crane. The building contains 181 exterior wall panels, 103 interior wall panels, 11 precast concrete stairways, and 194 precast prestressed concrete floor planks.*

WESTFIELD, Massachusetts—(Right) *Women's dormitory at Westfield State College is a three- and four-floor Bison building. The precast concrete building system is ideal for this type of low-rise housing where a fireproof structure is mandatory.*

4—(Below) *Bay areas between supporting walls conform to a 1 by 4 foot modular grid. Since the complete bay is self supporting, the area can be divided into a variety of room arrangements.*





buildings in the United States for many years, and its aesthetic benefits for those types of structures have already been well demonstrated. Now, its flexibility for architectural design of residential buildings is gaining that same acceptance.

Although the precast concrete building system is primarily associated with high-rise residential construction, its major advantage of being fireproof also qualifies it for certain types of low-rise structures, such as townhouses and motels, where lower-cost building methods have dominated the market in the past. Now, as building codes are requiring these types of residential structures to be safer for their occupants, fireproof construction becomes a basic consideration.

Blakeslee marketing studies have indicated that the need for multistory residential construction in the United States—which includes public housing programs and FHA-insured programs, conventional and luxury apartment buildings, institutional and university buildings, dormitories, and low-rise structures such as garden apartments, townhouses, and motels—should create a $25-billion market by 1980. The economic advantages of building with mass-produced concrete components should give those industrialized building systems 70 percent of that market.

Plant-Growth Lamp Improved in Efficiency

Richard Corth

Research on the light requirements of growing plants has resulted in development of a fluorescent lamp that meets those requirements more efficiently than others have.

Although sunlight sustains nearly all of the world's green plant life, it is an inefficient light source for plant growth because most of the energy in it is unusable by plants and thus is "wasted." Efficiency is not important when the energy is free, as it is in sunlight, but it is important when plants are grown under supplemental or total artificial illumination. And plants are increasingly grown that way—in ornamental plantings for commercial buildings, by home and commercial flower growers, by commercial seedling producers, and by vegetable growers.

The results achieved in growing plants under artificial illumination have been limited by the available lamps, whose spectral power distributions (mix and intensity of output wavelengths) are usually designed for human vision rather than for plant growth. Like sunlight, the light from ordinary lamps has much radiation that plants do not use; it is therefore inefficient and, since it is not free, it is not as economical as it could be

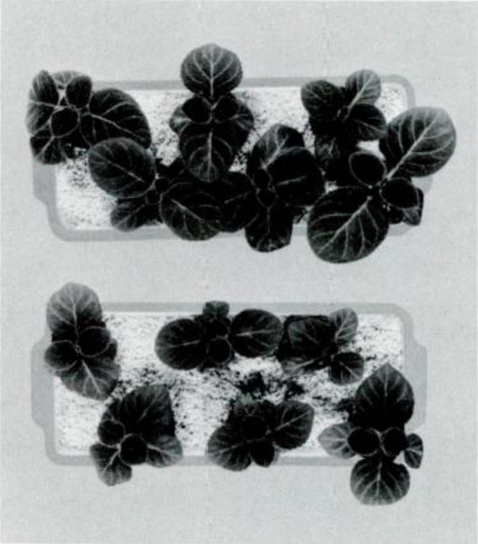
A research program conducted by North Carolina State University has produced much new information about spectral requirements for plant growth. The Westinghouse Fluorescent and Vapor Lamp Division provided special lamps for the program, and it used some of the results to design a new fluorescent lamp that produces plant growth more efficiently than any other light sources tested for comparison.

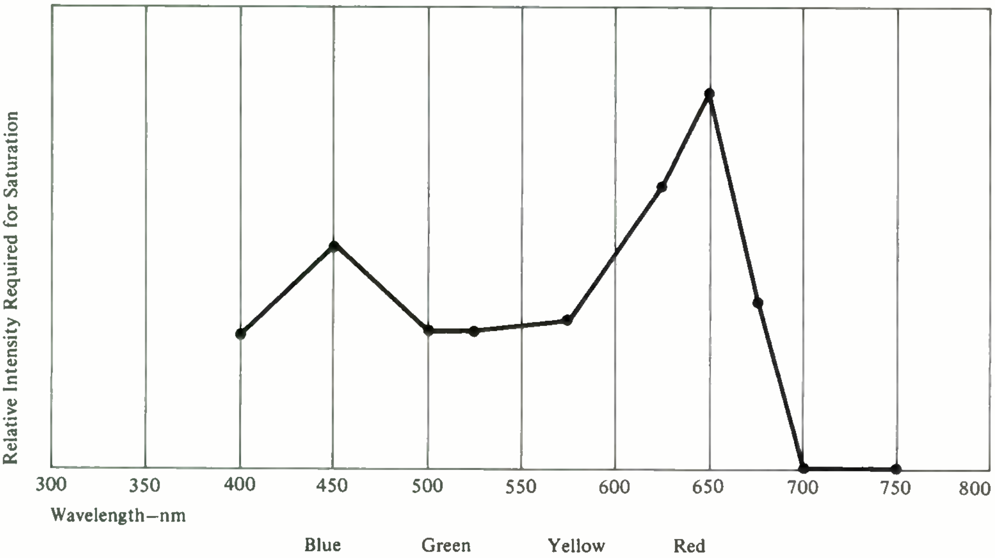
Light and Growth

Since most plants appear green, they obviously reflect some of the energy in the central part of the visible spectrum instead of absorbing it, so an artificial light rich in that part of the spectrum should be inefficient for plant growth. Earlier studies confirmed that surmise and showed that a combination of blue and red light is most efficient for photosynthesis.

Cool White fluorescent lamps plus incandescent lamps have been widely used for plant growth because the Cool White lamp has a fairly good range of wavelengths except for the needed red and far-red radiation, and the incandescent light is rich in those wavelengths. The logical next step was to design fluorescent lamps that would deliver sufficient energy in all those regions of the spectrum to eliminate the need for incandescent lamps, which expend much of their energy in the useless infrared region and also are shorter lived than fluorescent lamps. Such lamps were developed, but results with them have been disappointing.

The recent studies were undertaken to learn more about the optimum mix and intensities of wavelengths for plant growth.[1] The plants used were radish, lettuce, and milo (a grain plant). Seedlings were placed in controlled-environment rooms, which all had an equal base level of illumination by Cool White fluorescent lamps. That lighting was supplemented by a series of special lamps producing spectral bands covering the region from 350 to 750 nanometers (nm). The intensity of illumination from each special lamp was increased in steps until the saturation point was reached, as indicated by production of plant material (weighed dry) in lettuce and radish. (The saturation point is the light level at





1—(Left) *The effects of various light mixes on plant growth were studied by weighing radish and lettuce plants grown under supplemental lighting with a number of wavelengths and intensities. This curve shows the relative intensities that produced maximum growth ("saturation") at various wavelengths.*

2—(Right) *The plant-growth studies were used to design a new fluorescent lamp with this spectral power distribution (which approximates the curve of Fig. 1). Comparisons have shown the lamp (called the Agro-Lite lamp) to be more effective than other lamps or combinations of lamps.*

Photo—In one comparison test, gloxinia grew faster under the Agro-Lite lamp than it did under the plant-growth lamp that has heretofore been most widely used. The gloxinia also produced more blossoms under the Agro-Lite lamp.

Richard Corth is a Senior Engineer in the Fluorescent and Vapor Lamp Division, Westinghouse Electric Corporation, Bloomfield, New Jersey.

which further increase in intensity produces no increase in plant growth.)

The dry-weight yield data produced the "action spectrum" of Fig. 1, which shows the relative intensities required for saturation in various regions of the spectrum. It confirms that plants use light for photosynthesis in broad areas in the blue, red, and (to a lesser extent) yellow-green regions.

Red light from 625 nm to 675 nm required the highest levels for saturation and produced the greatest amount of dry weight per watt of input. However, red and far-red from 700 to 750 nm did not appear to affect dry-weight production.

Elongation appeared to be controlled by the blue-to-red ratio. The amount of blue necessary was determined not by photosynthetic production alone but also by the effect on the hormone control of plant growth. Blue control of growth is believed to be the result of the complexing or destruction of the growth hormone indoleacetic acid (auxin), the chemical that promotes cell elongation. The proper ratio for maximum dry-weight yield and good plant conformation appears to be three watts of blue peaking at 450 nm to five of red at 660 nm.

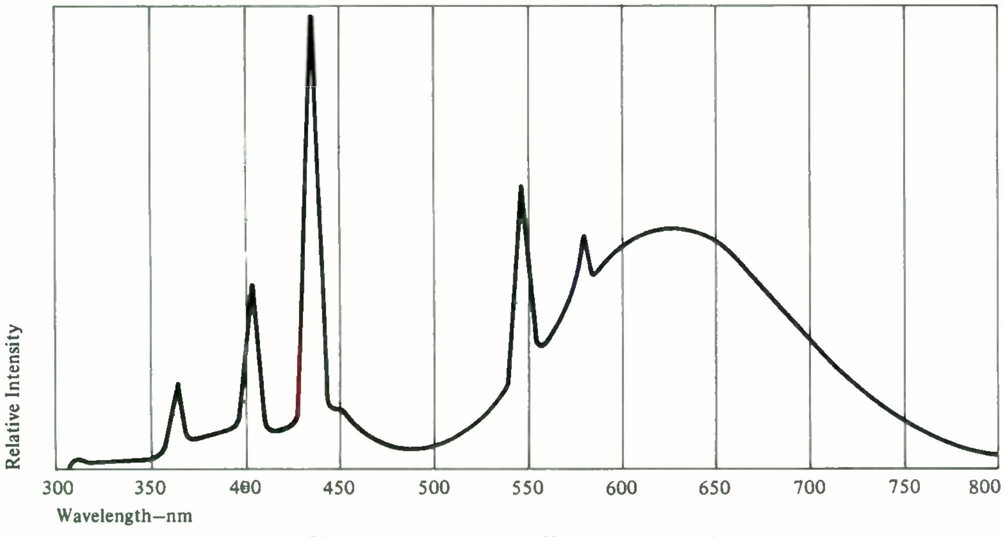
Lamp Development

An experimental fluorescent lamp was fabricated whose spectral power distribution approximated the curve of Fig. 1. It was employed in further plant growth studies, and the results were used to design an improved lamp whose spectral power distribution is shown in Fig. 2. That lamp, named the Agro-Lite lamp, was then compared for effectiveness with the presently most widely used plant-growth lamp and with the combination of Cool White plus incandescent lamps. The comparisons were made at equal input wattage to determine relative efficiencies of each type of lighting. Results are summarized in Table I; they show the Agro-Lite lamp to be definitely superior for all three crops.

In addition to the work with North Carolina State University, the Fluorescent and Vapor Lamp Division is experimenting independently with lower light intensities, such as are more likely to be used by commercial growers and by amateur growers at home, to see if the new lamp's good characteristics are retained at those levels. Again, the new lamp has proved more effective than the others in producing dry weight, root development, and flowering.

Table I—Average Dry Weights (mg) of Plants Grown Under Three Kinds of Lighting

	Radish			
Lighting	*Root*	*Shoot*	*Lettuce*	*Milo*
Present Plant-Growth Lamp	130	340	350	340
Cool White plus Incandescent	190	395	375	560
Agro-Lite Plant-Growth Lamp	250	490	390	665



As one example, gloxinia plants grew noticeably faster under the Agro-Lite lamp than they did under the presently most widely used plant-growth lamp. (See photograph.) When they blossomed, the ones grown under the Agro-Lite lamp had an average of 50 percent more blossoms per plant.

Corn, lettuce, and tomatoes consistently showed 50 to 60 percent higher dry-weight production of plant tops. The first blossom on the tomato plants (Tiny Tim variety) appeared a week earlier under the Agro-Lite lamp than it did under the other one; a week after that, the plants under the Agro-Lite lamp had an average of six blossoms each compared with two for the other plants. The plants were thinned to four per chamber to prevent overcrowding and, when all had fruit, the fruit was picked for weight comparison. The plants grown under the Agro-Lite lamp produced 340 grams of ripe and 519 grams of immature fruit in that growth period, compared with 187 and 414 grams for the other plants in the same period.

The new lamp's maintenance of its original spectral distribution with time compares favorably with that of Cool White lamps. A small change in the ratio of blue to red output was measured, but it did not appear to affect the plant-growth qualities of the lamp.

Experiments with lamps of somewhat different spectral power distributions are still under way. The resulting improvements in understanding of plant growth requirements may lead to still better lamps in the future.

REFERENCE:

[1] Richard Corth, Gay M. Jividen, Robert J. Downs, "New Fluorescent Lamp for Plant Growth Applications," *Journal of the IES*, January 1973.

Geared Drives for Aerators Are Effective and Reliable

C. F. Garland
D. L. Moser
D. L. Seager

Low-speed aerators in biological treatment systems transfer atmospheric oxygen to wastewater economically and efficiently. The oxygen facilitates decomposition of organic materials in the water by microorganisms. Westinghouse aerators are reliable because dynamic analysis of their reduction gearing, in the design stage, locates any potential vibration problem so it can be eliminated.

Depletion of the dissolved oxygen in streams and other natural bodies of water often results when too much untreated municipal and industrial wastewater is discharged into them. The oxygen is used up by bacteria that require it for their metabolic activities as they decompose the organic materials commonly found in wastewater. Serious nuisances can result, such as bad odor, bad appearance, and fish kills.

Therefore, a stream management program involves treatment of organic wastewaters before discharge to limit the loading on the stream's oxygen resources and thus maintain water quality objectives for that stream. In effect, the natural biochemical waste-stabilization process is removed from the stream and accelerated in an engineered treatment system involving some type of oxidation process. The treatment may range from a simple oxidation pond, in which the oxygen required by the microorganisms responsible for treatment is furnished by algal photosynthesis and natural reaeration, to a sophisticated activated-sludge plant comprising an extensive aeration system for oxygen supply. Anything but the simple oxidation pond requires supplementary oxygen, which commonly is provided by intimately contacting air with the wastewater.

Air can be compressed and introduced under pressure into the aeration basin through diffusers, but it is more efficient to introduce it by mechanical aerators such as those shown in Fig. 1. (See *Characteristics of Aeration Systems* at right.)

Infilco mechanical aerators are available in standard units rated from 1 to 150 hp. They are installed on bridges spanning basins or ponds or, in larger basins, on column-supported platforms with access by walkway or boat. Where water level varies appreciably, surface-entrainment aerators are raft-mounted to ensure constant and optimum submergence of the impellers.

Both the Vorti-Mix and the Vortair aerators are low-speed types, driven through reduction gearing. Torsional vibration was once a problem in such drives, but the dynamic analysis described later in this article has completely overcome the problem in Westinghouse units. The result is

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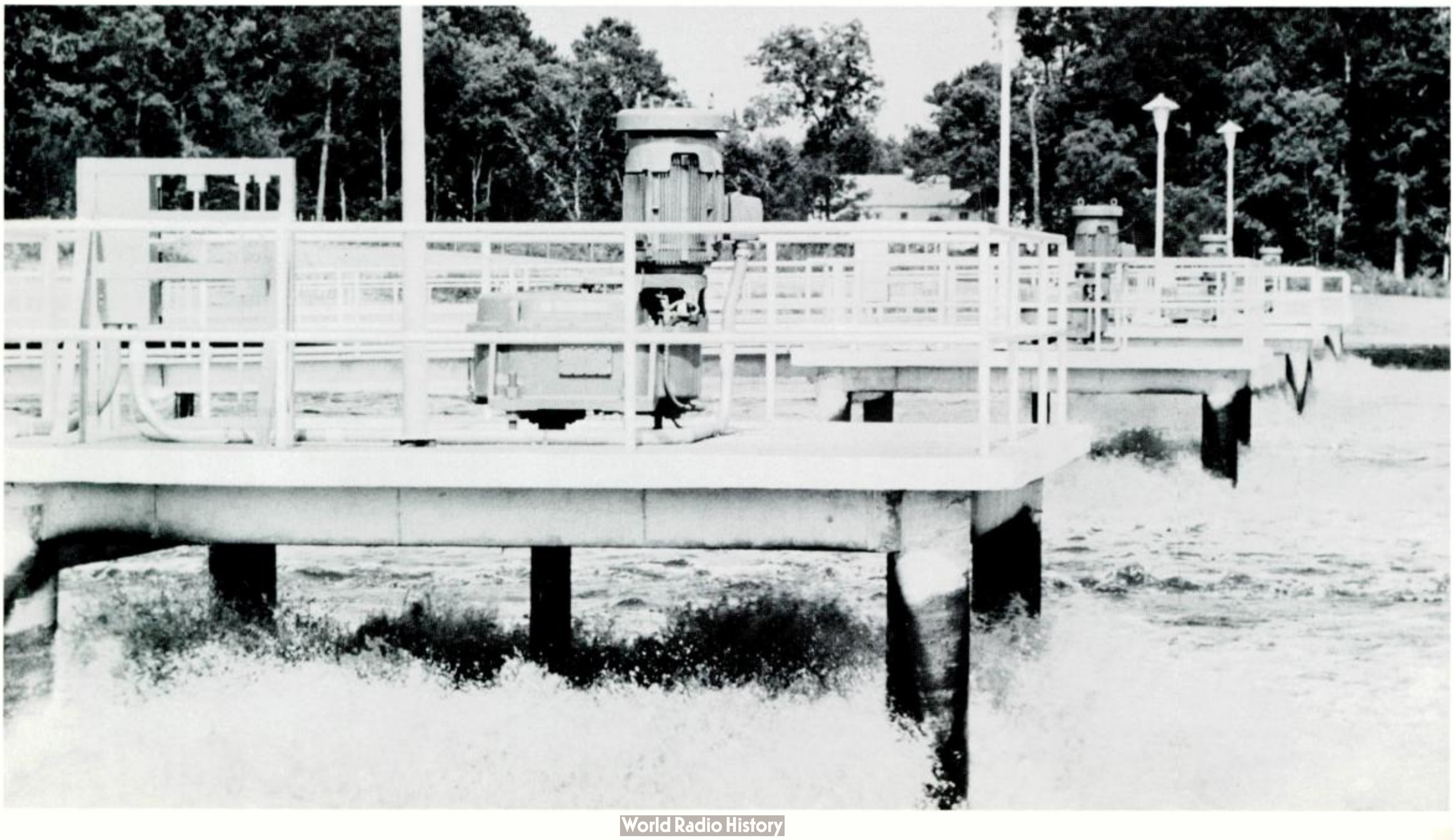


Photo—These platform-mounted Vortair aerators treat wastewater from a textile mill.

1—Mechanical aerators manufactured by the Infilco Division are of two general types: submerged-turbine and surface-entrainment. The Vorti-Mix submerged-turbine aerator (a) *and the Vortair low-speed surface-entrainment aerator* (b) *are driven by their motors through speed-reducing gear units. The Westaire high-speed surface-entrainment unit* (c) *is driven directly by its motor.*

Characteristics of Aeration Systems

Evaluation and comparison of aeration systems requires quantitative expression of the two principal functions performed: *oxygen input* and *mixing*.

Oxygen input is defined as the weight of oxygen transferred per unit of power per unit of time (commonly pounds of oxygen per delivered brake horsepower per hour). It is referenced to standard conditions, arbitrarily selected as clean water at one atmosphere of barometric pressure, zero dissolved oxygen, and a temperature of 20 degrees C. The oxygenation capacity of optimum diffused-air systems is about 2 lb/hp-hr. For a submerged-turbine aerator under similar conditions, it ranges from 2 to 3 lb/hp-hr; for surface-entrainment aerators, it is 3 to 4 lb/hp-hr and more, depending on basin size and shape. The reason the oxygenation capacity of diffused-air systems is low is that their total power requirement is for air compression, a relatively inefficient process.

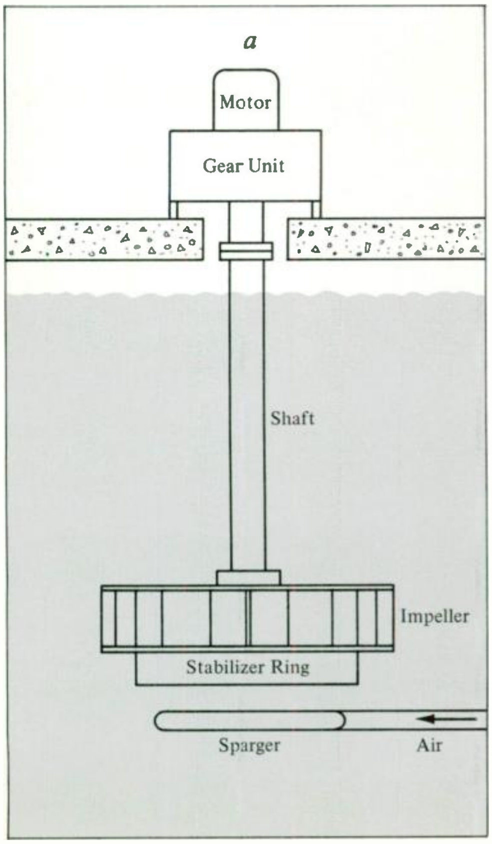
Mixing is important because oxygen must be dispersed and maintained throughout the aeration basin, and the microorganisms must be contacted with the wastewater and kept in suspension. Both effects are achieved by generating a strong basin circulation that provides continual turnover and intermixing. The important factor is the quantity of liquid pumped or circulated through the oxygenation device or zone. Again, such pumpage is more efficiently accomplished by mechanical means than by compressed air. However, high-speed mechanical devices that can induce intense local turbulence may be poor aerators if they fail to provide the pumpage required for good mixing.

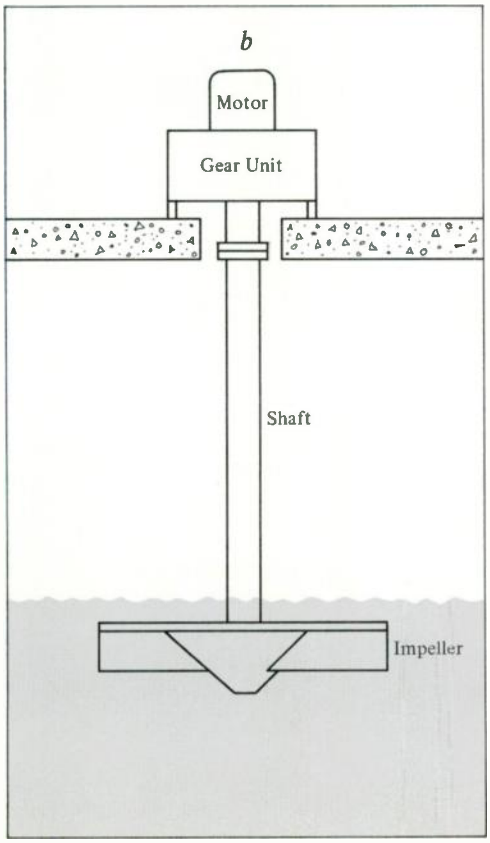
Since oxygen transfer is enhanced by creation and constant renewal of air-water interfaces, impeller designs are a compromise between that objective and the objective of efficient pumping for basin mixing.

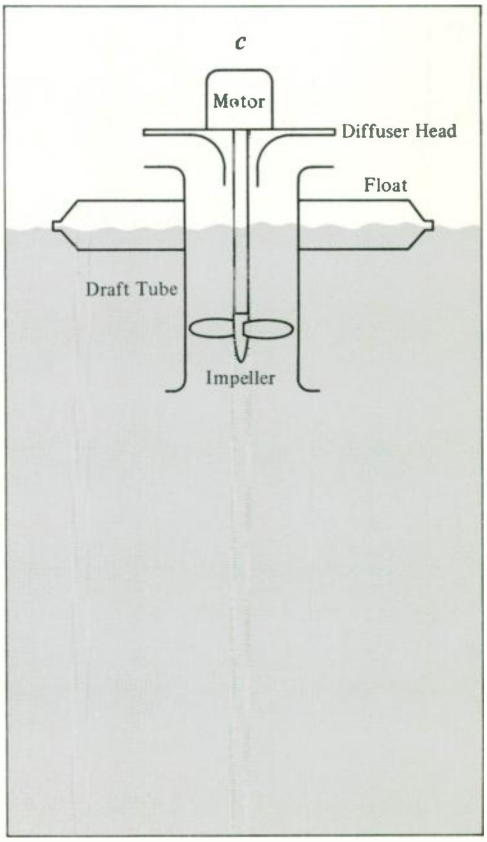
The Vorti-Mix submerged-turbine aerator has a flat-bladed impeller positioned toward the bottom of the aeration basin. The impeller disperses compressed air, introduced through a sparger beneath it as fine bubbles, by its shearing action and by the liquid turbulence generated in the vicinity of the rotor by the pumped discharge. Oxygen is transferred from the air through the resulting air-water interfacial area. Additional transfer is obtained as the air bubbles rise through the strongly mixed tank contents.

The Vortair low-speed surface-entrainment aerator has a flat-bladed impeller positioned just below the basin's liquid surface. Rotation of the impeller induces a strong pumping action, which draws oxygen-deficient liquid from the bottom of the basin and discharges it radially at the surface through an annular zone of intense turbulence just outside the impeller. In that area, large quantities of air are entrained in the form of small bubbles. The bubbles are short-lived, and impeller energy is thus directed toward continuing generation of new gas-liquid interfacial surfaces to take advantage of the fact that oxygen transfer is greatest at the moment of creation of interfacial surface. Additional air is aspirated into the region of negative pressure behind each impeller blade through apertures in the top plate, enhancing oxygen transfer and stabilizing operation by eliminating hydraulic instability.

The Westaire high-speed surface-entrainment aerator has a direct-drive propeller that pumps large volumes of liquid from well below the surface through a draft tube, from which it is discharged radially above the surface in the form of a myriad of droplets and thin sheets of liquid. Oxygen is absorbed in the discharged liquid as it passes through the atmosphere; further oxygenation is obtained when the pumped liquid impinges on the basin surface, creating additional interfacial area for gas transfer.







an effective and reliable family of low-speed aerators.

Geared Aerator Drives

A geared drive for water aeration consists of reduction gearing with an electric motor mounted on the gear housing or on a separate base. The gear unit must be capable of withstanding vertical forces (both up and down) and side forces, all of which result from impeller configuration and water behavior. Moreover, it must withstand those forces while multiplying the motor torque by a factor of 40 and transmitting it to a large impeller. The nature of the application is such that the greatest amount of turbulence gets the most air into the water, which is the objective. However, the behavior of turbulent water is not uniform, so the impeller can meet impact resistance one moment and, the next moment, encounter no resistance, which is like an impact in reverse—a release of effort that creates a countershock. Forces from impellers have been recorded (at the gearing output shaft) as high as 24,000 pounds. Such forces would be destructive if allowed to enter the gear meshes.

The new Westinghouse Type V gear unit has been designed especially for such service. It has a large double-row tapered roller bearing that is axially restrained to shield the gear meshes from the external vertical forces while also restraining the parts from deflective movement (Fig. 2). It is made in ratings from 50 to 150 hp.

The gear housing is made of high-strength cast iron. Its sturdiness enables it to support the driving motor and two or three gear trains of high horsepower-to-size ratio. (The number of gear trains depends on desired output speed.)

The capacities of the rotating parts are greatly enhanced by metallurgical factors and by manufacturing techniques. Gear materials, for example, are of high hardness to maximize horsepower capacity per unit volume, and gear teeth are hobbed with the latest tooling on precision machinery.

A distinctive feature is the recessed housing, which partially envelopes the motor coupling to make a compact package. A flanged motor is normally applied, supported by a bracket that mounts on the gear housing at two levels for maximum support (as shown in the photograph on page 12). For users who prefer foot-mounted motors, that type is readily applied by use of an alternate bracket. The recommended motor is the Westinghouse mill and chemical type having Class-F insulation, epoxy fortified and with epoxy exterior paint.

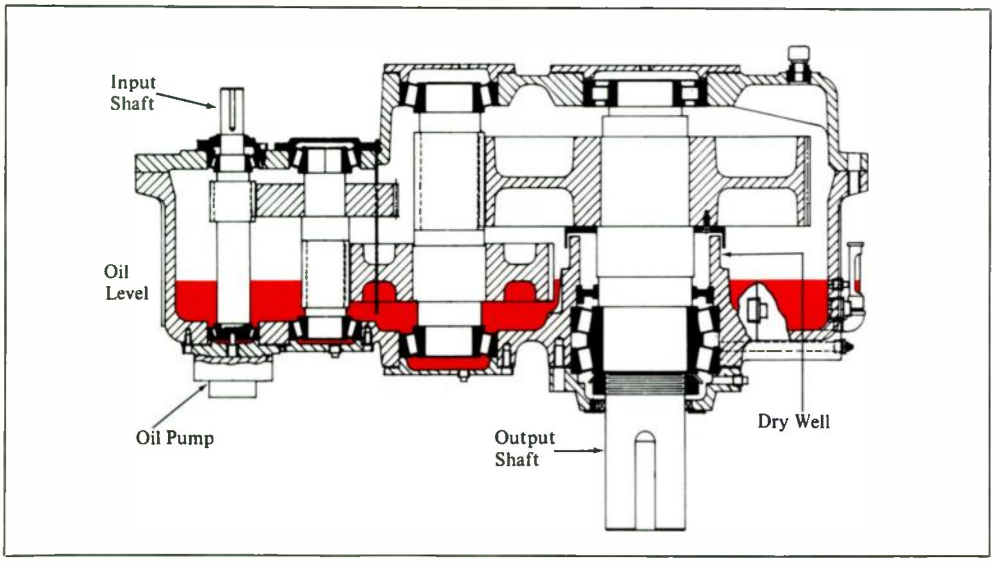
The main low-speed bearings are grease-lubricated and are encased in a heavy bearing hub that extends to a high elevation inside the housing to form a "dry well" (Fig. 2). This dry well is a cylindrical dam that separates the output shaft from the oil reservoir. An overlapping umbrella on the shaft prevents oil from finding its way in at the top of the well. The arrangement constitutes the most positive of assurances that oil will not leak out around the output shaft. Such leakage would further pollute the wastewater being treated.

Oil is distributed to rotating parts above the reservoir level by a positive-displacement pump mounted on the underside of the unit. The pump has a condensate drain plug, as do the endcaps at points where water condensed from the air could collect. A low-oil-pressure switch shuts the motor down in the event of interruption of the oil supply to the rotating parts.

Successful operation of the aerator drive system is further assured by a computerized dynamic systems analysis in the design stage of each application. The analysis looks for destructive dynamic forces resulting from operation at or near resonance.

Dynamic Analysis

If gearing in any application fails after very short service by pitting or breaking of the teeth, and there is no evidence of



2—The new Westinghouse Type V gear unit for low-speed aerators is designed and built to withstand forces transmitted from the impeller. A large double-row tapered roller bearing shields internal parts from vertical movement and deflection of the output shaft.

misalignment or metallurgical deficiency, then the gears must have been overloaded. Overloading may occur either if the loads transmitted by the gearing have been underestimated or if the system vibrates, causing an excessive dynamic load to be superimposed on the transmitted loads.

In many applications, including aerator drives, environmental variables make it difficult to determine the actual spectrum of transmitted loads. In addition, some degree of dynamic loading is inevitable, due to the flexibilities and inertias of the system components. The usual approach to the problem of finding the right design load is to multiply the maximum theoretical transmitted load by a service factor and a dynamic factor. The *service factor* for aerator drives is about 2, dictated by uncertain variables such as wind velocity and extraneous debris. However, it is not possible to make any general estimate of the *dynamic factor:* the only way to calculate a reasonable dynamic factor is by a dynamic analysis of the complete system—motor, gearing, and impeller.

In an aerator system, transmitted horsepower imposes on the teeth of each gear in a pair an average base load (W) that is fairly steady aside from unpredictable instantaneous shocks (Fig. 3). Vibratory forces on the system superimpose an additional oscillating component (W_d).

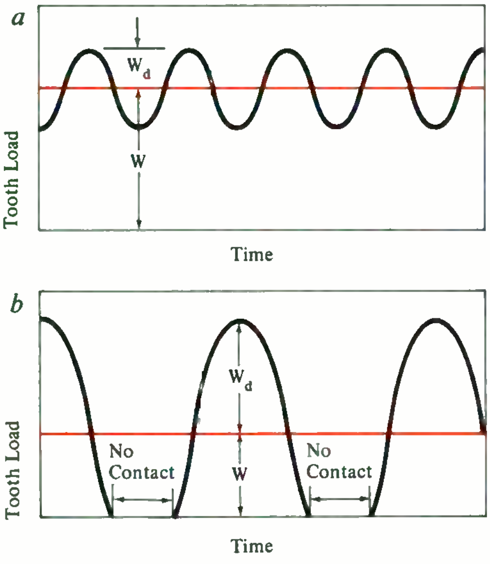
The average base component (W), in pounds, is expressed by the relationship 126,050 H/Dn, where H is transmitted horsepower, D is pitch circle diameter of the gear in inches, and n is speed of the gear in r/min. The maximum dynamic load experienced by the teeth is ($W + W_d$), and therefore the dynamic factor (C_V) is given by:

$$C_V = 1 + W_d/W. \qquad (1)$$

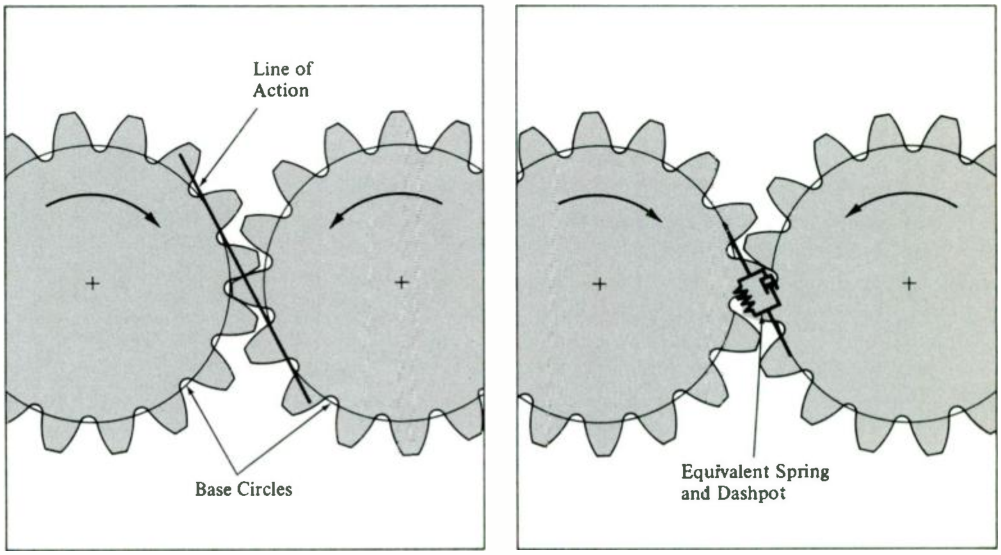
If W_d is greater than W, the teeth are unloaded during part of each cycle of vibration, as in Fig. 3b. That is, the teeth bounce out of contact, which is highly undesirable because it increases both tooth loading and noise.

The vibration that results in dynamic tooth loads is excited by vibratory forces or displacements imposed on the system. The level of vibration (called the "response") depends on the magnitudes and frequencies of the exciting forces, the inertias and stiffnesses of the components, and the amount of damping present in the system. When the frequency of an exciting force coincides with a natural frequency of the system, a condition of resonance exists and dangerously large amplitudes may result. Following some early field failures, dynamic analysis revealed that aerator drives are prone to run close to a resonance. Consequently, dynamic analysis is now a standard part of preliminary design procedure at Westinghouse; if it predicts troublesome vibration, the system is modified (as described later) to alter either the exciting frequency or the natural frequency.

The mode of vibration that causes dynamic tooth loads is mainly torsional. There are also some transverse and axial motions, due to the inevitable flexibility of the shafts and bearings; however, the tapered roller bearings used are very stiff, so the transverse and axial motions are so small that it is sufficient to consider tor-



3—Dynamic loading on the teeth of each gear in a pair consists of an average load (W), *the result of transmitted power, and an oscillating additional load* (W_d) *resulting from vibration. If* W *is greater than* W_d, *as in* (a), *the teeth stay in contact with each other; if* W_d *is greater, as in* (b), *the teeth bounce out of contact. Such bouncing would increase tooth loading and noise, so it is prevented in Westinghouse designs.*



4—Vibration consists mainly of torsional motions. One source of it is the meshing of the gear teeth, which are dynamically equivalent to a spring and dashpot joining the base circles of the gears. Small torsional displacements of the gear teeth, as a result of minor imperfections and flexibility, excite vibrations. Damping comes mainly from the oil film between teeth. (Another source of excitation is the impeller.)

sional motions only. The gears themselves play an important role in the dynamic system, because their teeth have flexibility and are also sources of damping and excitation. The teeth are dynamically equivalent to a spring and dashpot joining the base circles (Fig. 4).

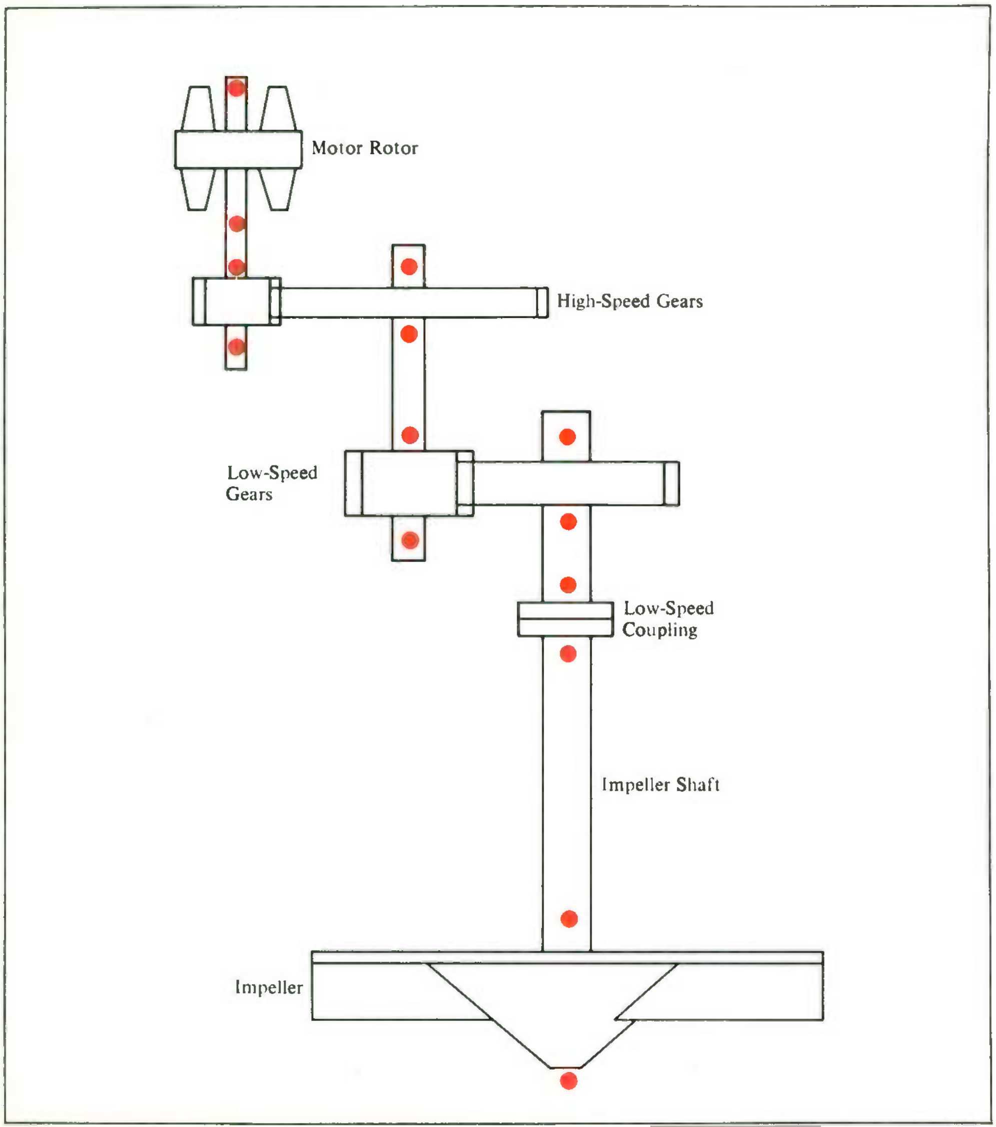
Damping arises mainly from the oil film between the teeth. Excitation arises from tooth flexibility and imperfections. If the gear teeth were rigid and had perfect involute profiles, then uniform rotation of one gear would be transmitted into uniform rotation of the mating gear. However, in practice, due to manufacturing deviations and tooth deflections, the gears undergo small torsional displacements from their ideal positions. The total displacement, measured as a linear displacement along the line of action (Fig. 4), is called the transmission error. Fluctuation of transmission error as each tooth goes in and out of mesh (at tooth meshing frequency) excites vibration.[1,2] Tooth pitch errors and profile errors are the principal sources of transmission error, and therefore high gear accuracy is essential to keep dynamic loads low. However, a transmission-error amplitude of as little as 0.0001 inch may cause severe vibration if the system is operating close to a resonance. (High-quality industrial gears may have a transmission-error amplitude as high as 0.0004 inch and still be within accepted tolerances.)

In addition to the gear teeth, the other important source of excitation is the impeller. The impeller torque is not constant but tends to fluctuate at blade frequency (the rate at which a given blade passes a given point). Therefore, in a typical double reduction system, there are three important exciting frequencies: tooth meshing frequency of the high-speed gears (f_1), tooth meshing frequency of the low-speed gears (f_2), and blade frequency of the aerator's impeller (f_3).

Analysis at the Westinghouse Research Laboratories revealed that the flexibilities and inertias of a typical system are such that it tends to have a number of natural frequencies of the same order as the exciting frequencies—especially f_1 and f_3. That is why vibration was a problem with geared aerators.

Once the role of the gears was understood and formulated, the analysis of the complete system was programmed by use of the transfer matrix method.[3] The analysis results in computation of the dynamic displacements and torques at each of the positions shown in Fig. 5 and also computation of the dynamic tooth loads.

Typical tooth-load response curves for excitation by a sinusoidal transmission error of 0.0001-inch amplitude at the high-speed gears are illustrated in Fig. 6a. Motor speed is 1775 r/min in this example, and the high-speed gear set consists of an 18-



5—(Left) *Principal elements of a double reduction system are illustrated here. Each proposed system is analyzed in the design stage by computing dynamic displacements and torques at each of the positions indicated by colored dots. Dynamic tooth loads also are computed. The object is to make sure that the frequencies of vibration-exciting forces will not coincide with a natural frequency to cause destructive resonant vibration.*

6—(Right) *Aerators tend to have a number of natural frequencies close to the exciting frequencies, causing resonance there. If the tooth meshing frequency is near one of those resonances* (a), *vibration causes excessive tooth loading. When dynamic analysis reveals such a situation in a prospective design, the design is altered to eliminate the problem. One way to do so is to change to gears of finer pitch and thereby move the operating frequency away from the resonant frequency* (b). *Another way is to alter the response curve by stiffening the impeller shaft* (c).

tooth pinion and a 79-tooth gear. Therefore, tooth meshing frequency of the high-speed gears is:

$$f_1 = 1775/60 \times 18 = 533 \text{ Hz.} \qquad (2)$$

Horsepower is such that the transmitted loads on the high-speed and low-speed gear teeth are 500 and 1100 pounds, respectively, per inch of face width.

The response curves show a resonance (maximum amplitude) at 520 Hz, which is very close to the tooth meshing frequency. Dynamic loads on high-speed and low-speed gears are 800 and 650 pounds, respectively, per inch of face width, giving dynamic factors (from Equation 1) of 2.60 (loss of contact) and 1.59. Those dynamic factors are excessive, especially for the high-speed gears, so the design must be altered. There are two possible remedies.

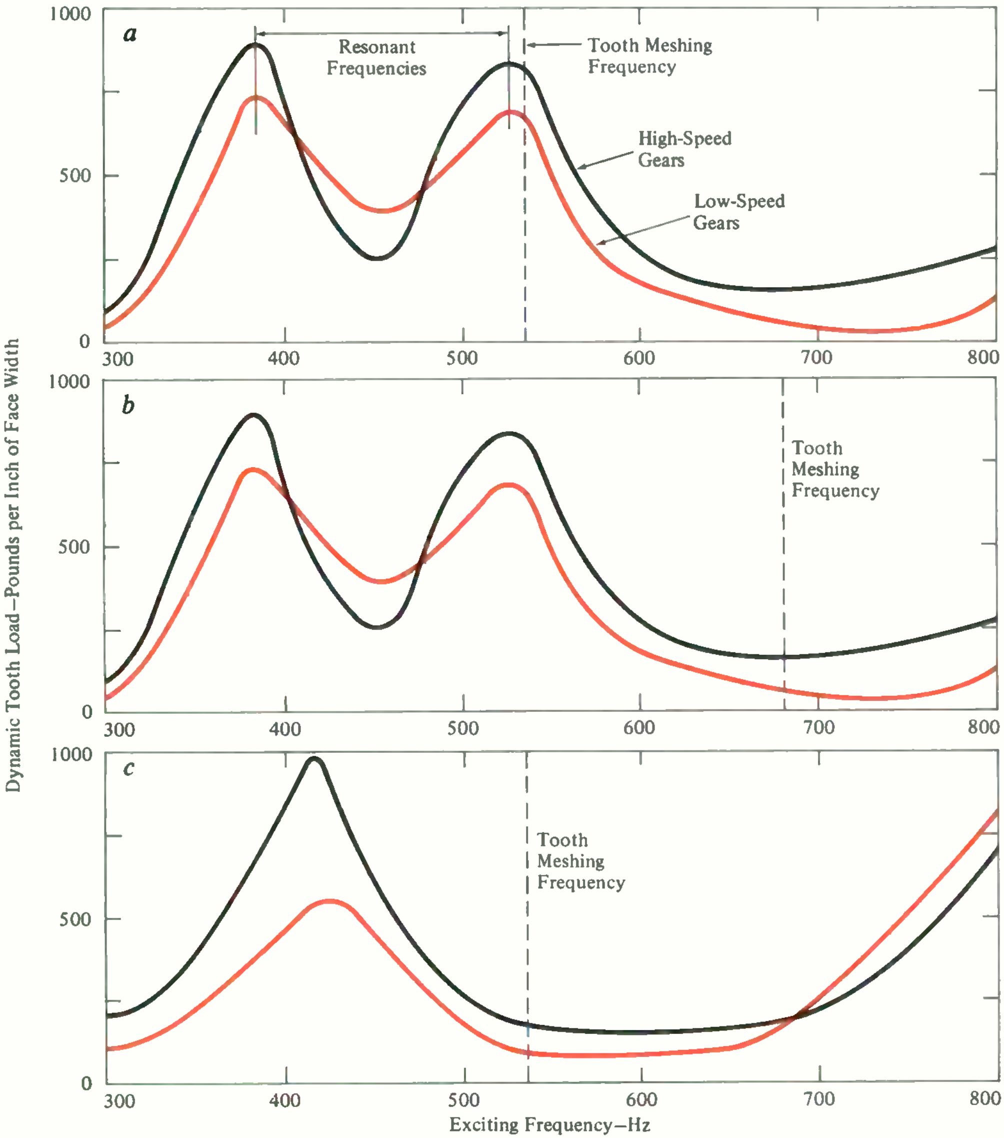
One is to change the exciting frequency by changing the pitch of the gears. If the original gears (18/79) are replaced by gears of finer pitch (23/101), the response curve is unchanged but tooth meshing frequency is increased to 680 Hz (Fig. 6b). The resulting dynamic factors are 1.35 (high-speed gears) and 1.07 (low-speed gears).

The other remedy is to change the response curve by altering one or more of the inertias or stiffnesses of the system. The most practical candidate for modification is the long impeller shaft, which has a considerable influence on the natural frequencies of the system. Stiffening it by changing from a solid shaft to a hollow shaft of twice the diameter has the effect shown in Fig. 6c. The resulting dynamic factors are 1.35 and 1.09.

If excitation is caused by the impeller blading, it is not desirable to alter the number of blades to alter the exciting frequency because the number of blades has been chosen to optimize oxygen transfer. Instead, modification of the impeller shaft again provides a satisfactory remedy.

Conclusion

Low-speed aerators combine efficient aeration with effective mixing of the contents of an aeration basin. The geared drives in Westinghouse units are reliable and long lived, a result of care in manufacturing and dynamic analysis of each new aerator design.



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Sensor System for the National Data Buoy Project

Edward L. Caldwell

Worldwide measurement of meteorological and oceanographic parameters will provide scientists with information for developing a better understanding of the origin of the world's weather patterns. The United States will broaden its scope significantly in this field of endeavor through the research, development, test, and evaluation of environmental data buoys now being conducted by the National Data Buoy Center. Westinghouse is providing the meteorological and oceanographic sensor system for those data buoys.

Although 70 percent of the earth's surface is covered by water, too little is known about how the oceans and the atmosphere interact to create the world's weather, particularly severe storm patterns generated over the ocean. The National Data Buoy Project can help overcome this lack of knowledge by providing the technical capability to support short- and long-term national and international programs directed towards the collection of oceanographic, meteorological, and air-sea interaction data with cost-effective data buoys and instrument packages.

Origin of the Data Buoy Program

The National Data Buoy Program began in 1966 when the Interagency Committee on Oceanography (ICO) suggested that a single national system of data buoys for the collection of environmental information, rather than the proliferation of uncoordinated development programs within government agencies and federally sponsored scientific institutions, would improve the efficiency of the development effort. A feasibility study confirmed the desirability of that approach and the U.S. Coast Guard was selected as the lead agency for establishing the National Data Buoy Program. In the summer of 1970 the Coast Guard issued specifications for the design and construction of the ocean platform system and the sensor system for the Engineering Experimental Phase (EEP) of the project. The EEP phase comprises five data buoys that will be placed in the Gulf of Mexico (Fig. 1) and one data buoy in the Gulf of Alaska. These regions have most of the environmental parameters needed for intensive evaluation of the data buoy system.

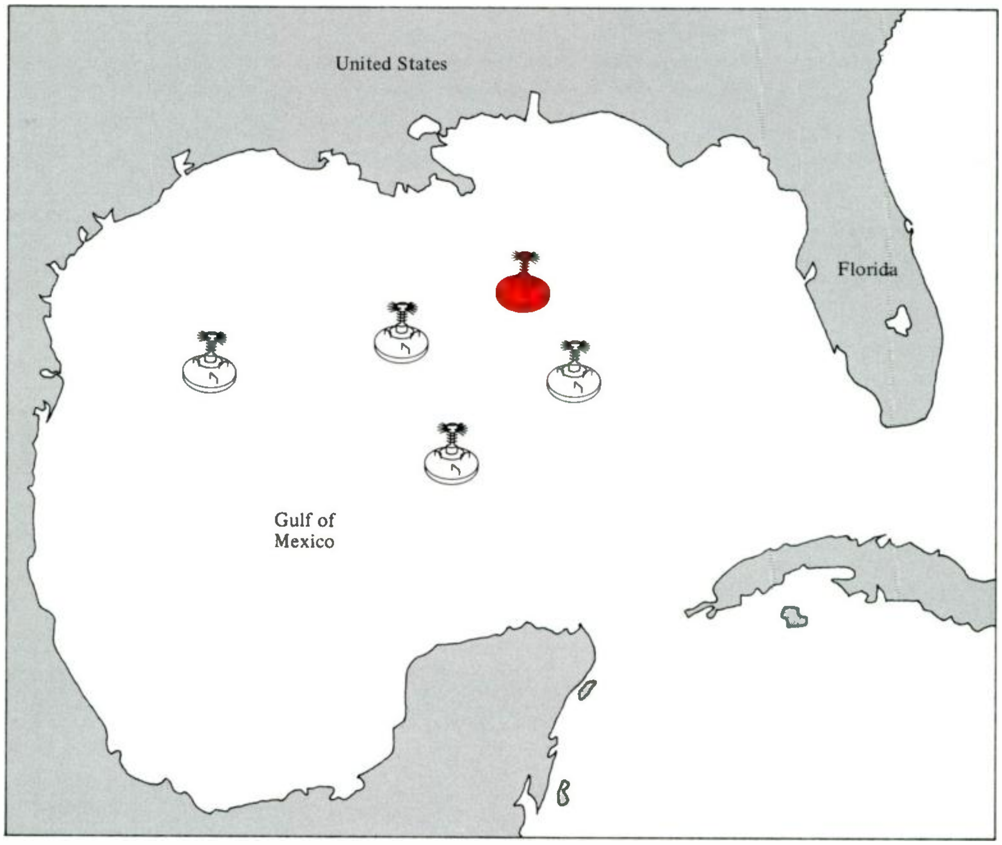
In early 1971, a contract was awarded the Electro Dynamic Division of the General Dynamics Corporation for design and production of the six EEP ocean platforms. Shortly thereafter, the U. S. Government's newest agency within the Department of Commerce, the National Oceanic and Atmospheric Administration (NOAA), awarded Westinghouse's Oceanic Division the contract to develop the meteorological and oceanographic sensor packages that are being placed on the buoys to measure environmental parameters. In June 1972, the first buoy was deployed 225 miles south of Gulfport, Mississippi (Fig. 1).

The data buoys are programmed to operate unattended for periods of up to one year. Signals from a shore-based telemetry station in Miami, Florida, activate data collection via a telemetry link.

Sensor System

Sensors on each buoy will measure six meteorological parameters and five oceanographic parameters (Table I).

Meteorological sensors are mounted on two levels on the buoy mast, one at 5 meters above the ocean's surface and the other at 10 meters (Fig. 2). An electronics package on each level provides signal processing for



1—The Engineering Experimental Phase of the National Data Buoy Program will have five data buoys anchored in the Gulf of Mexico and one in the Gulf of Alaska. The first buoy (color) was deployed in June 1972. All six are planned to be in place by the end of fiscal year 1973.

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Table I—Measured Parameters of the National Data Buoy Sensor System

Meteorological
Wind Speed and Direction Air Temperature Dew Point Temperature Atmospheric Pressure Global Radiation (two bands) Precipitation Accumulation and Rate
Oceanographic
Water Pressure Water Temperature Conductivity Current Speed and Direction Sound Speed

all sensors on that level. The electronics package includes an analog-to-digital converter and a mean-value computer.

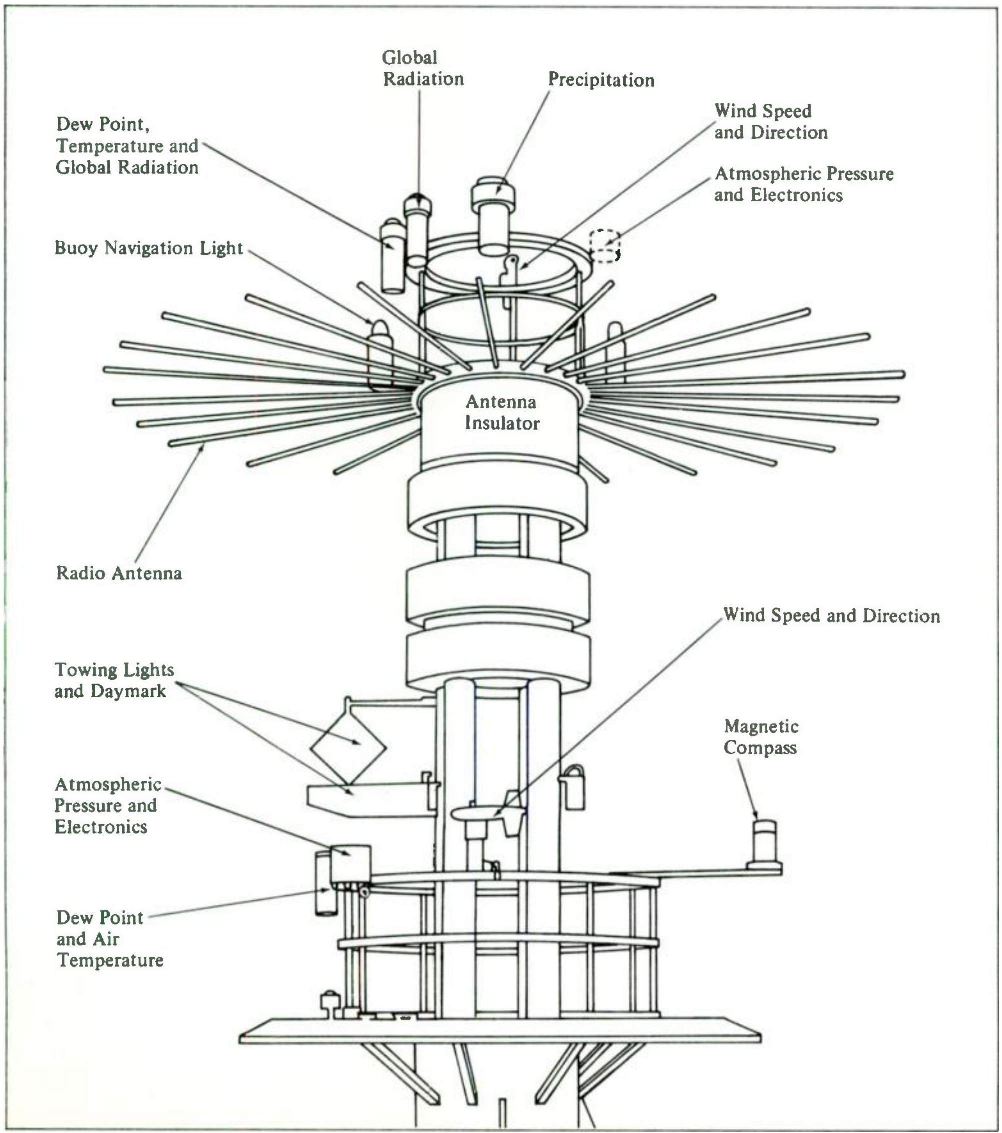
Oceanographic sensors for each buoy are placed in 13 packages—a hull-mounted unit and 12 units attached to the mooring-line data line at intervals down to 500 meters (Fig. 3). The hull-mounted package and the mooring-line packages are identical except for the method of providing power and interrogating. Package housings are made of titanium for corrosion resistance and have a crush depth of about 1700 meters (2250 lb/in²).

The electronics for all sensor packages use low-power-consuming elements, and power saving is maximized by means of power switching techniques. Standardization of meteorological and oceanographic electronics where possible minimizes logistics support requirements. Modular packaging techniques are used to simplify maintenance.

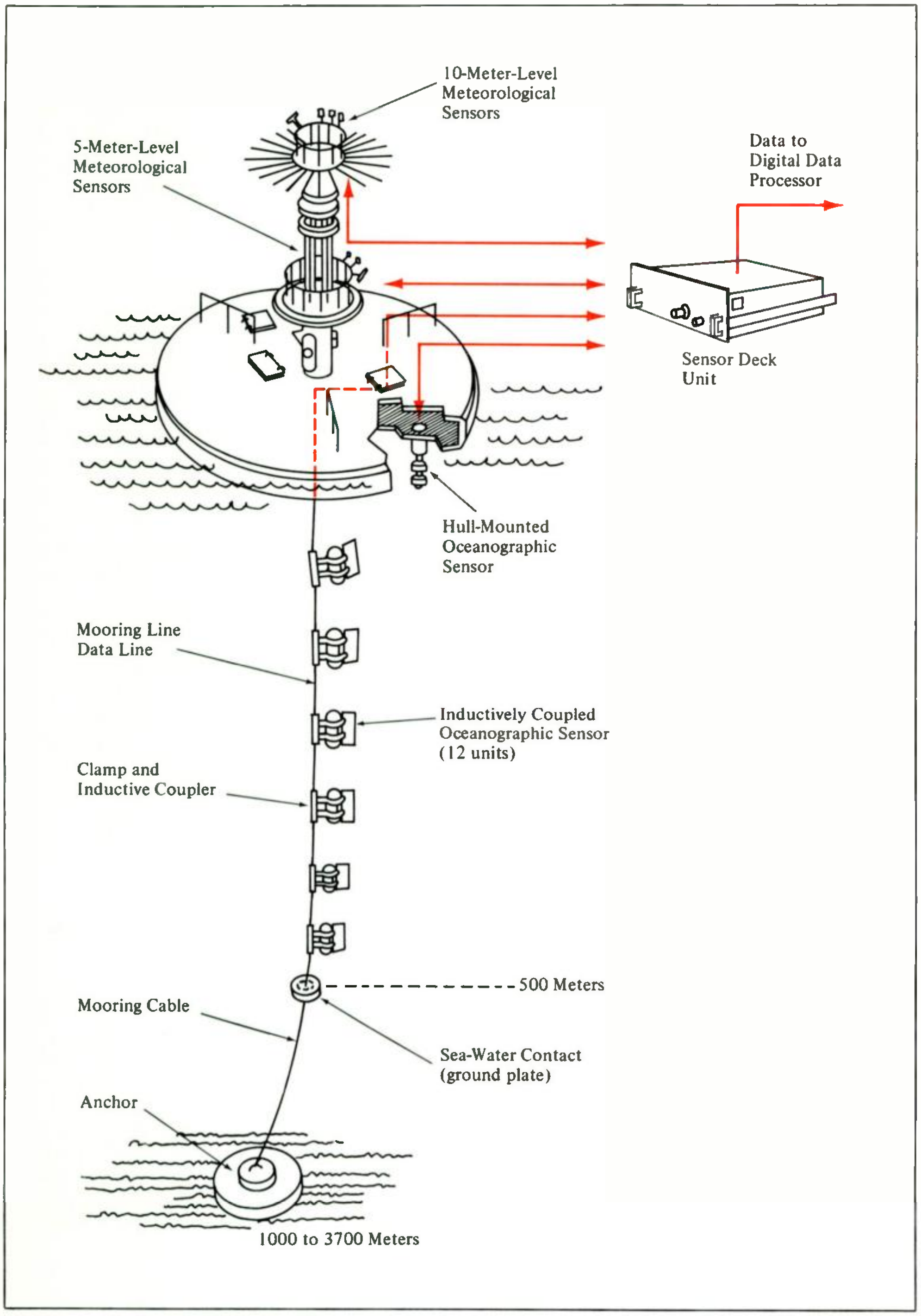
Meteorological Sensors

The six parameters measured above the ocean's surface are wind, temperature, dew point, pressure, global radiation, and precipitation.

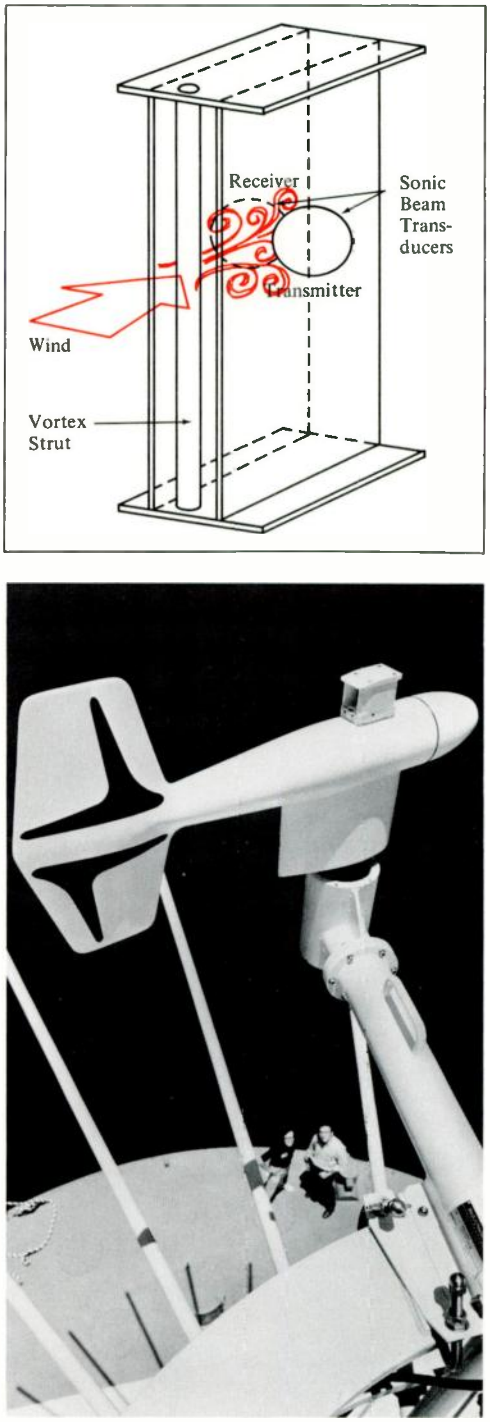
Wind Speed and Direction—Interaction between the atmosphere and the ocean is affected by air movement over the ocean surface. Since the necessary measurement range for wind velocity is too great for



2—Meteorological sensors are mounted at two levels, 5 and 10 meters above sea level. The sensors for the six meteorological parameters are identified by the drawing (the atmospheric pressure and electronics package at the 10-meter level was not installed when the photograph was taken).



3—The 100-ton buoy is anchored in water depths ranging from 1000 to 3700 meters. Oceanographic sensors are placed in a hull-mounted unit and 12 units attached to the mooring-line data line. Data transfer between the oceanographic sensors and the buoy is accomplished by inductive coupling.

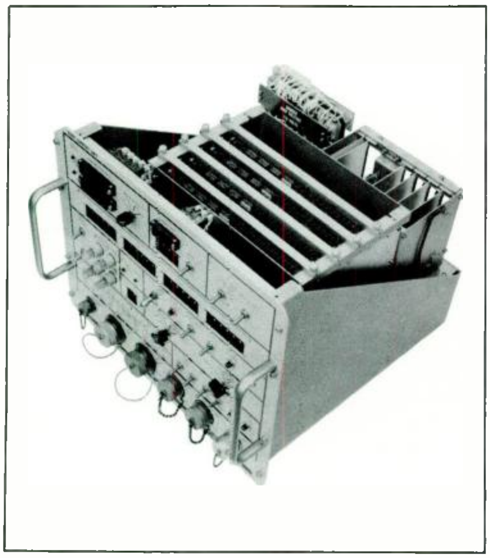


4—The wind-speed transducer (sketch) is mounted on top of a vane that keeps it headed into the wind. Wind speed is measured by measuring vortex-formation frequency as wind passes a vortex-generating strut.

The meteorological sensors mounted on the buoy mast also have power supplies in the sensor deck unit; data is transmitted to and from the meteorological sensors via the electronics package on each level at 300 Hz (base band).

Inductive Coupler—Electrical breakouts from the mooring-line data line to the 12 submerged ocean sensors are avoided by using inductive coupling. Each inductively coupled ocean sensor package is powered by an internal battery that is continually recharged except when data is being transmitted from the ocean sensor to the sensor deck unit. Data transfer to and from the MLDL to each ocean sensor is accomplished via the inductive coupler.

Battery charging and data transfer are accomplished as follows: A power amplifier in the sensor deck unit feeds a 7.2-kHz signal into the MLDL at a sufficient level to overcome line and inductive coupler losses for battery charging. Information is placed on this 7.2-kHz signal by phase reversals, which are interpreted by the ocean sensor as logical "1's". Each ocean sensor contains a transmitter that sends collected transducer information back to the sensor deck unit via the copper-wire and ground-plate path but at a 9.6-kHz phase-shift-keyed rate.



7—Buoy support unit is used to check the calibration of deployed meteorological sensors. The sensor deck unit is of similar construction.

The inductive couplers are split-core ferrites, which can be placed around the line without threading from one end. This eases the deployment problem and permits replacement of a failed unit or the addition of a new unit without removing the anchoring system or intervening sensors.

Since ferrite is already an oxide and will not rust or deteriorate when exposed to the seawater, the cores are clamped around the line and the split faces are unprotected other than being impregnated with antifoulant in the surrounding plastic.

Sensor System Support Equipment

Three separate pieces of test equipment have been developed for the Engineering Experimental Phase of the National Data Buoy Program: the Buoy Support Unit, the Ocean Sensor Test Unit, and the Ocean Sensor Comparator.

Buoy Support Unit—This test equipment (Fig. 7) is a multipurpose simulator, interrogator monitor, and meteorological comparator for the sensor deck unit. The comparator function provides a check on the calibration of deployed meteorological sensors. Recently calibrated transducers are mounted on the buoy mast next to their meteorological sensor counterparts, and the calibrated sensor and comparator equipment serve as a "secondary standard" for checking deployed transducers.

Ocean Sensor Test Unit—This test equipment is used to charge batteries in an ocean sensor package before deployment. It can also interrogate the sensor to verify operation.

Ocean Sensor Comparator—This equipment is used to check an oceanographic sensor whose operation appears questionable. In addition, this unit can be used to do profile studies from the support ship in locations where no buoy has been moored. Those profiles will be useful in determining potential buoy locations. The ocean sensor comparator consists of three units—a comparator deck unit, a magnetic tape unit, and one ocean sensor. A comparator sensor nearly identical to the deployed oceanographic sensor is lowered from a Coast Guard cutter to the vicinity of the sensor to be checked, and a qualitative comparison made between the data provided by the two sensors.

Applications

The potential benefits to be gained from the National Data Buoy Project are far-reaching. This program may be a portion of the U.S. contribution to UNESCO's Integrated Global Ocean Station System Program. In that program, member countries around the world will deploy a network of manned and unmanned stations to provide extensive and timely information on, and prediction of, the state of the ocean and its interaction with the atmosphere. The goal of this worldwide program is improved oceanographic services to increase the safety and efficiency of marine activities.

The National Data Buoy Project will also provide a new source of information on a systematic basis for oceanographers and meteorologists probing the still unsolved mysteries of the environment. Benefits from effective and efficient use of these advances will have a direct impact on industries that operate within the marine environment such as offshore oil production, deepsea mining, and commercial fishing, and on many of the industries and activities that are concentrated along the coastline of every nation.

Expanding the use of the data buoy sensor system to include pollution monitoring capabilities would be a major step forward in providing environmental baseline data and continuous monitoring of those parameters.

Hybrid Load-Flow and Transient Stability Calculators—New Tools for Power System Security Monitoring

Norman R. Carlson

An analog transmission-network simulator for performing high-speed load-flow solutions and a complete power system simulator for calculating system stability during transient conditions have been developed. These simulators, with the digital computer that controls them, provide a self-contained analytical subsystem for on-line system monitoring and off-line training and study.

Power system planning problems such as load flow, transient stability, and short-circuit current were originally solved with special-purpose analog computers that recreated the power system in miniature. But as systems and system interconnections grew more complex over the years, system analogs became unwieldy and minor inaccuracies arose because of increased range of impedances due to the introduction of higher voltage levels. Today, system planning problems are primarily solved with large general-purpose digital computers. However, despite the speed of the digital computer, some finite time is required to obtain a solution. Thus, this type of solution for a large power network may not be practical in certain on-line applications that normally have a heavy duty cycle. In those cases, fast on-line solutions would provide the system dispatcher with invaluable information for operating the system on a day-to-day basis.

To meet that need, two new on-line calculators have been developed. One is a *load-flow calculator* that simulates the transmission system (lines, transformers, and buses) with a special-purpose analog network; boundary conditions for the network are controlled by a digital process computer. The other is a *transient-stability calculator* that uses the same analog network to simulate the transmission system, but with the addition of analog models for system generators, load, and ties; again, the digital process computer supervises the analog network and models.

The basic advantage of this hybrid approach is the major reduction in digital storage and computing requirements: network parameters need not be stored digitally because they are represented in the analog circuitry, and computing time is reduced because it is not necessary to solve cumbersome simultaneous equations mathematically to determine bus voltages—rather, those voltages are read directly from the analog network. And although the hybrid computer, like the digital computer, uses an iterative approach, the settling of the analog network to a steady-state solution that satisfies boundary conditions requires less time than required for an all-digital solution. For example, convergence to a solution with the hybrid calculator usually requires some 10 to 12 iterations for a typical base load-flow solution, or about 20 seconds when a process computer is used to control the analog network. In contrast, an all-digital solution using such powerful techniques as the Newton-Raphson method usually solves a problem in about three iterations, but more time is required for the total solution.

Solving System Load Flows

The simplified hypothetical system shown in Fig. 1a can be used to describe the calculation of system load flow. In this simple four-bus network, a base-load plant feeds the system at bus *A*, using either one or two generators depending upon total load requirements. The less economical unit at bus *D* (the swing bus) makes up the difference between base-load generation and system requirements.

For a purely *analog* solution, a miniature power network is operated just like the real system. Base-load generators are set to provide a rated real power and their excitation adjusted to hold voltage magnitude. Analog load elements are adjusted to draw scheduled real and reactive loads, and the swing-bus generator is adjusted to maintain its scheduled bus voltage and phase angle. All unknown values of voltage and current flow are measured directly from the analog circuit.

This form of load-flow solution is very fast once the analog circuit is set up. System contingencies such as open lines are quickly simulated by merely opening switches, and the resulting system response is measured directly. But as already mentioned, system analogs have become impractical for today's large interconnected power networks.

For an *all-digital* load-flow solution, the power system is represented by its equivalent impedance (or admittance) network (Fig. 1b). Boundary conditions are specified for each bus: at generation buses, scheduled real power generation (P_{AG}) and voltage magnitude ($|E_A|$); at load buses, real and reactive loads (P_B+jQ_B); at the swing bus, voltage magnitude ($|E_D|$) and phase angle. Solution consists of selecting an initial set of bus voltages, solving the network equations, and using the difference between the specified and computed bus quantities to compute bus voltages for another solution. This iterative process continues until the solution satisfies all system boundary conditions. Although digital computing procedures (called algorithms) are now available to solve load-flow problems for the most complex power systems, solutions are generally performed off-line on large high-speed computers where timing requirements are less stringent than those encountered by on-line control computers. However, there is a genuine need today for an on-line load-flow calculator that imposes less strain on the control computer's core and duty cycle resources. The *hybrid* computer fulfills this need, and it meets the cost and performance requirements necessary for a practicable on-line load-flow computer.

Hybrid Load-Flow Computer

The hybrid approach utilizes a transmission network simulator controlled by a small process-type computer. The simulator is an analog model of the transmission system

1—In the conventional analog representation of a power system (a), *distributed line impedances are replaced by lumped-impedance elements, and scheduled generation and load are imposed on the network. To calculate load flow by digital computer, an equivalent impedance diagram is developed for the transmission network* (b). *Bus voltages and line currents are solved to satisfy generation and load constraints. In the hybrid computer approach* (c), *a network of analog modules represents lines, buses, and transformers. A digital computer calculates bus injection currents, and the analog network solves for system bus voltages.*

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made up of modules that individually represent lines, transformers, and buses. However, the analog is not the conventional miniaturized ac circuit of inductance, capacitance, and resistance elements. Rather, each module is constructed of integrated circuits, dc operational amplifiers, capacitors, and resistors. These modules work with dc quantities that represent real and imaginary components of voltage and current; admittance is separated into its conductance and susceptance values. A complete explanation of the network simulator is beyond the scope of this article, but the simplified description of a transmission-line module and a bus module on page 26 will provide some insight into the simulator circuit's mode of operation. The photographs show typical modules.

A block diagram of the transmission network simulator for the simplified power system is shown in Fig. 1c. Although voltages and currents are shown by their phasor designations (E_A, E_B, I_{AB}, etc.) the actual analog circuitry handles these quantities as real and imaginary components as described for the transmission-line module and bus module.

The approach for solving a load-flow problem on the hybrid calculator is similar to that for an all-digital solution, but the analog transmission network replaces the digital solution of simultaneous equations.

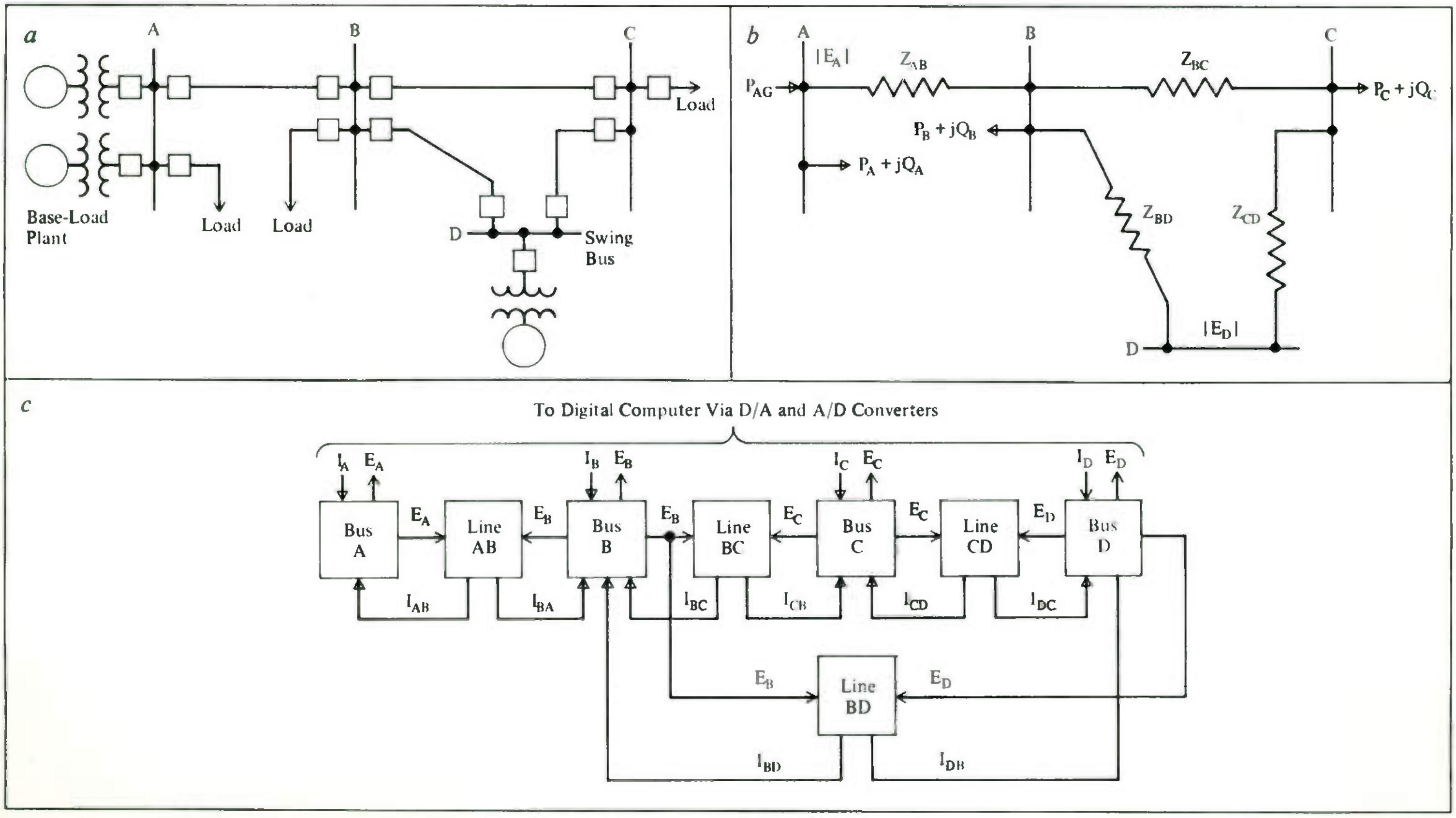
In the hybrid approach, the digital computer follows a procedure (algorithm) that estimates bus voltages and computes an injection current at each bus to satisfy scheduled real and reactive load flow at load buses, and computes real power flow and voltage at generation buses. The computed injection currents are fed through digital-to-analog (*D*/*A*) converters to the network simulator (in real and imaginary values), as shown in Fig. 2. The resulting steady-state bus voltages of the analog network are read back to the computer through analog-to-digital (*A*/*D*) converters. Computer calculation of injection currents is an iterative process because the interflow of current between buses as the system balances itself results in bus voltages different from those that were estimated from boundary conditions to calculate injection currents. Thus, the computer continues to recalculate injection currents until system load and generation constraints are satisfied.

From the final steady-state solution, the computer determines current magnitude, line losses, and any other desired system quantities. The hybrid computer reaches a load-flow solution within 2.5 to 25 seconds, depending upon the speed of the digital computer and the size of the system.

Transient-Stability Calculator

To form an analog power system simulator for transient-stability studies, analog models of system generators, loads, and ties are added to the transmission system simulator. Again, construction is modular with a module representing each power system load, generator, or tie line.

Load modules are of three types: constant admittance, constant power, and constant current/constant power factor. Load constraints are specified in terms of real and reactive power. Therefore, in the case of constant-admittance loads, admittance



Transmission-Line Module

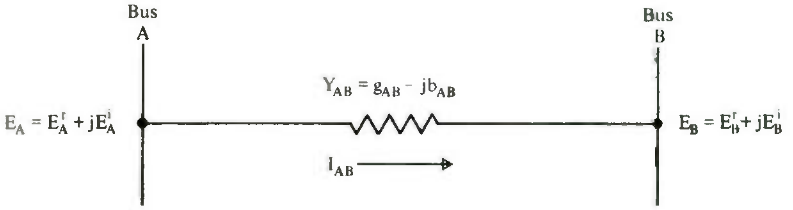
Current flow in a transmission line is a function of transmission line admittance and bus voltage difference, as shown in (*a*), assuming a short line in which distributed capacitance to ground can be neglected. (Modules for longer lines also account for shunt susceptance.) Line current from bus *A* to bus *B* is expressed in phasor quantities as: $I_{AB} = Y_{AB}(E_A - E_B)$. When all quantities are converted to real and imaginary values (designated by superscripts "*r*" and "*i*"), line current flow can be expressed in real and imaginary values:

$$i^r_{AB} = g_{AB}(E^r_A - E^r_B) + b_{AB}(E^i_A - E^i_B),$$
$$i^i_{AB} = -b_{AB}(E^r_A - E^r_B) + g_{AB}(E^i_A - E^i_B).$$

Solution of these two equations requires only the linear operations of addition and subtraction because line admittances (conductances and susceptances) are constants and can be implemented by plug-in resistors. The solution to real and imaginary current is provided by the circuit shown in (*b*), which uses integrated circuits to add and subtract dc voltages and currents and plug-in resistors to represent conductance and susceptance values.

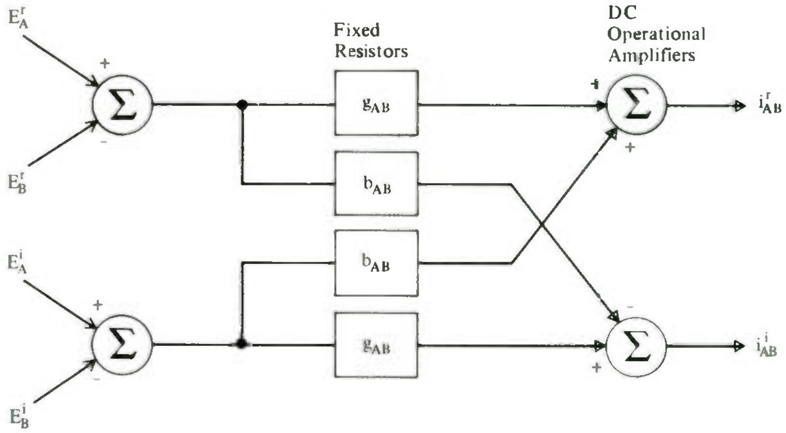
All transmission-line and transformer modules are of this type of dc amplifier circuit, with four modules mounted on a printed-circuit board.

a



$$I_{AB} = Y_{AB}(E_A - E_B)$$
$$i^r_{AB} = g_{AB}(E^r_A - E^r_B) + b_{AB}(E^i_A - E^i_B)$$
$$i^i_{AB} = -b_{AB}(E^r_A - E^r_B) + g_{AB}(E^i_A - E^i_B)$$

b



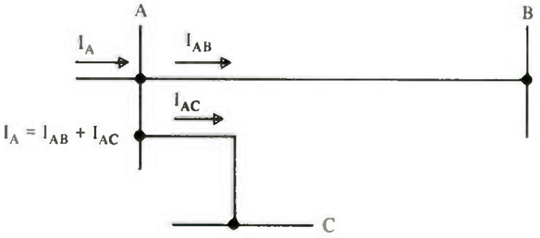
Bus Module

The bus module is an analog device that solves Kirchhoff's current law: the summation of currents flowing into a node must equal those flowing away (*a*). In the power system, current balance at buses must occur because conductors from transmission lines, loads, and generation sources are interconnected. However, in the hybrid simulation, generation sources and loads are external to the transmission system simulator, so the net flow of current into a bus because of an attached load, or away from a bus because of an excess of generation, must be forced. This is accomplished by having the digital computer calculate injection currents for each bus to satisfy scheduled generation and load demand. Injection current flow into the bus modules causes bus voltages to assume values that accommodate Kirchhoff's law at each bus.

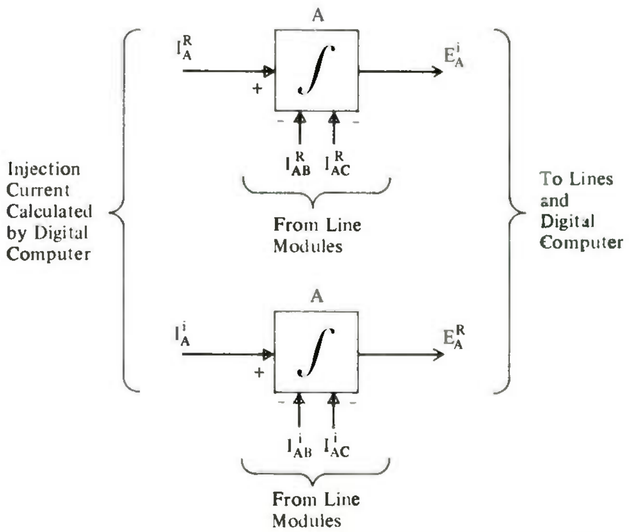
As illustrated diagramatically in (*b*), bus modules, like transmission-line modules, operate with real and imaginary values. Note that imaginary bus voltage is determined from real current, and vice versa. This choice is made to insure stability of the analog solution.

In the simplified system simulator diagram shown in Fig. 1c, phasor representation is shown for line and bus modules. Actually, real and imaginary values are used throughout the transmission simulator.

a



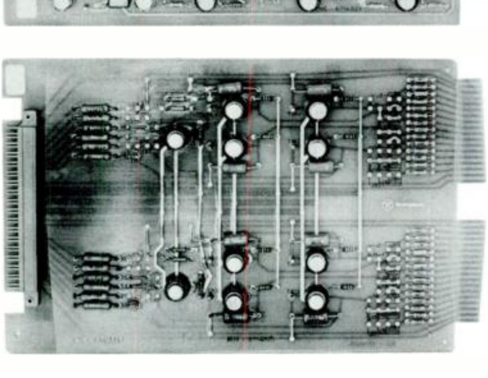
b



values depend upon bus voltage and therefore must be determined by a steady-state load-flow solution. Once determined, the digital computer sets and holds those constant-admittance values in load modules during a transient solution.

Generator simulation may be simple or complex. In the simplest case, only fixed turbine power and fixed voltage magnitude are represented. A more complex representation includes transient effects of the turbine, speed-governing system, generator excitation, and generator flux changes. However, regardless of the complexity of the simulation, interfacing requirements between the digital computer and generator module are the same: each generator module requires two D/A conversion points, one for megawatt setpoint and one for voltage magnitude setpoint.

Tie lines in the transient stability calculator are simulated by transmission line modules identical to those used in the transmission network simulator. These modules may terminate in infinite bus voltages set by digital control. Two D/A conversion points are needed for computer control—one for setting the real components and one for setting the reactive components of each infinite bus voltage. Tie-line modules can also be terminated in equivalent generators and even in external system analog models, depending on the user's requirements.



The transmission-network simulator consists of such printed-circuit boards as these. Transmission-line modules (top) *are mounted four to a board. Bus modules* (bottom) *also are mounted four per board, with each module corresponding to a specific bus in the power system.*

The basic configuration of the transient stability calculator is shown in Fig. 3. The digital computer iteratively guides the power system simulator to a load-flow solution by computing and setting values of load admittance, infinite bus voltage, and generator setpoints. The computer reads bus voltages for each simulation, and it continues to recalculate values for load admittance and infinite bus voltage until all load power and tie-line constraints are met. The simulator is then ready to perform the transient stability analysis.

Transient-stability calculations are performed by the analog simulator alone and therefore take far less time than the duration of the actual transient on the power system. At the fastest speed (50 times faster than real time) a transient of 3 seconds duration on the actual power system is simulated in 0.06 second. The digital computer's only functions are to impose the transient condition on the system simulator and to monitor results. The simulator accepts the imposed condition, and the generator modules respond with generator swing angles that determine the system stability. Possible impending instabilities are detected and reported by the digital computer.

Hybrid Computer Applications

The short time required for load-flow solutions and transient stability studies permits the checking of many contingency situations, both periodically and on demand by the operator. For example, the hybrid computer is typically programmed to provide a continuing picture of existing system load flow, representing those portions of the system in service. Periodically, hypothetical contingency situations on a checklist are solved one at a time, taking out major lines, transformers, or generators. For each of those contingency situations, system response is determined to provide advance warning of potential transmission-line or transformer overloads or of out-of-range voltages. The hybrid computer is then used to search for a system dispatch that avoids those undesirable situations.

Another useful task for the hybrid computer is to help the dispatcher anticipate system response to a change that is immediately forthcoming. If the change will create a problem, the computer also helps him find a solution.

And finally, the computer can be useful to the dispatcher as he operates the system for maximum economic dispatch. For example, the assignment of available generators to handle the daily load forecast, normally provided on an hourly basis, can be quickly checked to be sure that the system will not be placed in jeopardy by any foreseeable contingency.

A computer that can make the above on-line predictions can be an invaluable aid to the electric utility in making sure that spinning reserve and tie-line and transmission capacity are always adequately maintained for system security.

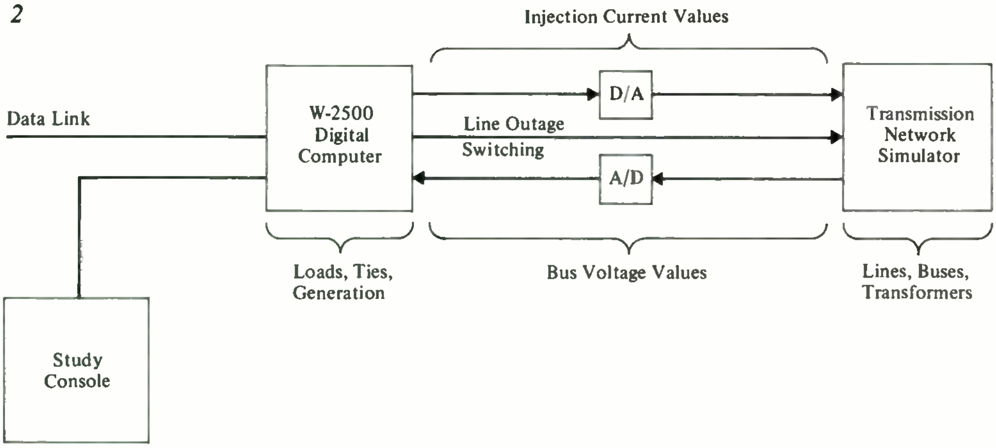
Hybrid Load-Flow Calculator on Line

The first Westinghouse hybrid load-flow calculator went into operation at the New England Power Exchange in 1972. It models a system of 270 lines, 39 of them 345 kV, a few 230 kV, and the rest 115 kV. Peak load on the system is about 11,000 MW. The network simulator simultaneously calculates voltages at all buses within ½ second after receipt of the last bus injection current. After initial system debugging and tuning, load-flow solutions were checked against an all-digital planning load flow; 85 percent of the solutions were found to be within 3 to 4 MW of computed values and 96 percent within 10 MW. The largest discrepancies found (7.5 to 20 MW on the 345-kV lines) were reduced by refinement of the data base to a maximum error of about 10 MW.

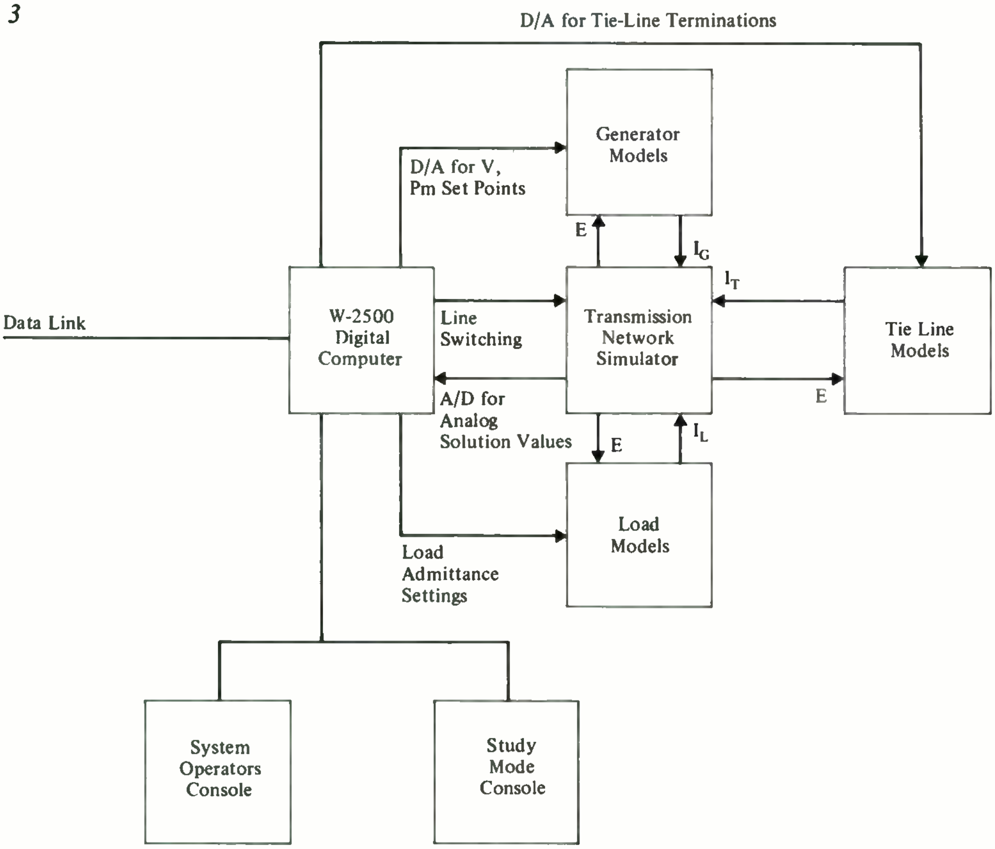
System performance tests run recently at the New England Power Exchange with 38 contingency conditions and an average of six iterations per contingency required a total of 24 minutes machine time. Of that time, only 14 minutes were used for all of the load-flow solutions. The other 10 minutes were used by the machine to check the results against power system equipment limits. Software in the system is capable of running one iteration every 2¼ seconds.

The computer system at the New England Power Exchange includes a Westinghouse P-250 computer used for on-line control, interfaced with a second P-250 computer that operates off-line for accounting, compiling, engineering programs, and system security monitoring. Future security monitoring systems will probably be interfaced through a smaller W-2500 computer furnished with the load-flow calculator. The on-line control computer will only be used for data acquisition, and the W-2500 will perform all control and monitoring functions required for load-flow calculations. This approach is recommended because the on-line duty cycle of the dispatch computer may be high due to the performance of normal dispatching and control functions. The approach also makes it easy to interface the system with any dispatch computer, regardless of model or manufacturer, and it permits the hybrid computer to be used for off-line training and study when not required for on-line operation.

2



3



2—In the hybrid load-flow configuration, the digital computer calculates injection currents and controls line outage switching; the transmission network simulator determines the resulting bus voltage values. The process is iterative until the simulator satisfies system load and generation constraints.

3—The transient analyzer configuration adds generator, load, and tie-line analog modules to the network simulator. The digital computer controls setpoints to these modules to obtain steady-state load flow, inputs line switching to the network simulator, and monitors network response.

Compact 5-MW Superconducting AC Generator Passes Initial Tests

Many electrical generators being supplied for central power stations are large—rated between 600 and 1200 MW—because power needs have risen rapidly in the United States. Large ratings are chosen because the economics improve with increased size. About 2000 MW appears to be the present technical limit on rating, imposed by such size-related problems as heating and centrifugal force on the rotor. However, shipping imposes more immediate size limits, such as the need to get through tunnels and underpasses.

A way to get around the present size limitations is to greatly increase the rating of a particular generator size by using superconductivity. Superconducting wire can carry much more current than can ordinary wire of equal size, resulting in much larger magnetic fields and thereby permitting a three- to four-fold increase in the amount of electric power generated. Therefore, superconducting generators would weigh only 10 to 30 percent as much as present-day generators of the same rating and would have about a third of the volume. The same principles apply to electric motors, since a motor is essentially a generator working in reverse.

A major step has been taken in development of such generators and motors by the recent completion and operation of a 5-MW generator, with a superconducting rotor, at the Westinghouse Research Laboratories. (See photographs.) The generator is about 40 inches in diameter and 63 inches long. It can readily be upgraded to produce 15 MW, and that may be done on completion of thorough testing at 5 MW.

The superconducting wire used in the rotor can carry about 50 times more current than equal-size ordinary wire. Thus, even though the rotor is much smaller than a conventional rotor of equal rating, its magnetic strength is 3½ times as strong (50 kilogauss in the prototype machine).

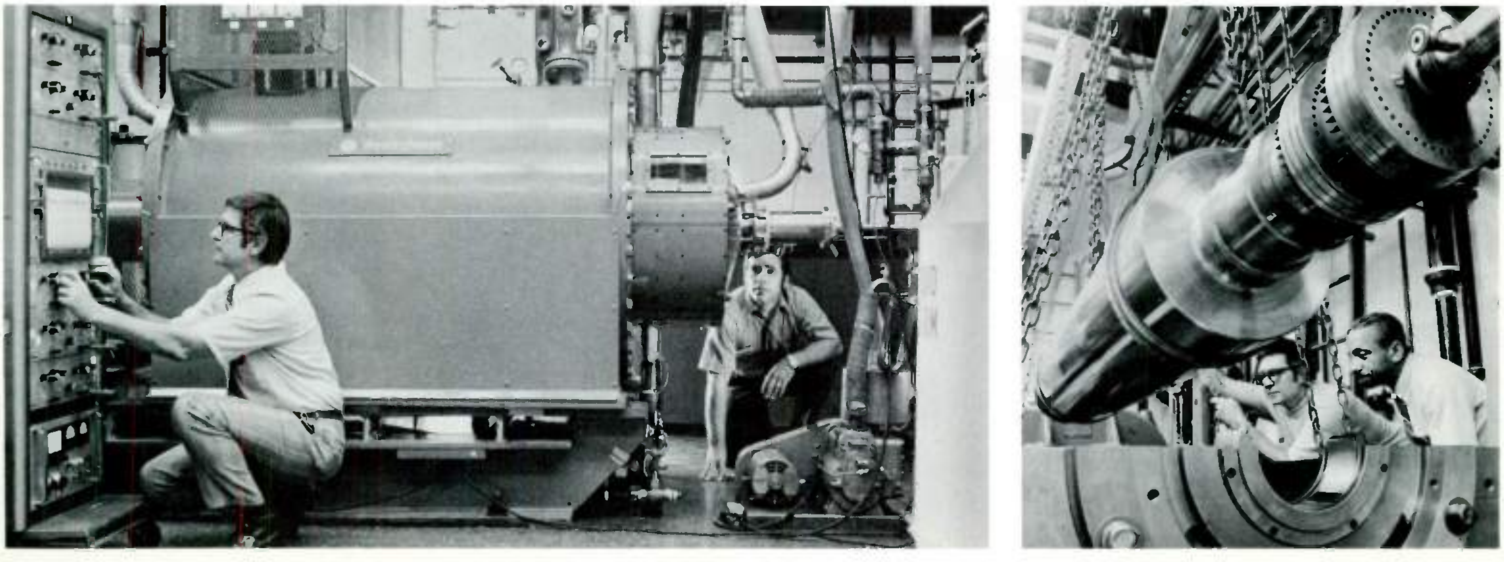
In addition to their shipping advantage, high-power superconducting generators may be more economical to utilities because of lower installation cost and higher efficiency. They are expected to convert into electricity 99.6 percent of the turbine power turning the rotor as compared with the 98.8-percent efficiency of conventional generators. The difference is significant in an advanced industry such as power generation, where improvement of even a tenth of a percent is hard to come by. The reasons for the efficiency improvement are the lack of energy loss in the rotor through resistance heating, reduction in stator winding losses, and reduction in friction and windage losses due to the smaller machine dimensions.

In principle, the Westinghouse superconducting generator is the same as a conventional generator: direct current in the spinning rotor produces a spinning magnetic field that induces alternating current in the copper stator windings. The rotor turns at 3600 r/min to produce 60-hertz power, and the voltage is 4160 volts.

However, the superconducting generator is radically different, in many ways, from ordinary generators because of its use of superconductivity, intense magnetic fields, and cryogenic temperatures. Instead of copper, its rotor is wound with an intrinsically stable superconductor based on a half-and-half alloy of niobium and titanium that has a critical temperature of minus 441.8 degrees F.

That last paragraph contains some terms that are unfamiliar to many, but a brief review of superconductivity will clarify them. First, superconductivity is the state in which some metals offer no resistance to current and therefore do not heat as normal conductors do. Thus, superconducting wire can carry much more current than normal wire. Superconductivity occurs only at very low temperatures; the temperature is different for each material and is known as the material's critical temperature.

In addition to temperature, the strength



This ac generator is rated 5 MW despite its small size, and it could be upgraded to produce 15 MW. A superconducting winding in the rotor accounts for the high ratio of power output to size. The generator's rotor (right) *is being lowered into a test stand. Its superconducting winding is cooled by liquid helium and enclosed in a vacuum vessel for thermal insulation.*

and geometry of magnetic fields affect superconducting materials. A material suddenly loses its superconductivity ("normalizes") in a high-strength magnetic field, even a self-generated field, when it reaches a value known for each material as the critical field.

Premature normalization was a problem in earlier magnet coils because each turn was subjected to magnetic fields from the other turns that could cause normalization by a process called flux jumping. Scientists solved the problem in the late 1960's by making magnet wire from a bundle of fine strands of superconducting material slightly twisted into a spiral and embedded in copper. Wire in that form is known as an intrinsically stable superconductor. The copper draws off heat from any small portion of the strands that may happen to normalize, thus preventing a stray normalization from heating the strands and triggering destruction of superconductivity throughout the wire.

The superconducting alloy used in the Westinghouse generator is a compromise between high critical temperature and good ductility, which often seem to be mutually exclusive in superconductors. It is made into fibers only a thousandth of an inch in diameter, and many of the fibers are embedded in a copper sheath of rectangular cross section measuring 0.066 by 0.144 inch.

The rotor's intense magnetic field eliminates the need for the mass of iron that concentrates the field in the rotor of conventional generators. The stainless-steel structure of the rotor is mainly a support for the windings, which have to be firmly secured against the force of their own magnetic field.

The stator winding is secured to a shell that forms the outside of the stator. Superconductors cannot be used for the stator winding because, while they are lossless under direct current and the resulting magnetic field, their losses are too great when carrying alternating currents or when exposed to alternating magnetic fields. The stator in this machine does not have iron teeth, so its winding is exposed to much stronger alternating magnetic field than is the winding of a conventional machine. That condition results in potentially larger eddy-current losses in the winding, but the problem is overcome by making the winding of stranded copper cable instead of bars.

The stator shell includes an iron shield to insulate the surroundings from the generator's powerful magnetic field, which otherwise might induce currents in metallic objects in the vicinity. The rotor also has to be shielded because alternating current in the stator produces its own alternating magnetic field, which could extend to the rotor windings and not only normalize the superconductor but also (through hysteresis) waste energy in heating the copper portion of the wire. The shielding is a copper jacket surrounding the rotor; it acts as an eddy-current shield that allows the unvarying rotor field to reach the stator windings but prevents most of the alternating stator field from reaching the rotor windings.

Design of the rotor and its cooling system presented the most difficult problems in the project because of the cryogenic temperature needed. As absolute zero is approached, every degree of cooling gets more difficult—it takes 800 watts of cooling power to remove 1 watt of heat at the rotor temperature.

The rotor housing is made like a vacuum flask for thermal insulation, but, even so, heat can get into the rotor by conduction along the drive shaft and along the electrical leads from the exciter, and by some hysteresis and eddy-current heating in the wire. The rotor is extraordinarily sensitive to heat compared with a conventional rotor—little more than 10 degrees separate the temperature of the liquid-helium coolant from the critical temperature of the wire.

Liquid helium circulates slowly through the rotor, coming out as a gas and being reliquefied by refrigeration equipment. The equipment will be made small enough not to detract significantly from the size advantages of the generator.

Other rotor design problems include the need to provide for emergency ventilation of helium in the event of normalization and rapid heat buildup. Also, liquid helium has to be supplied to the rotor continuously while maintaining a low pressure inside and allowing rotation. Finally, metals shrink appreciably when cooled to liquid-helium temperature, a problem where close tolerances are involved.

While no major difficulties are apparent, additional testing of the prototype is needed, and a more powerful intermediate generator must be proven in the field before all of the technical problems related to the very large machines are solved. Special attention will be given to developing superconductors that will carry more current and be even less susceptible to hysteresis normalization. Refrigeration systems that have long life and great reliability will have to be developed.

In addition to the central-station application, uses are foreseen in ship propulsion. Prototype superconducting machinery could be ready for ships in the late 1970's and for central power stations by the mid-1980's. Because superconducting motors and generators will be much smaller than conventional machines, electrically propelled ships will be able to go farther and carry more than they can now. Elimination of the gears, shafts, and lubricants of mechanical systems will make way for systems that are smaller, quieter, cleaner, easier to maintain, less cumbersome to control, easier to automate, and less restrictive in configuration and design.

Aircraft also have electrical equipment requiring power generating systems, and, under contract with the U.S. Air Force Aeropropulsion Laboratory, Westinghouse is now developing a 5-MVA superconducting generator especially designed for use on airplanes.

Hybrid Technology Shrinks ACES Remote Input/Output Unit

Redesign of the remote input-output units for the ACES concept (automatically controlled electrical system) has greatly reduced their size and weight from that of the first-generation demonstration units. (See photograph.) The remote input-output units are data-processing interfaces between the system's control devices and its central control computer.

Second-generation remote input-output units are included in an ACES being installed at NASA's Marshall Space Flight Center in Huntsville for a laboratory installation that will simulate various vehicle control operations. An ACES with the first-generation units was installed last year for a similar application at NASA's Manned Spacecraft Center in Houston.

The ACES concept was developed for advanced aircraft, space vehicles, and other applications to reduce system wiring, crew work load, and the possibility of human error in switching.[1,2] In it, control and indication signals pass back and forth between a programmable computer and a number of remote power controllers, transducers, and indicators (via the remote input-output units and a multiplexed data bus) to initiate operation of the various electromechanical systems in the vehicle and to report the status of those systems.

The computer transmits address and command data over the data bus in periodic scans. When the transmitted address matches the unique address permanently wired into a remote input-output unit's connector, the unit decodes the 64 bits of command data transmitted in that scan and retains the information until the next scan. Buffers in the unit process the command bits and provide 28-volt signals to operate the various control devices in the system.

Each remote input-output unit also can accept 64 inputs from the other direction, such as transducer outputs, limit-switch outputs, and the status outputs (on or off) of remote power controllers. The buffers process the inputs, and the remote input-output unit then transmits the data to the computer for appropriate action.

System reliability is an important consideration, so each remote input-output unit consists of three redundant channels. Each command buffer includes a majority voter so that if one channel fails the remaining two will cause the unit to have the correct response. Status information is transmitted back through three redundant channels and then over three redundant data buses to a majority voter in the computer.

The first-generation remote input-output units had 1550 components, consisting of 1285 discrete components and 265 standard integrated circuits. The resulting package weighed 22 pounds and had a volume of 1850 cubic inches.

Redesign reduced the weight to 7 pounds and the volume to 260 cubic inches. Hybrid circuit technology was responsible for a significant portion of the size and weight reduction. The second-generation remote input-output unit contains 32 identical hybrid dual input-output buffers. Each section of a buffer (input and output) contains a majority voter, an output circuit capable of providing 40 milliamperes at 28 volts, and a circuit with high noise threshold for interfacing the external status signals with transistor-transistor logic gates. Each buffer contains 32 semiconductor chips on a ceramic substrate with an area of 0.3 square inch. Each substrate is hermetically sealed in a 16-pin dual-in-line package. In addition to the hybrid buffers, the unit has 90 standard integrated circuits and 241 discrete components for a total of 363 components, as contrasted with the 1550 components in the first-generation unit.

The remote input-output units are designed and built by the Westinghouse Aerospace Electrical Division. ACES is a joint development of that Division and the Systems Development Division.

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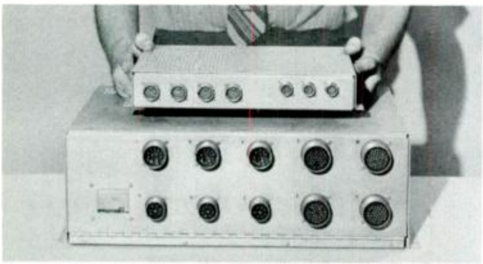
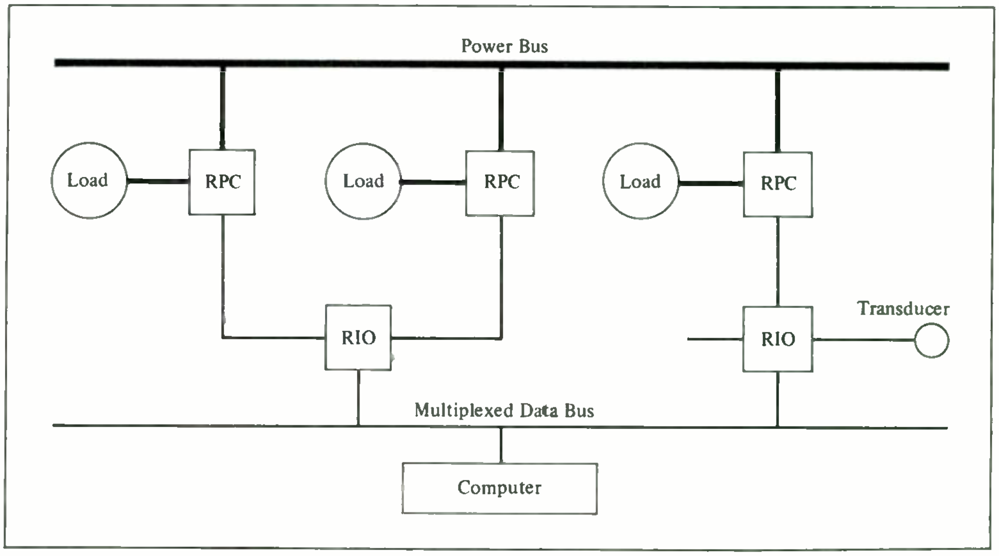




(Above) *Second-generation remote input-output unit, held by the man, was made much smaller and lighter than the first-generation unit below it.* (Right) *The units (RIOs) are used in an automatically controlled electrical system (ACES), which transmits control and indication signals between a programmable computer and a number of control devices such as remote power controllers (RPCs), transducers, and indicators.*

Products and Services

Electric cargo carrier, model 262, is fume-free and quiet, suiting it for indoor uses. The cargo carrier is highly maneuverable. Its deck is 46 inches wide and 74 inches long, behind the seats; removing the right seat increases the deck length to 96 inches for half its width. Speed is 10 to 12 mi/h, range up to 50 miles, and load capacity two passengers plus 1500 pounds. *Westinghouse Electric Vehicles, P.O. Box 712, Redlands, California 92373.*

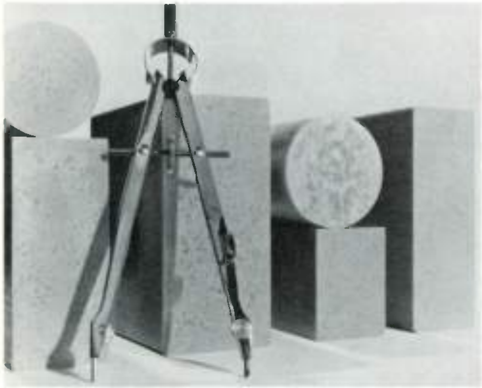
Polyglas pultruded beams with larger cross sections than previously possible are useful for structural applications where metal can't be used because of chemical or electrical problems and wood isn't strong enough. Typical applications include racks above electroplating tanks, lift rods in circuit breakers, tool handles, marine structural members, ladders, guard rails, and antenna structures. Beams with cross sections of 2 by 4¼ inches and even larger are now being fabricated. Pultrusion is a continuous molding process in which a reinforcement material—commonly glass fiber—is pulled through a polyester resin bath and then through heated dies where polymerization takes place. Since the process is continuous, costs are low relative to other methods of producing thermosetting fiber-reinforced parts. Cross-section size has been limited because heat given off by the hardening resin tends to crack thick parts; the problem has been reduced by careful control of processing conditions and use of a special resin/catalyst system. *Westinghouse Industrial Plastics Division, 1585 Lebanon School Road, West Mifflin, Pennsylvania 15122.*

"Why R-C Networks and Which One for Your Converter" is the latest in the Tech Tips series on selection, application, use, and maintenance of high-power semiconductors and subsystems. It explains and illustrates the major causes of voltage transients in typical thyristor converter circuits and the basic approaches to transient protection to prevent malfunction or device failure. Nine fundamental suppression schemes are explained and compared as to relative size, cost, and complexity. A reference list directs the reader to more complete information for specific applications. *Marketing Services, Westinghouse Semiconductor Division, Youngwood, Pennsylvania 15697. (In Europe, Compagnie Westinghouse Electric, 80 Avenue Victor Hugo, 75 Paris 16e, France.)*

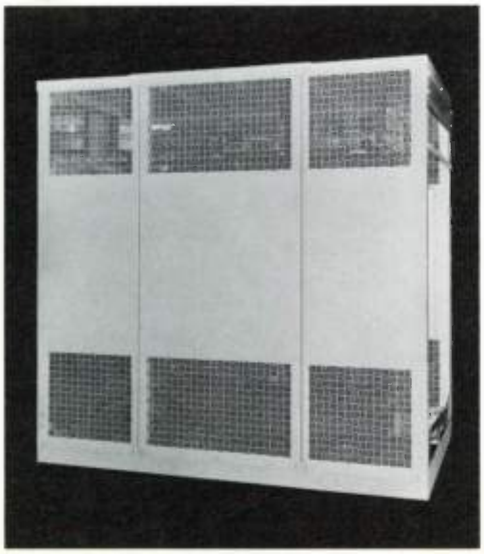
Dry-type distribution transformer is a 34.5-kV device available in ratings through 10,000 kVA for indoor and outdoor use as a power center and distribution-system unit substation. Made in 125- and 150-kV BIL, the new unit is particularly suited for locations where building codes prohibit use of flammable or explosive materials. The transformer is air-insulated and cooled by natural convection. It has a high-strength high-temperature nonhygroscopic varnish that is highly resistant to moisture, industrial and chemical contaminants, and extreme climatic conditions. The absence of valves, gauges, and pumps makes the unit virtually maintenance-free, and it can be installed in any convenient location with no vaults, special vents, domes, or other protection. Case designs vary with the application. *Sharon Transformer Division, 469 Sharpsville Avenue, Sharon, Pennsylvania 16146.*

Training in turbine-generator installation and operation is provided by the Power Generation Service Division for customers' operating and maintenance personnel as well as for its own field service engineers. A new training facility has been established on the campus of Widener College near the Westinghouse plant at Lester, Pennsylvania, a location that gives the staff access to one of the Corporation's major pools of technical talent and specialized knowledge. The resources of the college, including the library, are also available. Training tools include a turbine control-system simulator. Courses are conducted either at the training facility or at a customer's location. *Westinghouse Power Generation Service Division, Lester Branch, P.O. Box 9175, Philadelphia, Pennsylvania 19113.*

Westinghouse ENGINEER January 1973



Polyglas Pultruded Beams



Dry-Type Distribution Transformer

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The 1972 issues of the *Westinghouse ENGINEER* have been assembled in an attractive casebound volume having a durable cover of black buckram stamped with silver. The price is $4.00 in the United States and possessions, $4.50 in other countries. Order from *Westinghouse ENGINEER,* Westinghouse Building, Gateway Center, Pittsburgh, Pennsylvania 15222.

About the Authors

Robert B. Curtis graduated from Lehigh University in 1951 with a BS degree in Civil Engineering. Prior to joining C. W. Blakeslee and Sons, Inc., in 1958, Curtis had worked as a production manager for Eastern Prestress, as a design engineer for United Engineers, and as a field engineer and construction superintendent for Worthington Construction.

Curtis started work at Blakeslee as a design engineer for the Prestress Division, was promoted to General Manager of the Division in 1960, and was named to his present position of Vice President and General Manager of the Prestress Division in 1967. C. W. Blakeslee and Sons, Inc., became a wholly owned Westinghouse subsidiary in December 1969.

Richard Corth graduated from Brooklyn College with a BS degree in chemistry in 1948, and in 1963 he added a PhD degree in physical chemistry from the Polytechnic Institute of Brooklyn. He joined the former Lamp Division in 1955 in the Metals Research Group, where he worked on studies of lamp chemistry and diffusion in tungsten and was responsible for installation and operation of the Division's radioisotope facility. He then moved to the Photolamp Engineering Group and was responsible for the research and development program for an incandescent lamp with a tantalum-carbide filament.

Dr. Corth is now a photobiologist in the Phosphor and Chemical Engineering Department, Fluorescent and Vapor Lamp Division. He is responsible for all aspects of the effects of light on biological systems. Among the developments he has contributed to are the plant-growth lamps described in his article.

C. F. Garland has been responsible for a number of advances in sanitary and environmental engineering. Among them are development of product lines of low- and high-speed surface-entrainment aerators for wastewater treatment and development of integrated biological and physical-chemical wastewater treatment systems for disposal and re-use applications.

Dr. Garland received his BS degree in civil engineering in 1938 at Northeastern University and his MS in sanitary engineering at Harvard University in 1939. He then worked as a sanitary engineer, first for the Maryland State Health Department and later for the Florida State Board of Health. His Army service from 1942 to 1946 included two years in Europe as a Public Health Officer with Allied Civil Affairs/Military Government. He returned to the Florida Board of Health as chief of the sewage and industrial waste division.

In 1947, Dr. Garland went to Johns Hopkins University as a research associate in the Department of Sanitary Engineering and Water Resources. He was project manager for a comprehensive evaluation of the condition and waste-assimilation capacity of Baltimore Harbor, and he earned his DrEng degree in sanitary engineering and water resources.

Dr. Garland joined Infilco, Inc., in 1951 as a sanitary engineering consultant to the Marketing and R&D departments and progressed through a number of management posts. Infilco was acquired by Westinghouse in 1970 and is now the Infilco Division, with Dr. Garland its Manager of Research and Testing. He is responsible for evaluation and development of processes and equipment for water and wastewater treatment, management of government contract research, and internal consultation.

D. L. Moser graduated from the University of Pittsburgh in 1943 with a BS degree in mechanical engineering. After a year in the Army, he joined the Westinghouse graduate student training program. He went from there to the former Gearing Division at the Nuttall Plant in Pittsburgh and worked on virtually every type of gear product made by the Division. In 1957, Moser transferred to the Hydraulic Drives Department as an engineering supervisor. That Department was later sold, and he returned to the Gearing Division.

When the Nuttall Plant was closed in 1960, Moser moved with the Gearing Department to Buffalo as an engineering supervisor. The Department is now a part of the Medium AC Motor and Gearing Division. Developments that Moser has contributed to at Buffalo include the TDS line of speed reducers, redesign of the Moduline gearmotor line, standardization of gear sets for all lines, and the vertical lines of speed reducers.

D. L. Seager is a Lecturer in Engineering at the University of Aberdeen, Scotland, and a consultant to the Mechanics Department of the Westinghouse Research Laboratories. He received his BSc degree in mechanical engineering at the University of Glasgow in 1963 and his PhD degree in applied mechanics at the University of Cambridge in 1967.

Dr. Seager came to the United States in 1967 to join the Sikorsky Aircraft Division of United Aircraft Corporation as a senior design analyst in the transmission group. The following year, he moved to the Westinghouse Research Laboratories as a senior engineer in the Mechanics Department. He worked there until last year in research and consulting on lubrication mechanics, including mechanics of gear systems. He was responsible for developing the dynamic analysis of gear systems used by the Medium AC Motor and Gearing Division and also for the load distribution analysis of gear teeth used by that Division and by the Marine Division. Dr. Seager also contributed to the adoption by the Medium AC Motor and Gearing Division of gear teeth of improved shape (25-degree pressure angle) for certain applications and to development of gearing for the Westinghouse center-post agitator washing machine.

Dr. Seager is a member of the American Society of Lubrication Engineers. He served in 1971 and 1972 as associate editor of the Society's *ASLE Transactions* and *Lubrication Engineering*.

Edward L. Caldwell joined the Westinghouse Oceanic Division early in 1971 to be the lead design engineer on the sensor deck unit and all support equipment for the National Data Buoy Project described in this issue. He came on the job well prepared, having accumulated a dozen years of experience in detail digital design, lead engineering, and program management.

Following graduation from Penn State University (BSEE) in 1960, Caldwell worked for IBM Corporation in computer design. He moved to the U. S. Army Corps of Engineers to design and develop digital systems. Next came a stint with Wyle Laboratories on aircraft autopilot system design. From early 1969 until he joined Westinghouse, Caldwell was with ITT Navigator/Decca Navigator/Avian Associates as project and program manager, responsible for design and development of the Skyguide area navigation system and the Omnitrac computer.

Norman R. Carlson graduated from Dartmouth College in 1959 with an AB degree in physics. He went on to Stanford University, earning his MS degree in electrical engineering in 1961 and his PhD in electrical engineering in 1965.

Dr. Carlson joined Westinghouse in 1961 at the Research Laboratories, where he worked in Control Systems Research. He transferred in 1965 to the Computer Systems Division (now the Computer and Instrumentation Division). There he has worked on the application of digital computers to metal-making control, simulation, and power system analysis. He is now a Fellow Engineer, responsible for application of new techniques and programs in power system analysis and control.

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National Data Buoy. (*See page 18.*)