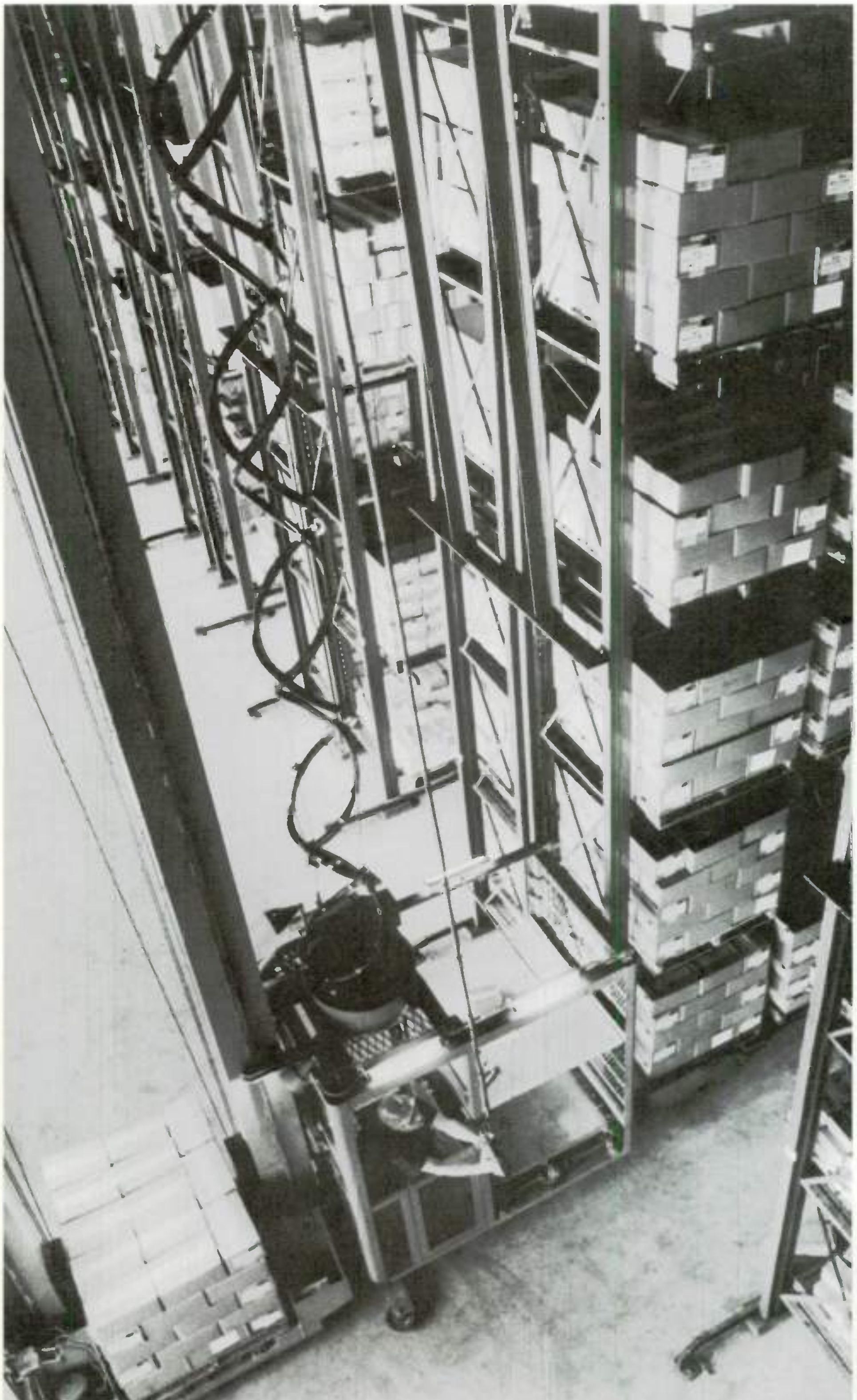
Westinghouse ENGINEER July 1968

Vertical Warehousing System Frees Manufacturing Space

When rising demand for its electrical distribution and control products compelled the Westinghouse Standard Control Division to seek more manufacturing space recently, it found the needed space by expanding into the 80,000 square feet of its former warehouse area. The replacement warehouse occupies only 48,000 square feet because it employs a mechanized vertical storage system designed by the company's Materials Handling Systems Group.

The warehouse is designed around five stacker-picker cranes, plus one special stacker crane for bus duct and oversize pallet loads. The cranes can be moved to any aisle, and they travel along the aisles at speeds up to 260 feet per minute. Their cabs move 36 feet vertically to enable the operators to reach top storage bins. Trays on the back of the cab and a fork on the front let the operator retrieve or store either individual items or a full pallet load. Once an item is selected from one of the 6000 storage bins, it is placed on an overhead conveyor leading to the shipping area.

Besides freeing space for manufacturing, the mechanized warehouse system provides more efficient handling of the Division's large and varied output, which encompasses about 4000 product styles dispatched in 750 to 1000 shipments of wide size range every working day. The system can be converted to semiautomatic operation, with computer-directed cranes, when product demand justifies the changeover.



Westinghouse ENGINEER
July 1968, Volume 28, Number 4

Subscriptions: United States and possessions, $2.50 per year; all other countries, $3.00 per year. Single copies, 50¢ each.

Mailing address: Westinghouse ENGINEER, P. O. Box 2278, 3 Gateway Center, Pittsburgh, Pennsylvania 15230.

Published bimonthly by the Westinghouse Electric Corporation, Pittsburgh, Pennsylvania. Printed in the United States by The Lakeside Press, Lancaster, Pennsylvania. Reproductions of the magazine by years are available on positive microfilm from University Microfilms, Inc., 300 North Zeeb Road, Ann Arbor, Michigan 48106.

Cover design: The concept of year-around environmental control in high-rise buildings is conveyed in this month's cover by artist Tom Ruddy. The Westinghouse Building now being erected in Pittsburgh is shown against a backdrop of color representing the four seasons of the year—winter, spring, summer, and fall. An article about a total electric environmental control system for the new building and other high-rise buildings begins on the next page.

Combining Lighting and Temperature Conditioning Saves Money in All-Electric High-Rise Building

Lisle G. Russell

The sixth and final office building in Gateway Center, Pittsburgh, Pennsylvania, will be total-electric, featuring a modern high-light-level lighting system incorporated in a sophisticated yet simple environmental control system. Analysis shows that it will cost no more to build and less to operate and maintain than conventional office buildings of comparable size.

The new Westinghouse Building, to house the Corporate Headquarters of Westinghouse Electric Corporation, is rising this year and will complete the Gateway Center office building complex. The 23-story building will be the largest total-electric office building in the northeastern part of the nation. Electricity will be used conventionally for elevators, lighting, electric stairways, and general power services, and in addition, electrically powered heat-transfer systems will redistribute heat in the building for environmental control. That redistribution of heat will provide all of the cooling and heating required, with practically all of the heating supplied by heat that otherwise would be wasted.

The basic structure of the building will be a steel frame, with curtain walls of aluminum and glass. The floor plan is one that has proved both practical and popular: in the center core are the elevators and other services, and surrounding them is an interior open area in which secretaries and others will work. Around the perimeter of the building are the executive offices. The architect has used a modular design, allowing the building owners to make any number of changes in office layout to suit the changing needs of tenants.

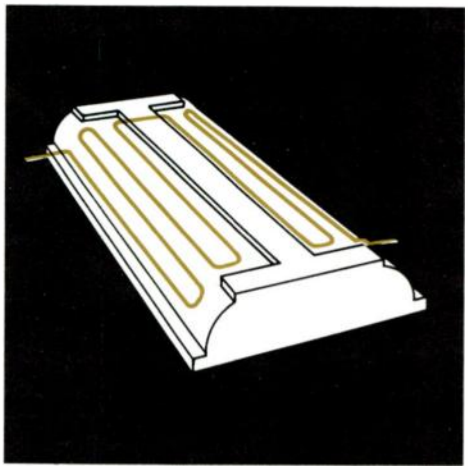
From an environmental control point of view, there is a basic problem with the conventional floor plan just described. Summer, fall, winter, and spring—heat must be moved. Except in the most extreme below-zero cold, the interior area always has too much heat. The perimeter offices, on the other hand, have a definite seasonal problem. During the winter they lose heat through the walls and windows. In summer, they build up too much heat, even though the building has insulated curtain walls and double-glazed windows of heat-absorbing glass.

Lisle G. Russell is a mechanical systems engineer in Major Projects and Urban Systems, Construction Group, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania.

Environmental Control

Basically, the new building's environmental system will almost always be moving heat *out* of the interior area, and either moving heat *out* of the perimeter area also or *into* it.

The Westinghouse Building—like many other modern buildings—has many built-in sources of heat. The largest constant source is the lighting system. The executive perimeter offices will enjoy a minimum artificial lighting level of 150 footcandles, and the open interior areas will often average from 200 to 225 footcandles. These illumination levels conform with the most recent recommendations of the lighting industry, and they are one of the chief attractions of the building. Many of the commercial buildings now being built have only 60 to 75 footcandles and will seem quite dark compared with the Westinghouse Building.



1—Water-cooled lighting reduces the amount of light heat that would normally enter the conditioned space by as much as 70 percent. Each recessed water-cooled lighting fixture has water channels in its housing for passage of cooling water. Flexible connectors are used to accommodate slight movements or vibrations and to permit fixture relocation without draining the cooling-water system.

These levels of lighting bring a bonus or a liability in heat. Approximately 20 percent of the electrical energy that flows into a modern fluorescent lamp emerges as useful light energy (and even that eventually converts to heat energy); the other 80 percent is converted directly to heat.

People are also heat sources, as are all the many types of office machinery in clerical work areas. This is why the interior area especially has more heat than it needs—even during the winter. It has many heat sources, and no exterior walls to drain the heat away. During winter months, the opposite is true in the perimeter office areas.

In the Westinghouse Building, all these heat sources add up to enough heat to take care of all the building's heating needs some 95 percent of the occupied time. Obviously, a traditional heating system is not needed. What *is* needed is a way to get the heat from the wrong places to the right places. Excess heat should be taken from the interior and moved to the perimeter offices during the winter, or into a storage system where some of it can be saved to heat the building at night and on weekends. Also, it is necessary, at times, to get some of this heat out of the building entirely, to just "dump" it. The last of these choices is, of course, the process of cooling by refrigeration; not moving coolness *in*, but moving heat *out*.

That needed "heat transferring" is started at the logical place—the lighting fixtures (Fig. 1). The fixtures will be cooled by water passing through channels that are an integral part of each fixture. The water will pick up heat from the lighting fixtures and carry it away, thereby sharply decreasing the amount of heat that would otherwise escape into the occupied area.

The water passages in the fixtures are made of bonded-steel sheets (forming the housing) that have a high rate of heat transfer. The cooling network is modular in design, with each module usually consisting of five fixtures connected in series. A minimum of 70 percent of the input

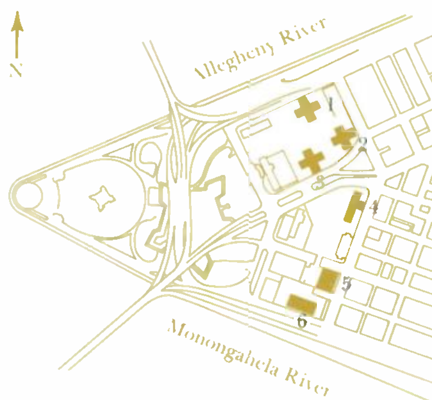
Gateway Center

When the Pittsburgh rebirth began at the end of World War II, The Equitable Life Assurance Society of the United States purchased the land at the confluence of the Allegheny and Monongahela Rivers, a blighted commercial area. Equitable demolished the buildings, cleared the area, and began construction of an office building complex called Gateway Center.

Equitable, working with Pittsburgh's planners, laid out a six-building scheme that stretched from three buildings in the north section of the Center to the final, the sixth building, in the south (see diagram below). The first three buildings (One, Two, and Three Gateway Center) were started almost simultaneously. They have stainless steel for the outside nonsupporting walls and are cruciform in cross section to give more offices outside exposure to the scenery of Point State Park and the three rivers. Four Gateway Center is an award winner, outstanding for its creative use of glass. The IBM building (Five Gateway Center) was another innovation in building design; its exterior walls are supported at the ground at only eight points and it wears an *outside* skeleton of high-strength steel.

Equitable's desire to incorporate in its buildings the latest construction technology is again realized in the last Gateway Center building—the Westinghouse Building—an all-electric high-rise building. A photograph of a model of the new building is shown at left.

Equitable has been careful in developing its property to provide parking facilities and a park-like atmosphere that has gained public acceptance of this method of land development.



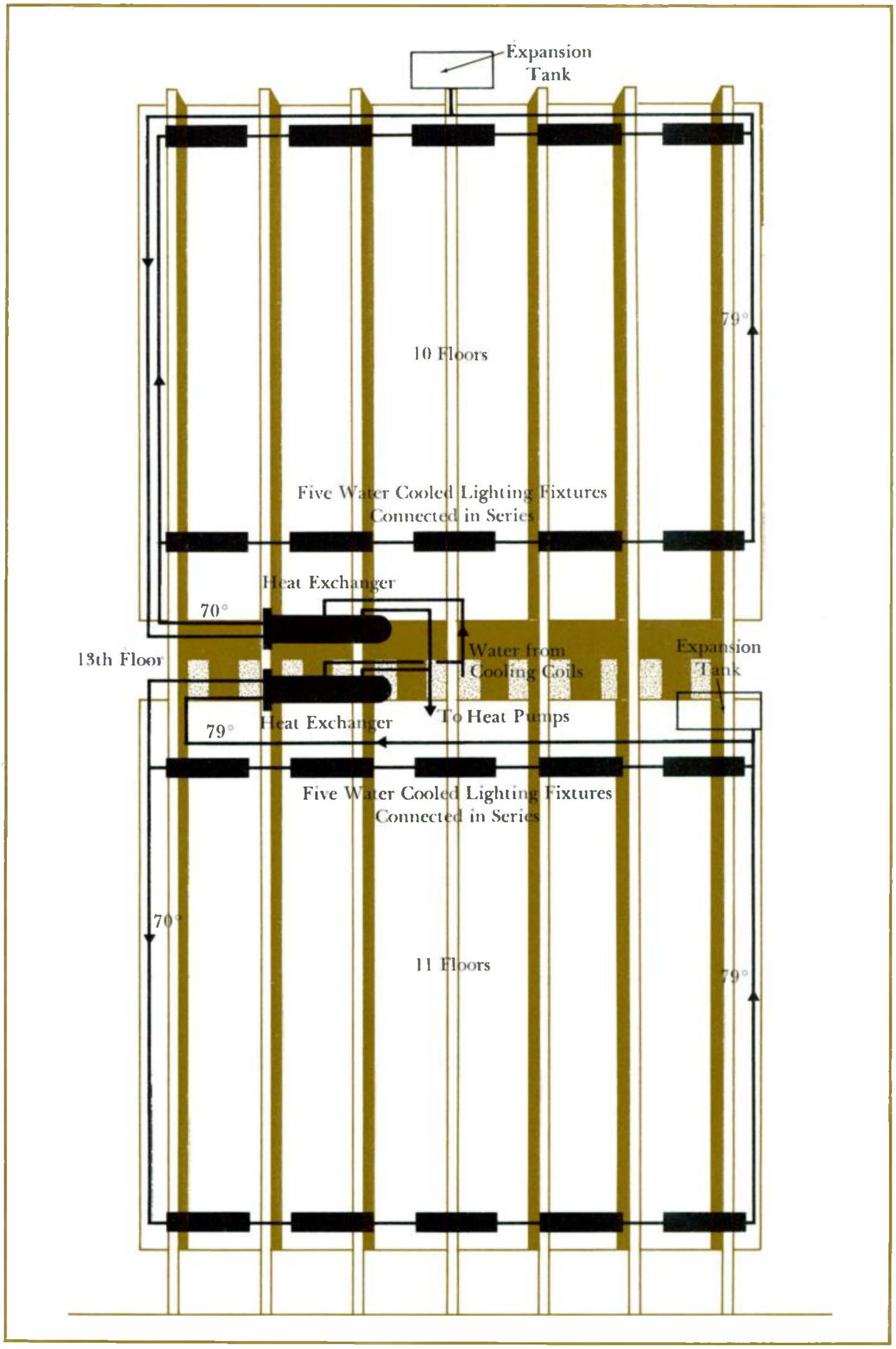
electrical energy from the lighting system is picked up as heat by water, at 70 degrees, circulating at 0.8 to 0.9 gallon per minute through the network. The desired lighting levels are achieved by operating the lamps at a lower temperature than they would be in uncooled fixtures, thereby increasing the lumen output of each fixture by about 10 to 12 percent. Although 7.1 watts per square foot is fed into the system, only 2.1 watts enters the area as heat.

The heat-removal system for the lighting is divided into two closed-loop water circulating systems (Fig. 2). The water in the upper loop is circulated up 10 floors through about 400 light fixtures per floor and returned to a heat exchanger on the 13th floor, carrying with it about nine degrees of heat from the light fixtures. The water in the lower loop is circulated down eleven floors through about the same number of fixtures per floor and is carried back to a second heat exchanger. The heat exchangers remove the heat from the lighting system and send the water back toward the light fixtures at its original 70 degrees.

The heat has now been transferred to a second water system operating at a lower temperature. The chilled water from the cooling coils enters each lighting system heat exchanger at approximately 55 degrees; after the lighting heat has been added to it, the water leaves at approximately 57 degrees and returns to the heat pumps. The chilled water, having removed much of the excess heat from the wrong places, must now transfer that heat to the right places.

The transfer process begins by taking the heat away from the 13th floor mechanical room, by way of the closed-loop chilled water circulating system, to heat pumps in the basement mechanical room. A heat pump is essentially a device that raises the energy level of the heat being supplied to it and moves heat from one place to another, so it meets the needs of the building.

The heat that has just moved downstairs in the chilled water system at approximately 57 degrees enters the heat pumps and is extracted from the water; it is now available for reassignment. It can



2—The thirteenth floor houses lighting system heat exchangers, air handling systems, and other mechanical equipment. Two closed-loop water circulating systems remove heat from the lighting fixtures and transfer it to the heat pumps for redistribution. (The superimposed water circulation diagram is drawn larger than scale for the purpose of illustration.)

either be dumped or sent back into the building to the right places. (These processes will be explained later.)

In addition to the heat from the lighting fixtures, there is also the heat from people and machines, from the uncaptured radiant heat the light fixtures give off, and, in summer, from the sun and outside air. This excess heat is picked up by an air distribution system, which supplies air to (and draws air out of) both the interior areas and perimeter areas (Fig. 3). As the air system draws air *out*, it takes heat along with it. The heat-laden air is carried through ducts to the 13th floor where the main air-handling systems are located. At the blowers, some of the circulated air is bled off and is replaced downstream from the cooling coils with fresh air. The bled-off stale air, at about 75 degrees, is sent down to the underground parking garage to help warm it in the winter and cool it in the summer.

The air in the building is completely changed at least eight times an hour, and some locations will enjoy an air change 14 times an hour. These air turnover rates are appreciably better than those in most modern office buildings. The air is electrostatically cleaned in each air handling system to remove pollen and other contaminants, and its humidity is controlled.

The rapid rate of air turnover eliminates smoke and other fumes that often linger when other systems are used. There is no "changeover" period when the system is changing from winter to summer or summer to winter operating conditions, since the air-handling system provides heating and cooling capability every hour of every day.

The incoming air in Pittsburgh can vary in temperature from a low of −20 degrees to a high of 95 degrees. Thus, the typical mixed and freshened air returned to the air-handling system can vary from a low of about 45 degrees to a high of about 85 degrees. Such variation in air temperature wouldn't be desirable because it would require additional controls and larger equipment; it will be eliminated in the Westinghouse Building by two outdoor-air systems that will precondition the incoming outside air by filtering, humidifying or dehumidifying, and heating or cooling to a constant 60-degree temperature. To cool the building the air will remain at 60 degrees, and to heat it the air temperature will be raised to 87 degrees.

This two-temperature air supply is provided by splitting the moving air into a two-duct system. One of the ducts passes through heating coils, and the other through cooling coils.

Actually, there are four double-duct air-supply systems, each serving one quadrant of the building. Two high-pressure air-makeup systems pump fresh air, at 60 degrees, into the cold side of each of the four double-duct systems.

The heat pump supplies heat to the heating coils and removes heat from the cooling coils. In the cold side of the air distribution system, water coming from the cold-water side of the heat pump at 45 degrees extracts a sizeable amount of heat from the air passing over the cooling coils in the duct. That reduces the temperature of the air in this half of the recirculating air system to the required 60 degrees, and the heat removed is carried by way of a side trip through the lighting system back to the heat pump.

The heat pump now has removed heat both from the lighting fixtures and from part of the recirculating air. Consequently, it now has at its disposal a large amount of heat that can be used as required.

In the winter, all or most of this heat is sent right back into the building, by connecting the hot-water side of the heat pump to the air-heating coils in the other half of the double-duct system. Thus, the temperature of the air in this system is raised to 87 degrees, about the same temperature at which air is obtained from a forced-air furnace system.

On hot summer days, the building thermostats will not call for much heat from the hot air duct. Therefore, when heat arrives at the heat pump, most of it will be diverted into the river-water condenser system, which will dump the heat into the Allegheny River. (The river-water condenser system will be the existing system now located in Three Gateway Center. It was designed for greater capacity than required for the existing Gateway Center buildings.)

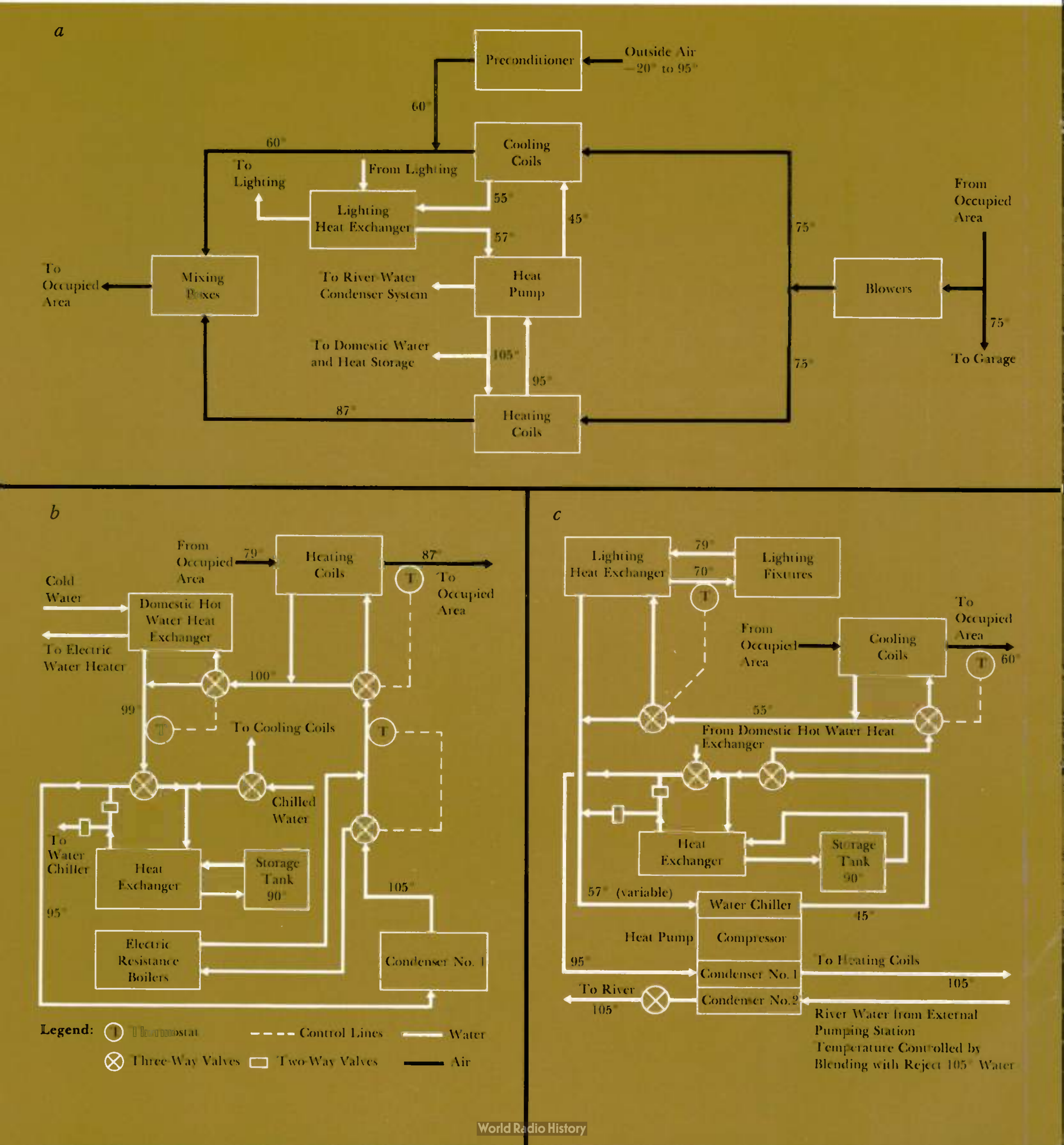
In summary, heat is extracted from the lighting fixtures and brought to the heat pump. Heat is also extracted from the air moving through one side of the double-duct recirculating air system. These two sources, with rare exceptions, supply all the heat required to handle the building's needs even in midwinter. In fact, most of the heat in the building is retained, except for the amount lost in exhausting stale air or through normal building losses.

Some additional details of the air-handling system deserve a closer look. Throughout the building are air mixing boxes designed to mix the hot and cold air to meet the exact needs of each perimeter office and each modular area of the interior. Air is supplied to the interior through a network of small, flexible ducts connected to air diffusers in the lighting fixtures. The perimeter offices have air diffusers located below each window. Air is returned, through slots in the light fixtures, to the ceiling plenum and the central system. Certain fixtures are used to supply air while other fixtures remove air, depending on the heating and cooling needs and air diffusion patterns of the area where those fixtures are located.

The system is designed so that partitions can be moved freely without regard for the air-handling system. Both the mixing boxes and low-pressure air diffusers are isolated acoustically from the occupied areas to minimize the levels of air noise.

The ventilation rate (outside air) for both perimeter and interior areas is approximately 0.25 ft^3/min per square foot. Each mixing box is controlled by a thermostat in the return-air slot of the light fixture. If an area needs heat, the thermostat allows more air to be drawn in through the hot-air half of the double-duct system. If the area needs more cooling, the thermostat triggers the mixing box to draw more air in from the cold duct.

Subsystems—A design review of the building, which incorporates good insulation and high internal heat loads, indi-


a
Preconditioner
Outside Air
−20° to 95°
60°
60°
Cooling
Coils
To
Lighting
From Lighting
Lighting
Heat Exchanger
55°
57°
45°
75°
From
Occupied
Area
To
Occupied
Area
Mixing
Boxes
To River Water
Condenser System
Heat
Pump
Blowers
75°
To Garage
To Domestic Water
and Heat Storage
105°
95°
75°
87°
Heating
Coils
b
From
Occupied
Area
79°
Heating
Coils
87°
To
Occupied
Area
Cold
Water
Domestic Hot
Water Heat
Exchanger
To Electric
Water Heater
100°
99°
To Cooling Coils
Chilled
Water
To
Water
Chiller
Heat
Exchanger
Storage
Tank
90°
95°
105°
Electric
Resistance
Boilers
Condenser No. 1
Legend:
Control Lines
Water
Three-Way Valves
Two-Way Valves
Air
c
Lighting
Heat Exchanger
79°
70°
Lighting
Fixtures
To
Occupied
Area
From
Occupied
Area
Cooling
Coils
60°
55°
From Domestic Hot Water Heat
Exchanger
Heat
Exchanger
Storage
Tank
90°
57° (variable)
Water Chiller
45°
Heat Pump
Compressor
95°
To Heating Coils
Condenser No. 1
105°
To River
Condenser No. 2
105°
River Water from External
Pumping Station
Temperature Controlled by
Blending with Reject 105° Water

cated that there would nearly always be *excess* heat energy available. Consequently, two subsystems (see Fig. 3) were incorporated to make additional use of the heat sent through the coils in the hot-air half of the double duct system. That heat comes from the heat pump at approximately 105 degrees. It returns to the heat pump at 95 degrees after it passes through two heat exchangers.

The first heat exchanger picks up some of the excess heat from the hot air system and uses it to preheat the building's domestic hot water supply.

The second heat exchanger transfers excess heat into a storage tank (located in the unrentable space below a parking ramp) containing 150,000 gallons of water. The water in that tank is heated to approximately 90 degrees. Then at night and on weekends, when the lights are off and the people gone, this heat is extracted and put back into the building. During the winter, enough heat can be stored in the water tank to keep the building warm through a two-day weekend, though not through every three-day weekend.

To take care of that occasional third day or when temperatures dip well below zero, there is an auxiliary system consisting of two small electric resistance boilers. Located in the basement, near the heat pumps, they are the only resistance heating devices in the central system.

Therefore, the only energy expended during a normal heating weekend will be the energy to operate the fans, chillers, and circulating pumps. By storing the heat energy that was already available in the building, a yearly operating saving of approximately $15,000 to $17,000 is predicted.

3—An electrically powered air-handling system (*a*), consisting of a heating circuit and a cooling circuit, redistributes building heat for environmental control. The heating circuit (*b*) provides practically all of the heating from heat that would otherwise be wasted; the electric resistance heaters will be needed only occasionally. The cooling circuit (*c*) cools by distributing excess heat to a heat exchanger for preheating the domestic hot water supply, to a storage tank for future use, or to a river-water condenser system for disposal.

Energy conservation and heat redistribution through the water-cooled lighting system and air supply systems are examples of the type of design engineering that has made total-electric office buildings economically attractive and feasible.

Computer Studies

The preceding analysis is not guesswork. Thanks to modern computer technology, more is known about the Westinghouse Building, which is not yet standing, than is known about most buildings that have been standing for years.

The use of computer technology for rapidly and accurately calculating the many variables that must be considered in environmental design is beyond the experiment stage. In 1964 computer engineers of the Westinghouse Construction Group began to offer this kind of service to the construction industry. Equitable decided to use the computer service itself when the time came to decide on the type of mechanical system to be incorporated in the new building.

Once the heating and cooling data was obtained, four basic mechanical and electrical systems were designed: a conventional system with steam heat and refrigeration, an all-air system with conventional lighting, an all-air system with water-cooled lighting, and an all-air system with water-cooled lighting and heat storage capability.

The operation of those four designs was simulated by the computer to determine what the energy requirements of each would be, while still staying within the economic limits previously established. Duquesne Light Company then determined the operating costs of the systems with both steam and electric energy. Also, the computer results assisted the consulting engineer (Meyer, Strong and Jones, New York) and the architect (Harrison and Abramovitz, New York) in preparing detailed specifications for the equipment required by the four systems.

The computer studies indicated that by using the environmental system described in this article it would be possible to have a total-electric building, with its higher lighting levels, at no extra cost in either capital investment or operation and maintenance.

The major reason why initial capital investment is no higher than it would have been with conventional systems is the use of the water-cooled lighting system to move heat, thereby reducing the amount of ductwork needed. The core of the building and the enclosed space above the ceilings still will contain many miles of ductwork, but not nearly as much had water-cooled lighting fixtures *not* been used. If water-cooled lights were not used, an additional 360,000 cubic feet of air per minute would have to be handled.

Moreover, elimination of that amount of air to be handled reduced the duct sizes and in turn reduced the height of the building by 37 feet, greatly reducing construction costs. Also, it made available another 4000 square feet of rentable space (space normally needed to house the larger shafts for air ducts).

Calculations also show that the water-cooled lighting system will save some $13,000 a year in operating costs, the money it would have cost to move all the extra air. That saving is in addition to the saving predicted because of heat storage.

Today, the new Westinghouse Building is an architect's plan and a steel structure climbing steadily higher. But soon, sometime in 1969, Westinghouse employes will move to one of the most modern office facilities in the world.

Soon many other new total electric high-rise commercial buildings will be in the planning stages or under construction in northern cities. Studies conducted here give proof that total-electric office buildings are economically feasible in cold climates.

Or to put it another way: All that was needed was, first, a fresh approach to environmental engineering—a willingness to break out of old familiar ways of thinking—and, second, basic system planning and computing to ensure reliability in the new method of environmental conditioning. The total-electric building—the Westinghouse Building—is becoming a solid, successful fact in Pittsburgh.

Planned Installation Speeds Startup of Industrial Systems

William S. McIntyre

Installation of today's more complex (and more capable) electrical systems for industrial processes requires well-managed planning and coordination to get the process into profitable production quickly. The supplier's systems management ability can be applied effectively to installation and startup as well as to the initial design and manufacture of the equipment.

Anything that can be done to place a large and complex industrial process into production faster improves the purchaser's return on his capital investment. Yet, surprisingly, two of the main factors in getting a process line going quickly—installation and startup—are rarely even mentioned in a customer's query about a project.

Actually, much can be done to reduce installation and startup time. Effective planning and management of the *entire* project is the key, beginning with the contract negotiation itself.

Need for Project Management

The complexity of modern industrial process lines has made effective planning through project management essential to the electrical supplier. Until about 15 years ago, the electrical supplier usually provided only *apparatus*, which the purchaser installed along with the mechanical equipment. Today, the electrical apparatus is unified under more complex control systems, and the electrical supplier has become a *systems* supplier with responsibility for the electrical performance of the complete system.

Since performance of individual system components is influenced by the performance characteristics of other components, the design of all must be closely coordinated to obtain the desired total performance. Only careful planning within the supplier's organization—coordination of application engineering, equipment design, manufacture, and factory test—can insure on-time delivery of the complete system to the customer. This coordination for a complex systems installation is accomplished by project management—utilizing such modern management tools as computer simulation for system design, and computerized scheduling with PERT and with critical-path techniques.

However, on-time delivery of system equipment at the purchaser's door cannot guarantee that the process will go into production in minimum time. The more complex the process, the more involved the installation and startup procedures and the more possibility for delays. Longer lead times are required for installation and adjustment of some components than for others, and many of the components must be adjusted in sequence. Thus, the systems management approach that is so useful for system design and component manufacture is also needed to plan and schedule installation and startup. Planning should begin with plant construction and follow on through mechanical equipment installation, electrical apparatus installation, control and instrumentation test and adjustment, and all the many other tasks that must be completed before the process can go into production.

Project Management Resources

Suppliers of industrial electrical systems now have experience with project management techniques and tools, and they have demonstrated the effectiveness of those tools in design and manufacture of complex systems. They can also apply the same systems management capability advantageously to installation and startup. In fact, the Westinghouse Industrial Systems Division was organized for that very purpose. Major contracts negotiated by the division define all installation and startup responsibilities, the organizational structures for implementing those responsibilities, and the time schedule.

During contract negotiation for an industrial system, individual and mutual responsibilities of all personnel that will be involved are agreed on and specified. That step avoids the confusion and uncoordinated effort that can otherwise occur. With the installation and startup schedule clearly outlined, the design, manufacture, and test of hardware is scheduled to meet installation requirements. Software, such as instruction books and computer programs (when a process computer is involved), is also planned so that it will be ready when needed.

Components that can be pretested and adjusted in the factory are scheduled with sufficient time allowed for factory testing, often with computer simulation of the rest of the system. That procedure greatly facilitates plant startup operations because any errors are located and corrected before the purchaser's process and time are involved.

Managing a Systems Installation and Startup

The installation and startup of every industrial process system must be tailored to the individual needs of that system. In general, however, the plan follows the sequence shown in Fig. 1.

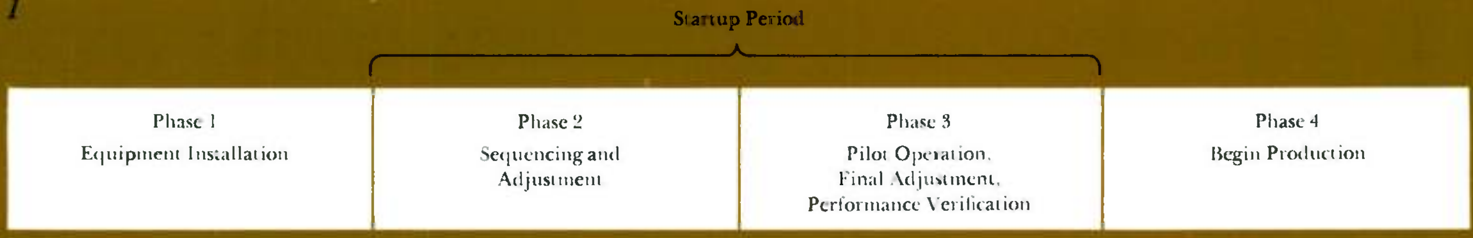
Before the beginning of equipment installation, the purchaser and supplier meet to plan and schedule installation and startup. The responsibilities and the type and extent of services to be provided by the purchaser or his contractors and

1—In Phase 1 of a systems installation and startup program, the purchaser or his contractors provide the necessary supervision and responsibility in receiving, storing, mountng, and aligning the components. Westinghouse provides technical assistance on a contract basis, if desired. Phase 2 begins after all equipment has been completely installed and wired and is ready to be energized as a system. Final adjustments are made during Phase 3 to obtain specified system performance. With Phase 4, production starts after all performance specifications have been met.

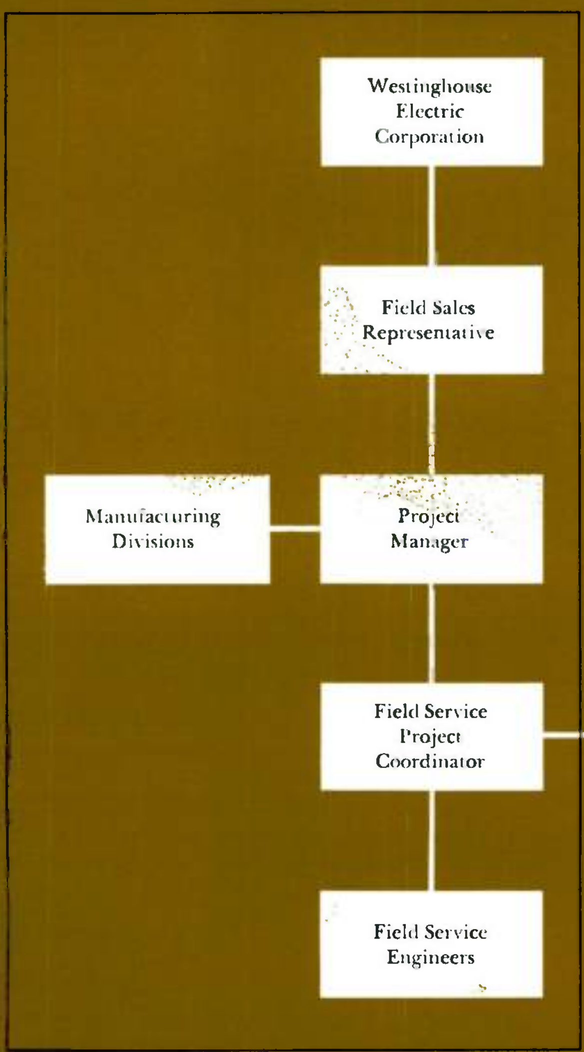
2—Before any equipment is installed, the supplier (Westinghouse) and the purchaser agree on responsibilities and procedures. The supplier provides a chart (*a*) that shows how each member of his project team reports. The purchaser provides a similar chart of his project organization (*b*), which is tied to the supplier's organization through the field service project coordinator. Such short communications lines minimize misunderstandings and delays in the installation and startup.

William S. McIntyre is General Manager, Industrial Systems Division, Westinghouse Electric Corporation, Buffalo, New York.

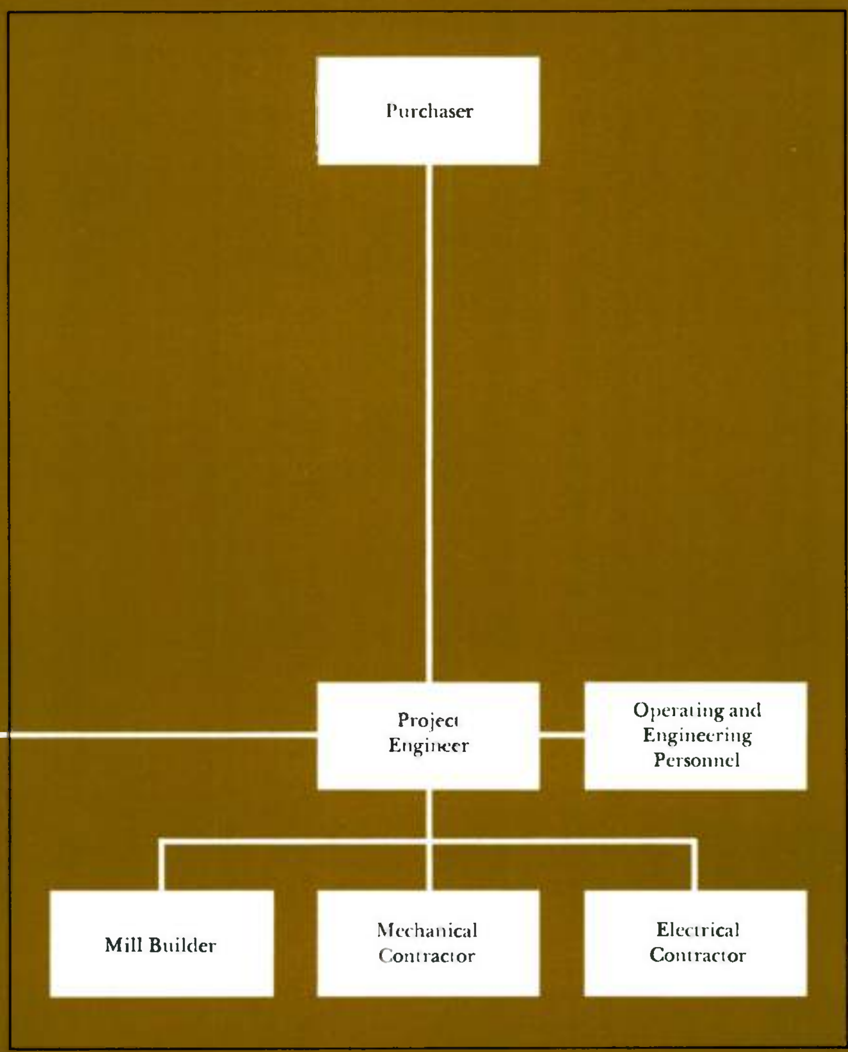
1


Startup Period
Phase 1
Equipment Installation
Phase 2
Sequencing and Adjustment
Phase 3
Pilot Operation, Final Adjustment, Performance Verification
Phase 4
Begin Production

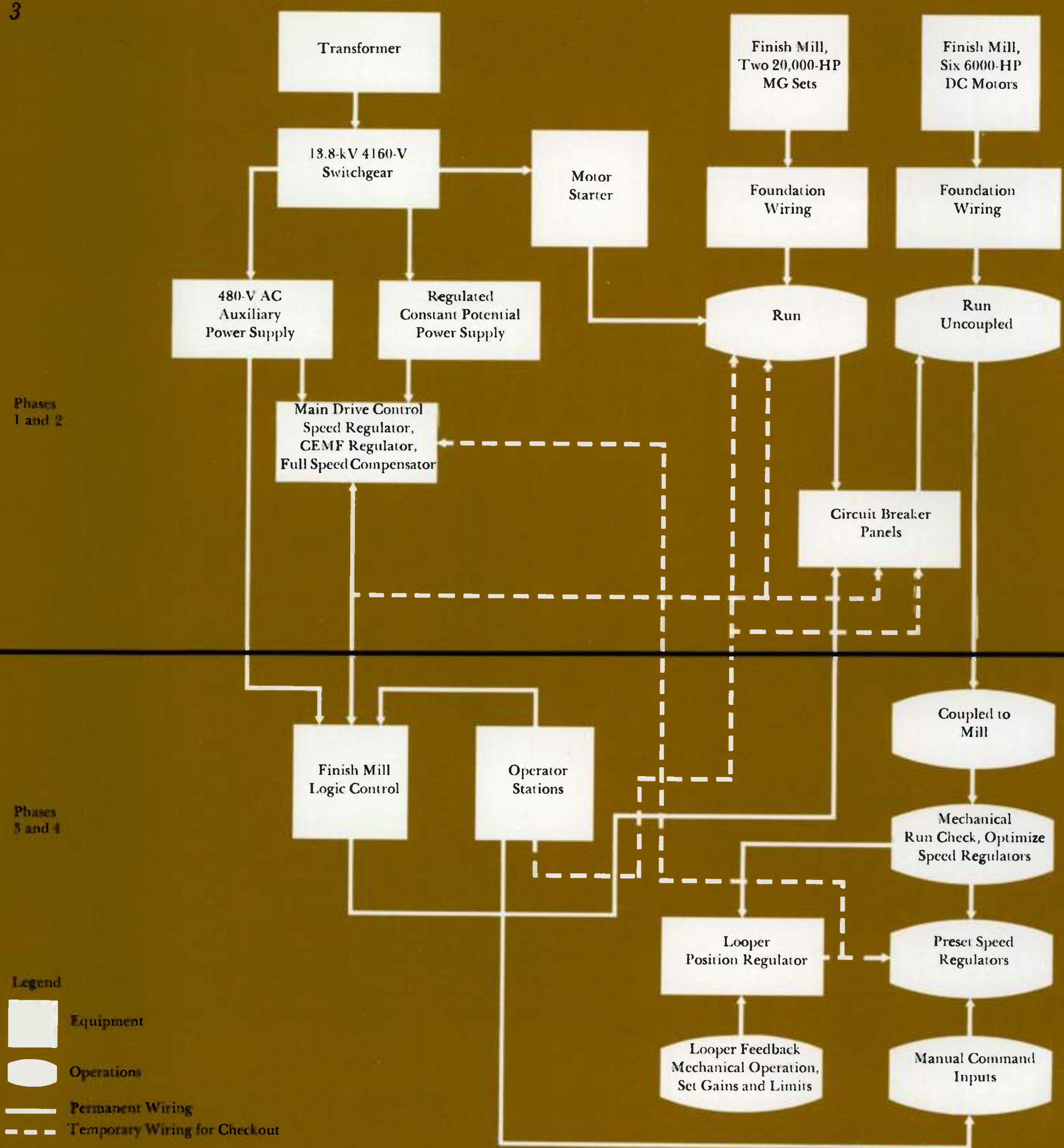
2a


Westinghouse Electric Corporation
Field Sales Representative
Manufacturing Divisions
Project Manager
Field Service Project Coordinator
Field Service Engineers

b


Purchaser
Project Engineer
Operating and Engineering Personnel
Mill Builder
Mechanical Contractor
Electrical Contractor

3


Transformer
13.8-kV 4160-V Switchgear
Motor Starter
Finish Mill, Two 20,000-HP MG Sets
Finish Mill, Six 6000-HP DC Motors
Foundation Wiring
Foundation Wiring
480-V AC Auxiliary Power Supply
Regulated Constant Potential Power Supply
Run
Run Uncoupled
Phases 1 and 2
Main Drive Control Speed Regulator, CEMF Regulator, Full Speed Compensator
Circuit Breaker Panels
Coupled to Mill
Finish Mill Logic Control
Operator Stations
Phases 3 and 4
Mechanical Run Check, Optimize Speed Regulators
Looper Position Regulator
Preset Speed Regulators
Looper Feedback Mechanical Operation, Set Gains and Limits
Manual Command Inputs
Legend
Equipment
Operations
Permanent Wiring
Temporary Wiring for Checkout

by the supplier are reviewed so that each person will understand his role in all phases of the project.

The supplier provides an organization chart to show the responsibilities of his participating personnel (Fig. 2a). Lines of communication and responsibility within the organization are clearly identified. Typically, the Westinghouse personnel who are most directly involved are the field sales representative, the systems project manager, and field service personnel.

The sales representative has overall responsibility for commercial negotiations with the purchaser, and the project manager from the Industrial Systems Division is responsible for the overall engineering (including installation and startup) of the total systems project. He maintains day-to-day contact with the field service project coordinator and stays with the project until it is completed. He is the focal point for the overall coordination of all aspects of the project within the supplier organization, from order entry through startup.

The field service project coordinator is the lead engineer designated to provide the day-to-day job-site technical direction of the installation and startup. Depending on work requirements, varying numbers of other field service engineers work under his direction on different phases of the project. All communication with the purchaser regarding the daily work program goes through the field service project coordinator once he begins active participation at the job site.

The purchaser provides a similar outline of his organization related to the project, naming the project engineer with whom the supplier's field service project coordinator can clear all matters requiring comments or decisions from the purchaser or his contractors. The combined installation and startup organization might then be as illustrated in Fig. 2, *a* and *b*.

The advantage of this form of organization is that it provides short lines of communication. Problems can be identified and solved quickly because day-to-day discussion between the purchaser and the supplier involves only two people. Delays caused by any of the parties involved can be quickly pinpointed, and the responsibility for those delays cannot be shifted.

With the organization established, a bar chart or a PERT diagram is prepared for the purchaser. It shows in detail the recommended sequence for installation of all the electrical system components. If the recommended installation sequence is followed, system checkout can begin sooner and can proceed in the most orderly manner.

Also, a list of equipment installation sequences is provided so that the purchaser will know what equipment must be ready during each phase of checkout and startup (Phase 2). For example, all or part of the system must be set in place, aligned, interconnected, and ready to be energized before checkout can begin (Fig. 3).

With the equipment installation sequence clearly outlined, the purchaser can dovetail his construction schedule with the supplier's checkout chart. The purchaser and the supplier have now established a complete and realistic timetable for the whole system installation and startup.

For the system to meet the established begin-production date (Phase 4), the schedule must be followed closely. Any slippage in the installation phase will force an automatic extension of startup dates. Providing additional engineering manpower during startup seldom shortens the required checkout time, because the startup schedules are based on use of an optimum number of experienced engineers following an optimum checkout schedule.

System checkout proceeds according to a written work program. After all functions have been "married" and all interconnections proved correct, the system is started in the pilot operating mode (Phase 3). Each element is optimized and the total system is checked for specified performance.

When the purchaser and supplier agree that all performance specifications have been met, the system is started up in Phase 4 and the purchaser takes over responsibility for operation and maintenance.

Maintenance Training

Another valuable service that can be provided by the electrical supplier is training in operation and maintenance of the electrical equipment. Such training can materially assist the purchaser in getting maximum production over the life of his system. This training is made available, when desired, in the form of an organized series of classroom sessions at the purchaser's site, at a Westinghouse plant, or both.

Training in maintenance procedures has become especially desirable with the advent of solid-state control and power-supply equipment. Actually, the new equipment is not more difficult to maintain (easier, if anything), but, because it is unfamiliar, maintenance personnel often assume that it requires exotic knowledge and techniques.

The primary value of a training program with solid-state equipment is to "de-mystify" the equipment. The hardware is modular and functional, so maintenance personnel do not have to study semiconductor theory to maintain it. Test points and gauges are built into the modules so that a malfunctioning module can be located readily with standard test procedures that are easily learned. A faulty module is simply removed and replaced with a spare.

Conclusion

Program management and technical assistance from the systems supplier are aimed at getting the purchaser into profitable production as quickly as possible. When installation and startup are carefully planned and scheduled, they become the final stages of a managed systems project.

3—A simplified example of a system installation and startup illustrates the planning required. Operations must be performed in sequence (top to bottom) because many of them depend on completion of earlier ones.

New Tables of Steam Properties Improve Turbine Performance Calculations

C. A. Meyer
G. J. Silvestri Jr.
N. R. Deming

The 1967 ASME Steam Tables are the result of a world-wide (and in this country industry-wide) effort to standardize on steam properties for industrial calculations. Although the steam properties from the ASME tables do not produce large changes in the calculated performance of steam turbines, the calculated performance is closer to measured performance.

The interrelationships between the thermodynamic properties of steam—enthalpy, entropy, pressure, volume, and temperature—were first "standardized" for international use in 1934 when the *1934 International Skeleton Tables* were adopted. Those tables established values and tolerances for the thermodynamic properties at selected intervals of pressure and temperature. The steam properties were derived from experimental investigations that extended to 860 degrees F and 5300 psia for pressure-volume-temperature data, and to 1022 degrees F and 5000 psia for enthalpy data.

From the reference points established by the skeleton tables, Keenan and Keyes developed their more comprehensive steam tables,[1] which were published in 1936 and became the accepted standard of U.S. industry. Thermodynamic properties for steam conditions beyond the boundaries established by the skeleton tables were derived for the K & K tables by extrapolation.

As steam turbine throttle pressures increased into the supercritical region, discrepancies between calculated turbine performance and actual performance became noticeable. These discrepancies appeared primarily in the regions of extrapolated values and, although small in magnitude, signaled the desirability of updating the steam table information, especially in the high-temperature high-pressure region.

To meet this need, the American Society of Mechanical Engineers has developed and published the *1967 ASME Steam Tables.* (See box.) These new tables are based on the *1963 International Skeleton Tables* which are derived from world-wide research, and they are computed with formulations developed by the 1967 International Formulation Committee. The 1963 skeleton tables are based on a range of experimental data for steam conditions up to 1472 degrees F and 14,500 psia, and the 1967 IFC formulations cover this entire range. Since the new ASME tables incorporate only limited extrapolation beyond the skeleton table values, use of these tables should result in more accurate performance calculations together with world-wide consistency due to the common formulation identical to nine places. Previously, the various national tables were not identical but fell within the tolerance band of the skeleton tables. The effect on plant heat rate of using the various tables was unpredictable and depended on the steam conditions of the particular plant.

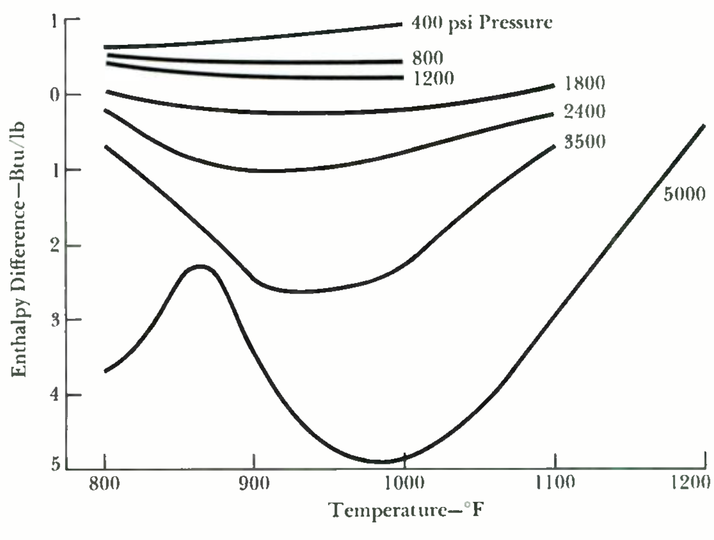
The effect of the new steam properties on turbine performance calculations can be demonstrated graphically on the Mollier (enthalpy-entropy) chart, which represents most of the steam properties except specific volume. The significant differences (Fig. 1) in specific values of enthalpy occur above 2400 psia at 1000 degrees F. The differences decrease for lower pressures and for both lower and higher temperatures up to 1200 degrees F. The value of entropy as a function of pressure and temperature is also altered.

Those differences result in a relocation of the temperature and pressure lines on the Mollier chart, particularly at higher pressures and temperatures. The change is illustrated for the 1000-degree F line in Figs. 2 and 3. Thus, at 3500 psi and 1000 degrees F (typical conditions for turbine inlet steam in today's high-pressure turbine elements), the steam state point is at lower entropy and lower enthalpy than shown on the previous Mollier chart.

Although the values of enthalpy and entropy have changed noticeably at higher steam conditions, these changes do not always significantly alter turbine performance calculations. For example, the calculated guarantee heat rates for steam turbines change very little. The reason for this can be seen in the heat rate equation for a reheat turbine:

$$HR = \frac{W_t(H_t - h_{ff}) + W_{rh}(H_{hrh} - H_{crh})}{KW}$$

where W_t and W_{rh} are throttle flow and reheat flow, H_t and h_{ff} are throttle en-



1—The differences in enthalpy (1967 IFC value minus K & K value) over a wide range of operating pressures and temperatures become significant only in the supercritical region.

C. A. Meyer and G. J. Silvestri are an Advisory Engineer and a Senior Engineer, respectively, in Development Engineering, and N. R. Deming is a Supervisory Engineer in Large Turbine Engineering, Steam Divisions, Westinghouse Electric Corporation, Lester, Pennsylvania.

1967 ASME Steam Tables

Refinement and extension of the *1934 International Skeleton Tables* began in 1954 when international meetings to develop new skeleton tables were resumed. In the United States, the American Society for Mechanical Engineers established a Research and Technical Committee to coordinate the work here with the international effort.

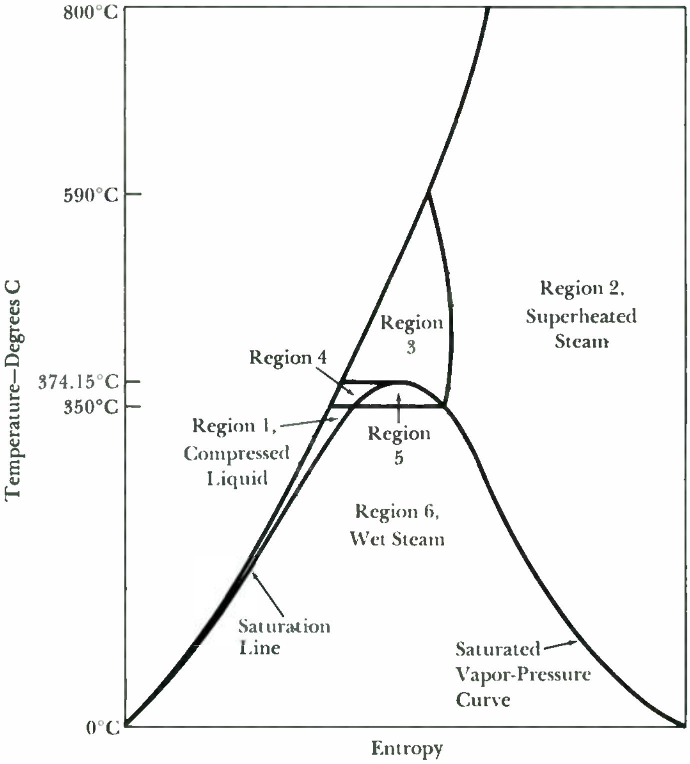
In 1963, the sixth International Conference on the Properties of Steam (ICPS) met in New York and adopted new International Skeleton Tables.

Computer programs were required for industrial calculations to interpolate values between the reference points established by the 1963 skeleton tables. To obtain worldwide agreement on computer representations, an International Formulation Committee, consisting of representatives from Czechoslovakia, the Federal Republic of Germany, Japan, the U.S.S.R., the United Kingdom, and the United States, began meeting in 1965 in Prague and Glasgow, and by early 1967 had completed the *1967 IFC Formulation for Industrial Use.* The IFC formulation consists of various subformulations for six steam regions, functions that define the saturated vapor-pressure curve, and functions for the interregional boundary between the superheated vapor region and the supercritical pressure region. (See illustration.)

With international acceptance of the 1967 IFC Formulation, the ASME Research Committee, through a small working group of representatives from U.S. industry, proceeded to develop a comprehensive set of tables.[6] The ASME steam table properties have been extended by extrapolation slightly beyond the 1963 skeleton table values to 1500 degrees F and 15,500 psia.

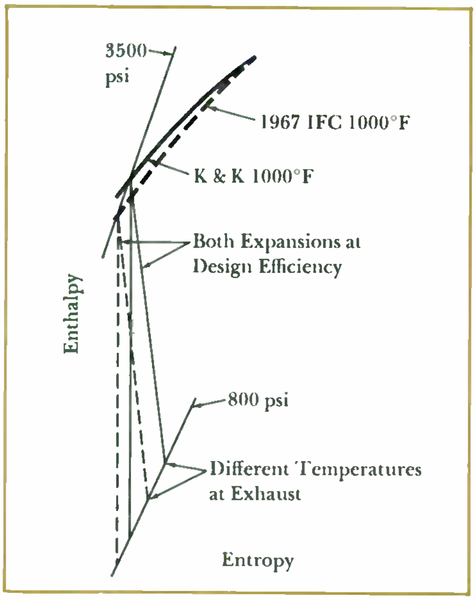
Additional information included in the new tables and based on other international formulations are the values of thermal conductivity, viscosity, Prandtl number, specific heat, sonic velocity, and critical flow rate.

The Seventh International Conference on the Properties of Steam is to be held in Tokyo in September 1968. This and future conferences will be devoted to improving and extending the skeleton tables and to developing a scientific formulation based on molecular and physical theories rather than on a curve fitting of the data. However, since no restrictions have been placed on the complication of that formulation (some terms involve temperature to the 414th power), it is felt that the formula will be impractical for day-to-day industrial use. Computation times and costs will be several times those of the industrial formulation with only a meager improvement in accuracy.

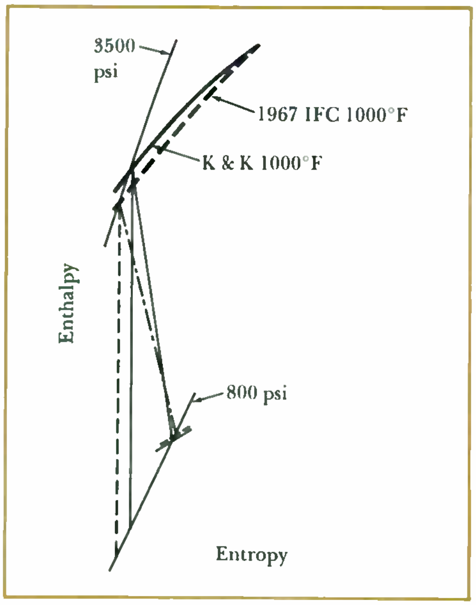


The *1967 IFC Formulation for Industrial Use* consists of a set of equations describing the properties of steam. The equations represent the six specific steam regions, and the interregional boundaries shown on this temperature-entropy chart.

The *1967 ASME Steam Tables* were calculated by digital computer with formulations developed by the 1967 International Formulation Committee.



2—Relocation of the temperature and pressure lines on the Mollier chart causes a change in the location of the expansion line for a typical high-pressure turbine element.



3—High-pressure turbine efficiency can be measured by comparing actual enthalpy drop with the isentropic (constant entropy) drop. Because of the relocation of the pressure line on the Mollier chart for the new formulation, the determined efficiency will be slightly lower.

thalpy and final feedwater enthalpy, H_{hrh} and H_{crh} are hot reheat enthalpy and cold reheat enthalpy, and KW is the calculated kilowatt output (turbine efficiency times available energy).

The calculated kilowatt output (KW) is about the same regardless of which steam table is used, because guarantee efficiency is considered the same for either case and available energy differs by a very small amount. Final feedwater enthalpy (h_{ff}) and hot reheat enthalpy (H_{hrh}) have almost the same values whether obtained from the ASME tables or the K & K tables. As shown in Fig. 2, throttle enthalpy (H_t) and cold reheat enthalpy (H_{crh}) both change in the same direction and nearly offset each other. Thus the net effect in the heat rate equation is nearly zero.

The situation is different when the evaluation of test data is considered. As before, the final feedwater enthalpy is nearly unaffected. The kilowatt output is measured. Both cold-reheat and hot-reheat enthalpies are affected to about the same degree in the same direction, so that the net heat added in the reheater and charged against the turbine (H_{hrh}–H_{crh}) is essentially the same when calculated from either table. Throttle enthalpy (H_t) does vary as shown in Fig. 3, and therefore is the only value that significantly affects the heat rate equation. Since throttle enthalpy is lower on the ASME tables, calculated heat rate is correspondingly less. For the familiar throttle conditions of 3500 psi, 1000 degrees F, the difference in test heat rate is about 0.2 percent at full load.

High-pressure turbine efficiency can be measured directly on reheat units by the enthalpy drop method—the ratio of the actual enthalpy drop (used energy) to the isentropic enthalpy drop (available energy)—as shown for a 3500-psi, 1000-degree high-pressure turbine in Fig. 3. Throttle enthalpy is 2.3 Btu lower by the IFC formulation, and high-pressure turbine exhaust is 0.5 Btu higher, so used energy is less by 2.8 Btu. The isentropic (constant entropy) enthalpy drop is about the same for either case, so the net result is a 1.5 percent lower test efficiency with the new formulation. That brings the test efficiency in line with the prediction.

The ultimate measure of the validity of the new steam properties is a comparison of calculated output with actual output. One such comparison can be made for cross-compound units that have superheated exhaust on one shaft; the calculated work output of the high-pressure shaft derived from test values of flow and corresponding enthalpies can be compared with the measured shaft output. When the K & K steam property values are used for this comparison, the discrepancy between measured and calculated output is about one percent; when the comparison is made with the new ASME values, the difference nearly disappears.

Thus, this cross-compound turbine kilowatt check and other performance tests have demonstrated that the 1967 ASME steam property values do provide more accurate results than the previously used values. With the new steam properties, calculated test heat rates at higher throttle pressures are slightly lower, and high-pressure turbine efficiency is lower. Both results agree with observed turbine performance.

Another quite independent check of the new formulation is found in the comparison of the sonic velocity as measured by Professor Woodburn[5] with a crystal-excited resonant cavity, and the values based on the isentropic pressure-volume derivative computed from the formulation. The two values, for sonic velocity of about 1500 feet per second, check within a few feet per second.

Westinghouse ENGINEER **July 1968**

References:

[1]J. H. Keenan and F. G. Keyes, *Thermodynamic Properties of Steam*, John Wiley and Sons, Inc., 1936.

[2]K. C. Cotton, N. R. Deming, and E. H. Garbinski, "Effects of New International Formulation of Turbine-Generator Performance Calculations," *ASME Transactions*, Vol. 9, Series A, No. 1, Jan. 1968, 67–PWR–9.

[3]C. A. Meyer and R. C. Spencer, "The 1967 ASME Steam Tables," *MECHANICAL ENGINEERING*, March 1968.

[4]*1967 ASME Steam Tables*, ASME Order Department, 345 East 47th Street, New York, N.Y. 10017.

[5]J. Woodburn and Y. J. Fostyk, "Acoustic Measurements in High-Pressure Superheated Steam." To be presented at the Seventh International Conference on the Properties of Steam, Sept. 9, 1968, Tokyo, Japan.

[6]R. B. McClintock and G. J. Silvestri, "Formulations and Iterative Procedures for Calculation of Properties of Steam," Joint Power Generation Conference, Detroit, Mich., Sept. 1967.

Aerospace Electric Motors

R. W. Griffith
F. J. Bertoldo

Aircraft, space vehicles, and missiles rely for many of their functions on motors that have to be especially reliable and high in ratio of power output to size and weight. The design, materials, and construction features that achieve those requirements also fit the motors for many special ground uses.

An aerospace electric motor must pack the most power feasible into the smallest and lightest unit feasible to maximize the payload of the aircraft, space vehicle, or missile it serves. And it must operate reliably under severe conditions such as high vibration and impact loads, temperature extremes, and high altitude. Such capability and reliability enhance the cost effectiveness of the system the motor is used in, and, more important, they provide safety: a multimillion-dollar commercial aircraft, for example, and many lives may depend on the motor that powers the aircraft emergency hydraulic system.

Moreover, aerospace motors are used in a growing number of nonaerospace applications where special mechanical or electrical requirements dictate such qualities as unusual reliability, high ratio of power to size and weight, high speed, or ability to withstand extreme environmental conditions.

In aerospace applications, the motors drive such devices as axial and centrifugal blowers, fuel boost pumps, oil pumps, freon and air compressors, hydraulic pumps, and actuators. The down-to-earth applications include similar drives on ships, boats, and vehicles where weight and size are important; control-rod drives for nuclear reactors; and ground support equipment for airliners and for military and space systems. Typical ground support applications are radar antenna drives, blowers and refrigeration compressors for cooling electronic equipment in service vans and carts, and hydraulic pumps for leak testing in ground checkout.

R. W. Griffith is Customer Service Manager and F. J. Bertoldo is Utilization Systems Department Marketing Manager, Aerospace Electrical Division, Westinghouse Electric Corporation, Lima, Ohio.

Most users prefer ac motors over dc motors because they are simpler and require less maintenance (no brushes nor commutators). However, an ac power supply isn't always economically feasible, since ac generators cost more than battery or dc-generator systems. Thus, there are still many uses for dc motors. The main ones are in small utility aircraft and systems that rely on battery power, such as spacecraft and gas-turbine starters. The same considerations apply to ground uses; where a system doesn't warrant the greater cost of an ac generator, dc motors are used and are operated from batteries or from a dc generator.

Another reason for preference for ac motors is that line losses become a large economic factor in dc systems when the load is a long distance from the power source. That was a major consideration in selecting an ac system for the B-36 aircraft, one of the first to use ac power.

Motor Types and Sizes

Three-phase ac aerospace motors are made in the standard sizes shown in the accompanying table. The ratings accomodated by those frame sizes range from 1/25 hp to 65 hp at shaft speeds from 1850 r/min (for gearhead motors) to 12,000 r/min. Frequency usually is 400 hertz, the aircraft standard. However, three-phase 60-hertz motors operating at 3450 r/min have been built.

The dc motor line includes the standard frame sizes shown in the table; those sizes accomodate ratings from 1/25 hp at 16,000 r/min to 5½ hp at 8400 r/min. Most dc motors operate at voltages from 24 to 30 volts because those are the most common aircraft dc voltage levels; however, motors have been built for voltages as low as 12 volts and as high as 275 volts.

In addition to the standard sizes, both ac and dc motors are built in other sizes to special order. The basic configurations in which ac and dc equipment is supplied are self-cooled motors, smooth-frame motors, open through-ventilated motors, gearhead motors, brushless dc motors, and ac motor parts (Fig. 1).

Self-cooled motors have self-contained provisions for dissipating heat generated in the rotor and windings (Fig. 2a). They are generally used where cooling is not supplied by the driven device, by fuel immersion, nor by other means; applications include pumps, hoists, winches, and retractable aircraft stairs.

Aerospace Motor Sizes

Frame Number	*Frame Diameter (inches)*
AC Motors	
250	2.500
310	3.125
400	4.000
460	4.625
550	5.500
650	6.500
800	8.000
1000	10.000
DC Motors	
230	2.313
310	3.125
400	4.000
525	5.250
600	6.000
800	8.000

Heat from the windings is conducted through the epoxy slot-liner insulation, through the stator core, and out to the frame. There the heat is dissipated to an external air stream produced by a shaft-mounted fan in a shroud that partly encloses the motor housing.

Internal cooling often is used also, in all aerospace motor types, because the need to produce the most power possible in the smallest space often results in generation of more heat than conduction and natural convection can move from the rotor and windings to the frame. Fans create turbulence in the air inside the motor, assisting natural convection. In ac motors, they are simple centrifugal fans formed by extending the rotor bars; in dc motors, a separate centrifugal fan is secured to the shaft.

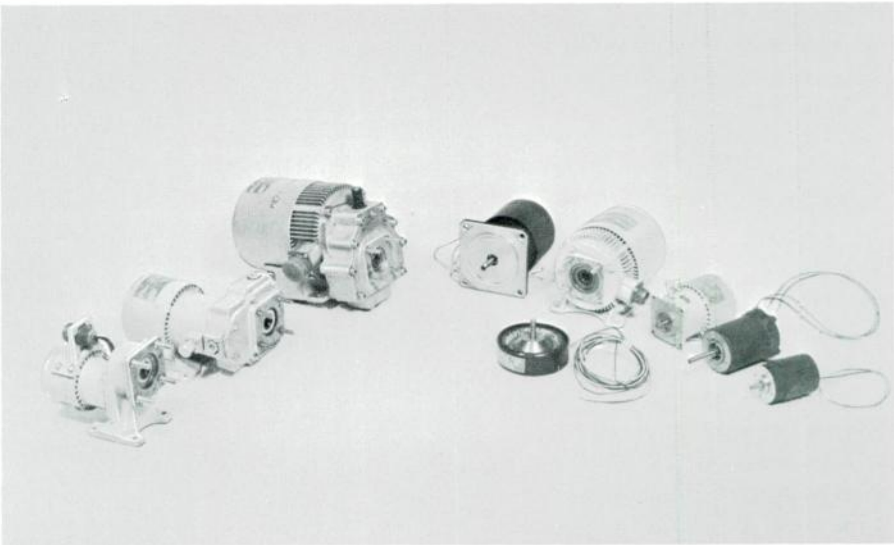
Smooth-frame motors are similar to self-cooled motors except that they do not have their own external cooling provisions; they are used mostly in blower applications in which the motor is cooled by the blower's air stream (Fig. 2b). Some smooth-frame motors, with specially designed smooth rotors to reduce fluid friction, are used for submerged pump applications in which the liquid being pumped actually enters (and sometimes passes through) the motor.

The front (antidrive) end is often made larger than the drive end, especially in the smaller motor sizes, to enlarge the area available for heat radiation and thus prevent overheating of the front bearing. The drive end doesn't require that treatment because it receives the full benefit of the air stream within the blower tube and, in dc motors, because the heat-producing brushes are usually in the antidrive end.

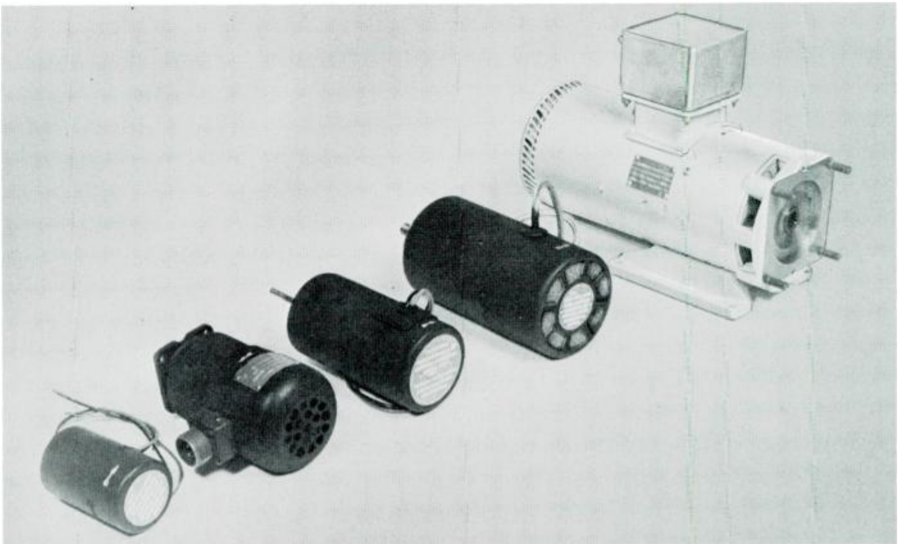
Some smooth-frame motors have frames made of commercial aluminum tube stock and end bells machined from aluminum bar stock. They cost less than regular motors but are somewhat less rugged. They are used as lightweight economical drives for blowers.

Open through-ventilated motors, which are also used for blower applications, have cooling air from the blower forced directly through the motor (Fig. 2c). The design is especially well suited for dc

a



b



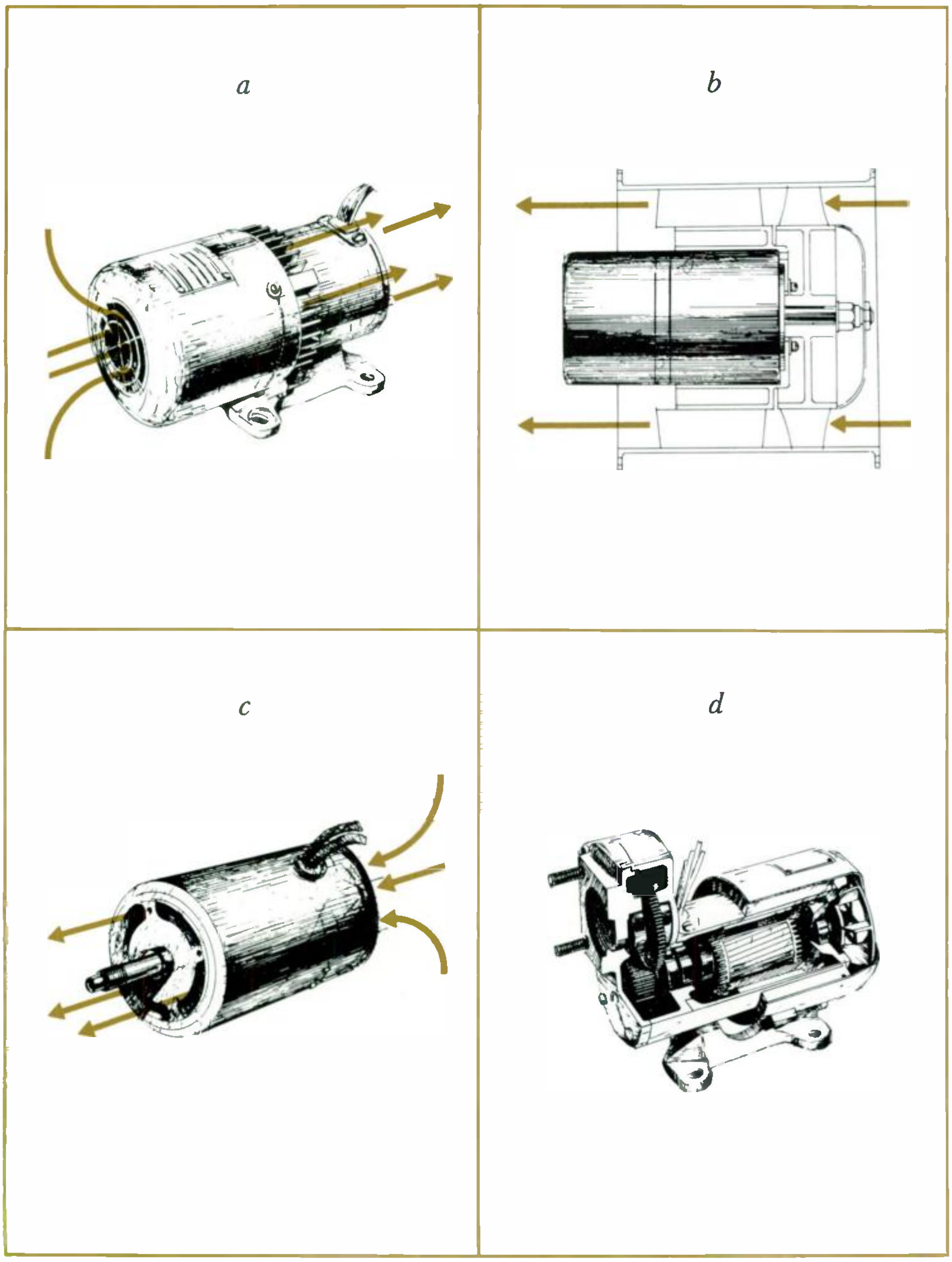
1—Aerospace motors are made in a variety of types and sizes to suit many applications. (*a*) Typical ac motors are, left to right, two 310-frame and one 460-frame self-cooled gearhead motors that drive hydraulic pumps, a 400-frame self-cooled motor for a centrifugal pump, a 400-frame self-cooled motor for a hydraulic pump, a 250-frame self-cooled motor for a compressor, and 250- and 200-frame smooth-frame blower motors. In the foreground is an open "pancake" motor used to drive an air-circulating fan in a galley oven on commercial aircraft. (*b*) Typical dc motors are a 230-frame smooth-frame motor for a vane axial blower, a 340-frame self-cooled motor for a centrifugal blower, a 310-frame smooth-frame motor for a vane axial blower, a 400-frame through-ventilated axial-blower motor (with flame suppressors to make it explosion-proof), and a 525-frame through-ventilated motor for a hydraulic pump.

a

b

c

d



2—(*a*) Self-cooled motors have their own fans for dissipating heat from the outside of the frame. They are usually totally enclosed and explosion-proof. (*b*) Smooth-frame motors are used to drive blowers; they are cooled by the air stream of the blower passing over them. Most are totally enclosed and explosion-proof. (*c*) Open through-ventilated motors, also used to drive blowers, are cooled by air passing directly through the motor. They can be made explosion-proof by placing flame suppressors in the air inlets and outlets. (*d*) Gearhead motors include reduction gearing to achieve a desired low-speed output from a light and efficient high-speed motor. The motor is usually of the self-cooled type.

motors because the cool air passes over the brushes and cools them.

In general, a through-ventilated motor cools more efficiently than a totally enclosed type (even when flame-suppressor cartridges are installed at the openings to make it explosion proof), so it can deliver more power in a given frame size. However, its application is limited by the need for an unrestricted air outlet, a need that must be considered in the design of the driven device. Also, a pressure differential is needed across the motor to induce air flow through it. For those reasons, through-ventilated motors are usually applied only to specially designed axial vane blowers.

Gearhead motors are usually self-cooled and consist of a high-speed high-efficiency motor mounted to a set of precision reduction gears (Fig. 2d). They are used wherever low output speeds are required.

Many gearhead motors are made "attitude free" by venting the gearbox with a small radial hole drilled in the shaft to intercept a longitudinal hole, instead of using a conventional gearbox vent plug. The holes provide a pressure equalization path that acts as a small centrifugal pump to prevent oil from escaping, as long as the motor is operating, by pumping it back to the gearbox. There is no leaking when the motor is off because the oil sump level is below the level of the shaft. A special seal is used to seal around the high-speed input shaft.

Brushless dc motors are used when only dc power is available and ordinary dc motors are ruled out by special requirements—such as operation at high altitude or in other environments that forbid use of brushes, long life and high reliability with little or no maintenance, and low acoustical and radio noise. Their main disadvantage is their higher cost, although cost varies greatly with the type. The first of the two main types is actually an ac induction motor driven from the dc power supply via an inverter. The second is a dc motor with electronic commutation: rotor position is sensed in one of several ways, and static switches change the excitation of the armature circuits to correspond to rotor position.

Ac motor parts are furnished in sets, in an almost infinite number of variations, for use when it is most economical to build the housing into the driven device. Typical sets are: basic wound primary and rotor core; basic wound primary, rotor core, shaft, and bearings; and basic wound primary, frame, thermal protectors, electrical connector, rotor core, and shaft. Because frame tooling is not normally required (although partial frames are sometimes furnished), the range of sizes is much larger than that of complete motors. Sets of motor parts have been supplied in ratings as high as 75 hp (for a centrifugal compressor). When the application involves submerging the motor in fuel or freon, motor parts are often cleaned in an ultrasonic cleaner and packaged in airtight dust-free bags to insure that they will not contaminate the systems they are used in.

Design Considerations

Because aerospace motors are generally used where conditions are unusually demanding and space and weight are at a premium, more attention must be given to fitting the motor design to the unique requirements of each application than is necessary with most other motors. Such optimizing is a complex task because there may be 20 or more design variables to consider. Computer programs have been developed to cope with the task; with them, a designer can consider more variables than was practical with the former manual calculating methods, and he can run several programs with different variable inputs to generate alternative designs quickly and accurately. He then chooses the design best suited to the application.

Variable inputs that can be considered in a computer program are punching dimensions, stator core length, wire size, number of turns per coil, wire distribution, rotor cage conductivity, windage losses, friction losses, magnetic steel characteristics, and temperature. Parameters that can be optimized are horsepower, torque, speed, current, efficiency, power factor, input power, and physical dimensions of the motor.

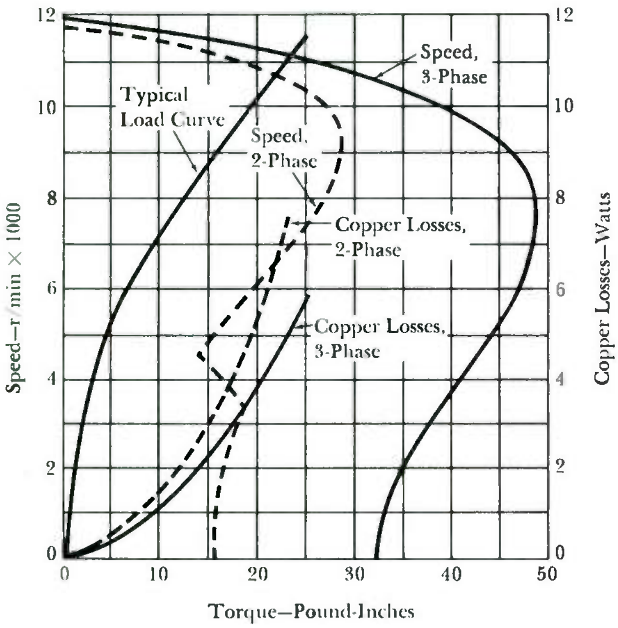
A typical example of optimizing a design is the development of the fuel-pump motor for the U. S. Air Force's F-111 aircraft. The initial design included a stator and rotor punching for which tooling already existed; the design provided 2.5 hp at 11,200 r/min with a weight of 2.5 pounds, 80 percent efficiency, 0.80 power factor, 8.4 amperes, 2.48-inch outside diameter, 2.125-inch stack length, and 0.57-inch winding end extension. This design did not meet the customer's specifications for weight and efficiency, so the designers went back to the computer to improve the iron-to-copper ratio and slot combination. The new design provided 2.5 hp at 11,300 r/min with a weight of 2.1 pounds, 81 percent efficiency, 0.87 power factor, 7.7 amperes, 2.5-inch outside diameter, 1.625-inch stack length, and 0.67-inch winding end extension.

To produce an optimum design, of course, the designers need to understand the application. Early in the negotiation process, they must have such information as the characteristics of the driven device, horsepower or torque required for starting and running, required speed, power supply characteristics, duty cycle, ambient conditions, required lifetime, mounting and shaft type, and any special restrictions such as dimensions or connector type.

Other design targets besides optimum size and performance are minimum cost, manufacturability, maintainability, and reliability.

Maintainability improvements are continually being developed and incorporated into new motor designs and modifications. For example, many motors used in the latest aircraft are of cast-frame design with only one removable end bell secured by four screws into the frame; the easy disassembly of the motor facilitates bearing replacement. Bearing standardization minimizes the number of spares required. Nearly all 310-frame motors, for example, (except two-pole designs) use identical bearings.

Reliability is imparted by the mechanical designs, materials, and manu-



3—For increased reliability, three-phase aerospace motors are designed to operate with one phase out. The drive application must be planned to accommodate the reduced torque capability and increased copper losses, shown here by curves comparing performance characteristics of the same 2.5-hp 11,300-r/min motor operated normally and with one line out. The typical load curve is for a centrifugal pump; it is well within the two-phase torque capability.

facturing practices discussed in the next section. Moreover, nearly all of the three-phase ac motors for four-wire grounded-neutral electrical systems are designed to operate in such systems even when one phase is out due to a motor malfunction or a failure in the electrical system itself. However, when the user designs a motor-driven accessory for contingent operation on two phases, he must take care to accommodate the reduced torque capabilities of the motor and the increased losses (Fig. 3).

Construction and Materials

After an aerospace motor is designed for a specific set of characteristics, there are still many options in building it. It is attention to those important details of construction and materials that assures maximum reliability and cost effectiveness (Fig. 4a).

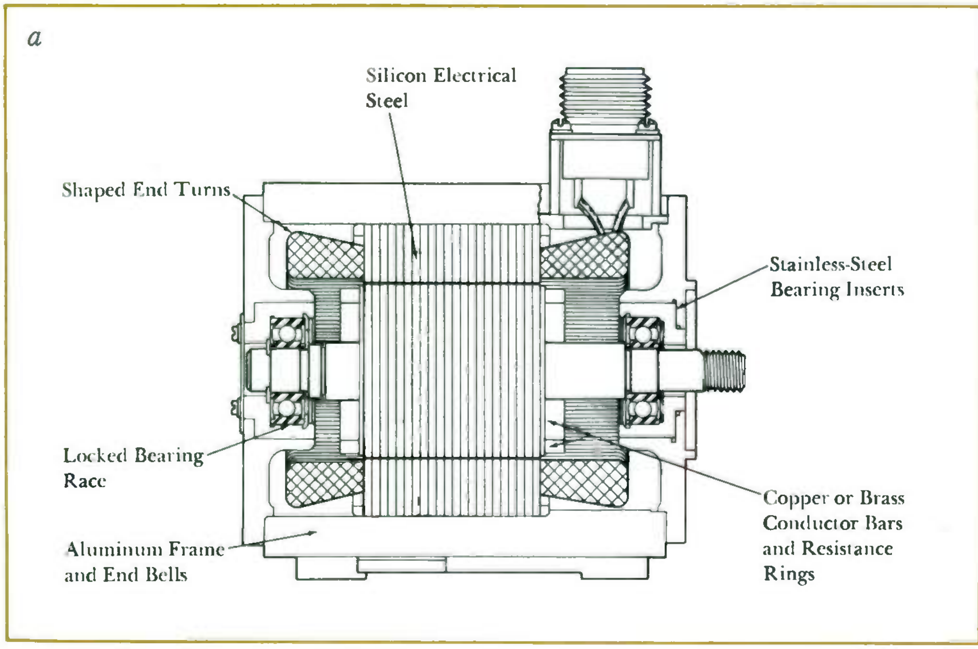
Frames and end bells of all ac motors made at the Aerospace Electrical Division are of aluminum, because aluminum is light but also strong enough to withstand extreme shock and vibration. Aluminum motors have been successfully tested under shock loads of more than 100 g. Aluminum also permits shrink-fit assembly.

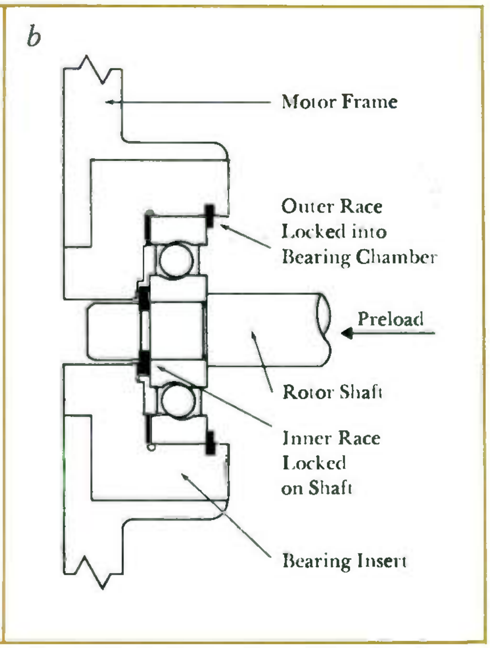
All ac motor stators are shrink-fitted into the frames to make a stronger assembly than other methods can. Shrink-fitting also provides maximum contact between stator and frame so that heat generated in the stator can pass efficiently to the frame, from which it is dissipated. That feature allows the motors to run at high loads without overheating in ambient temperatures up to 350 degrees F—far above most ambients encountered.

Stainless-steel bearing inserts are cast into the end bells of many motors to prevent the aluminum housing's greater contraction at low temperatures from seizing the bearing outer race. (The steel insert and steel bearing expand and contract at virtually the same rate.) Seizing would be bad because one or both of the bearings must be free to move axially a bit to accomodate the differential thermal expansion between steel shaft and aluminum frame. An aluminum frame without a steel insert could even contract enough to compress the bearing outer race and cause the balls to seize between the races.

In some motors, the outer race of one bearing is locked against axial movement to enable those motors to withstand severe shock and vibration (Fig. 4b). The other bearing then is provided with enough axial clearance to accommodate the total differential thermal expansion between shaft and frame. A wave spring behind the "floating" bearing exerts a slight thrust, called preload, on both bearings to insure positive contact of the balls with the inner and outer races and thereby prevent ball skidding and axial shaft movement, thus increasing bearing life and insuring quiet operation.

Proper bearing lubricant is especially important for aerospace motors because they usually run at high speeds—as high as 23,000 r/min on some blower appli-





4—(*a*) An aerospace electric motor must combine capability and reliability with small size, light weight, economical construction, and ease of maintenance. The major construction details that provide those qualities are shown in this cutaway view of a typical ac smooth-frame motor. (*b*) Outer race of one bearing is locked in some motors to prevent axial movement of the race and thereby enable those motors to withstand severe shock and vibration. An axial preload from a spring at the opposite end of the shaft assures contact between bearing balls and races to prevent skidding of the balls. (The effect of the preload on the relative positions of balls and races is exaggerated here.)

cations. Also, the motors often have to operate under severe environmental conditions, from tropical jungles to frigid Antarctica. To meet those needs, motor engineers have developed a special grease mixture that retains its lubricity at −65 degrees F and its body at +350 degrees F. It permits a high degree of bearing standardization, which tends to reduce lead time for motor design and development.

Bearing clearances also are optimized for long operating life. With too little internal clearance, for example, cumulative manufacturing tolerances and thermal expansion can overstress a bearing and cause premature failure; on the other hand, loose-fitting bearings tend to be noisy and are more likely to have ball skidding, which is equally damaging.

Both seals and shields have been used in aerospace motor bearings. (Seals keep lubricant in and dirt out; shields admit lubricant but keep large dirt particles out.) While seals are more effective for keeping dirt out, they also increase bearing friction—the effect of which is multiplied because the increased heat of friction cannot be dissipated efficiently through the seals. Shields cause less friction and generate less heat, but they allow some foreign material to enter the bearing as it "breathes" over a temperature cycle. Exhaustive laboratory and field testing with many combinations of fits, seals, and shields has showed that the maximum benefit and minimum disadvantage is obtained by using loose-fitting bearings, preloaded to eliminate skidding, with newly developed low-friction seals on at least the exposed sides of the bearings. Those improvements have been incorporated into production motors.

Special bearings are used when standard bearings would not be adequate because of a need to use unusual lubricants or to operate in unusual environments. Examples of such applications include submerged fuel boost-pump motors and submerged cryogenic-pump motors (both lubricated by the fluids they pump) and motors for space vehicles (which operate in vacuum and have solid lubricants).

Each phase of a three-phase aerospace motor is wound with a continuous wire instead of by inserting separate coil groups for each pole (Fig. 5). Such winding reduces the number of internal electrical connections and consequently improves reliability.

Stators and armatures are designed and built to minimize the amount of end-turn shaping required, and the only shaping is done by hand rather than by press-forming. Press-forming can shave some fractions of an inch from length, but the likelihood of damage to wire insulation is far too great.

Special silicon electrical steels are used because they can be worked at higher flux densities without excessive losses than ordinary commercial steels, resulting in maximum efficiency and minimum weight. Typical flux densities at rated load are 130,000 lines of flux per square inch.

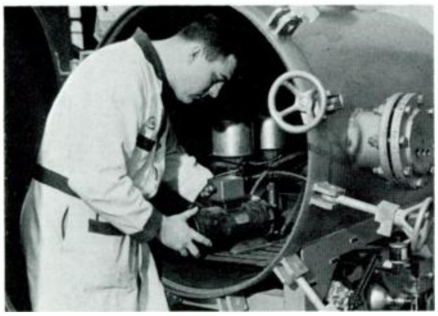
Copper and brass are the primary materials used for the rotor cage. Using those different materials provides design flexibility for an extremely wide range of performance characteristics by simply

Qualification Testing

Qualification tests prove the ability of aerospace motors to meet severe military and commercial specifications for resistance to shock, vibration, fungus, salt spray, sand, dust, high and low temperature, and high and low humidity. The programs also test brush life and motor performance in such conditions as overspeeds, explosive atmosphere, different operating positions, and altitudes up to 100,000 feet.

Tests shown in the photos include (*a*) testing explosion-proof motors with various mixtures of gasoline and air. Tests can be conducted in the chamber at sea-level or simulated altitude pressures. (*b*) Motors are tested under load to determine brush life. Further tests in the altitude chamber evaluate brush life under flight conditions. (*c*) Effects of humidity on motors at elevated temperatures are checked in these cabinets, and ability of equipment to meet the conditions is closely measured. (*d*) This altitude chamber can accommodate motors and generators rated up to 120 kVA. It is equipped and instrumented to check performance up to 100,000 feet altitude.

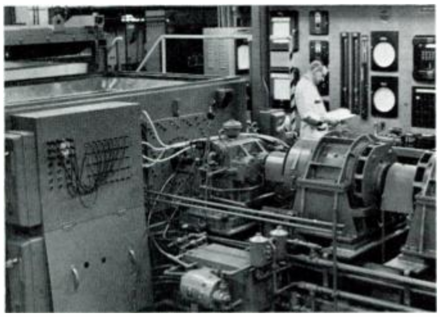
a



b

c

d



varying resistance (Fig. 6). The rotor design also is varied to suit the motor configuration and ambient conditions of service. All rotors are dynamically balanced to high precision: a typical self-cooled motor has an allowable maximum vibration of 0.001 inch double amplitude.

Aluminum parts often are anodized, and all are finished with a chemical film to protect against corrosion. That often is the only finish required, but for added protection a baked-on catalyzed epoxy enamel is sometimes added.

The insulation system developed for both ac stators and dc armatures is designed to impart long life and high reliability. The slot liner, for example, is a continuous epoxy membrane covering the inside area of the stator stack. It is formed by immersing the preheated stack into a fluidized bed of epoxy resin powder, which melts and flows over the entire exposed surface to form a film of uniform thickness. The coated stator stack is then cured in an oven.

This continuous slot liner has the advantage of eliminating sharp edges that could nick or scrape the wire as it is inserted into the slots. Also, since there is no air gap between epoxy membrane and steel core, heat generated in the windings can pass more readily to the core and out to the frame, so the motor can operate at higher loads without overheating. Moreover, since the epoxy membrane is only a few thousandths of an inch thick and adheres directly to the steel core, space wasted in other insulation systems is usable in this one. The added space makes winding easier and faster, and it sometimes allows more wire turns to be placed in the slots. Finally, the epoxy coating is tough and abrasion resistant; it doesn't rip or tear, because it is in intimate contact with the core.

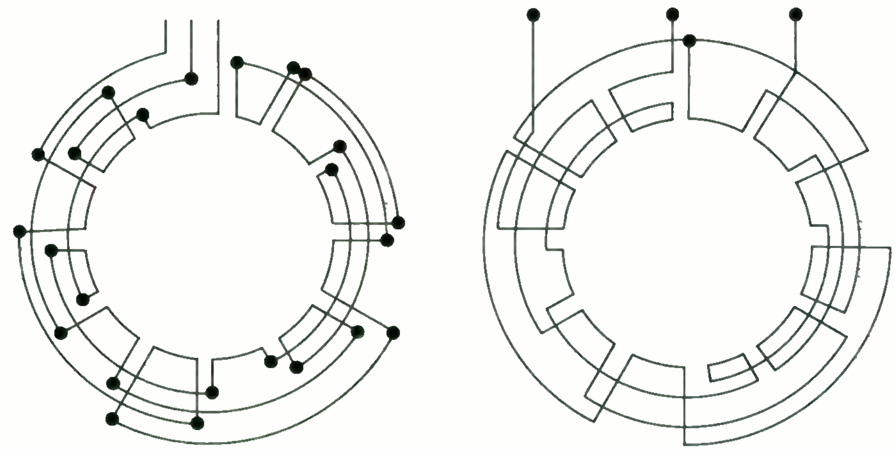
The magnet wire used in the coils is insulated with a recently developed polyimide high-temperature enamel that can operate continuously at 482 degrees F and is good for short periods as high as 572 degrees F. The enamel is also very tough and abrasion resistant. The wedges that hold the wire in the slots are made from closely controlled laminations of fiber-glass mat and polyester resins.

Impregnating varnish is applied in a vacuum chamber to be sure it flows all around the wires and fills all the voids far down into the slots. It is then heat-cured, and the process is repeated to build varnish thickness and increase the dielectric strength of the insulation.

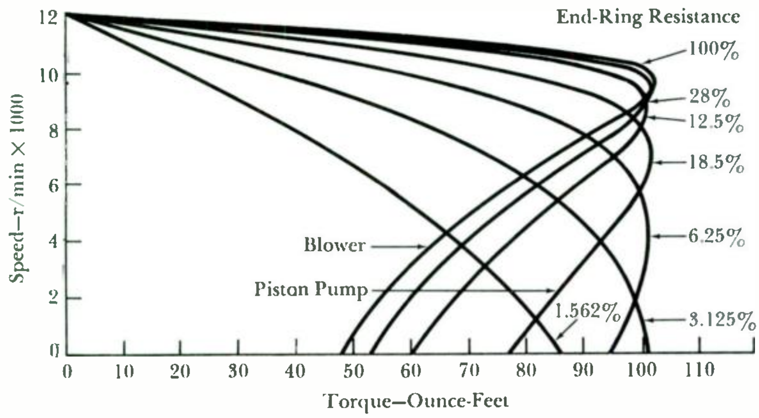
All motor windings are high-voltage surge tested for dielectric strength, both before the windings are set in varnish and after final motor assembly. The tests exceed requirements of the applicable military specifications, which often are as high as 2200 volts.

Conclusion

Aerospace motors are continually being improved by new designs and design methods, new materials, and new construction methods. The resulting high quality of their electrical and mechanical features shows up in high performance and high reliability. Those qualities are essential in aerospace applications, and they also serve a growing number of ground applications.



5—Reliability is enhanced by winding each phase of a three-phase motor with a continuous wire. The conventional method, inserting separate coil groups for each phase (*left*), requires 24 internal electrical connections, while the single-wire method (*right*) requires only 4.



6—Aerospace ac motors are given a wide range of performance characteristics by varying the resistances of the rotor cage end rings. The types of speed-torque curves a designer would select for a typical blower and piston pump are indicated.

New Techniques Enhance Effectiveness of Building Floodlighting

K. Chen
E. B. Karns

Floodlighting a building can achieve the owner's aesthetic and commercial purposes if the many variables in architecture, building material, and type of illumination are carefully considered.

Floodlighting a building is an effective means of identifying the structure at night and thereby calling attention to it and to its owner. Thanks to recently developed light sources, luminaires, and techniques, lighting effects can be tailored to the type of building and the significance the owner wants to give it. However, the equipment and techniques must be used intelligently and imaginatively, for it is essential that the building's form, beauty, and architectural identity be neither distorted nor obscured.

In general, floodlighting should achieve certain objectives. First, the building surface should have such a brightness that it appears in perspective when viewed from a distance. Shadows cast should look like those cast by the sun; they should not destroy the basic form and depth of the building's architecture. Walls and other flat surfaces should be illuminated to a level that reveals their texture and the character of the architectural design. And finally, the building should be identified with the area about it by illuminating sufficient surrounding area; that is, it should not appear suspended but rather oriented with adjacent grounds, slopes, and plazas.

K. Chen is an engineer in the Facilities Department, Lamp Division, Westinghouse Electric Corporation, Bloomfield, New Jersey. E. B. Karns is Product Communications Manager, Lighting Division, Westinghouse Electric Corporation, Cleveland, Ohio.

Choosing the Proper Light Source

The basic catagories of light source are incandescent, fluorescent, and mercury-vapor lamps (Table I). The lamps are applied in various kinds of fixtures, with the combination of lamp and fixture known as a luminaire (Table II). Final choice of a lamp type and luminaire depends on economics, maintenance characteristics, color, size, available floodlight locations, and, above all, the aesthetic achievement desired.

Incandescent lamps are perhaps the most useful and versatile floodlight sources. Their light can be directed easily by lenses and reflectors in beams of the desired shape, and the color of their light is accepted as "white." Efficiency usually is about 20 lumens per watt.

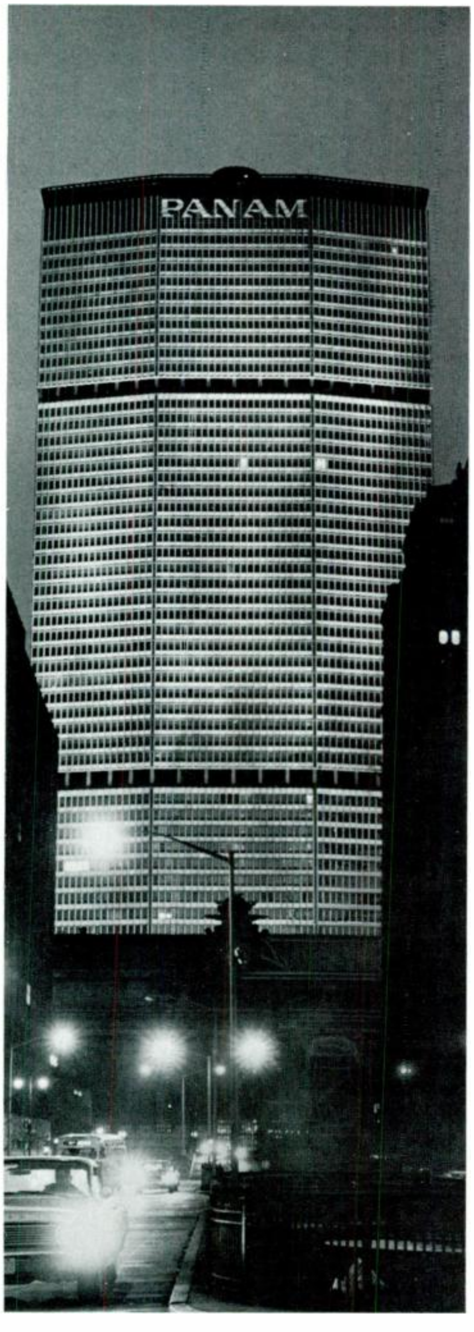
Quartz-iodine lamps, the newest incandescent sources, have efficiencies of about 25 lumens per watt. They contain iodine that continually removes vaporized tungsten deposits from the quartz envelope and redeposits it on the filament; consequently, they provide more light in their lifetimes than other incandescent types do because their light output remains almost constant instead of diminishing as a result of tungsten depositing on the envelope. The lamps used for building floodlighting are usually about the size and shape of pencils. Most floodlights designed for these linear light sources develop rectangular beam patterns, which are highly efficient for many building floodlighting applications.

Fluorescent lamps are lower in brightness than the other light sources, but more efficient than most (about 75 lumens per watt). The "cool white" type renders color well. Fluorescent lamps require a large specular reflector for precise control of light, but, even with such a reflector, control is limited to the light perpendicular to the length of the lamp.

Fluorescent lamps are sensitive to temperature both in starting and operating, although outdoor type ballasts insure reliable starting down to −20 degrees F. Regardless of ballast type, however, light output is reduced when the lamp is exposed to low temperature and moving air. This effect is minimized in Westinghouse SHO-II lamps, which employ a new amalgam principle of mercury vapor control to maintain high light output over a 100-degree temperature span. The amalgam is an alloy of mercury and indium that releases more

Table I. Comparison of Light Sources

	Incandescent			*Mercury*		
	Standard	*Quartz-Iodine*	*Fluorescent*	*Standard*	*Metallic Additive*	*High-Pressure Sodium*
Initial Cost	Low	Low	Higher	Higher	Higher	Higher
Annual Operating Cost	Medium	Medium	Low	Low	Low	Low
Service Life	Fair	Fair	Good	Very good	Good	Good
Color Definition	Good	Very good	Fair	Fair	Good	Good
Beam Control	Very good	Good	Poor	Fair	Good	Good
Cold Weather Operation	Very good	Very good	Fair	Good	Good	Good
Long Range Projection (narrow beam)	Very good	Fair	Poor	Fair	Fair	Fair
Medium Range Projection	Good	Good	Fair	Good	Good	Good
Lumen Output	Fair	Fair	Fair	Good	Very good	Best



1—Pan Am Building is floodlighted evenly by luminaires aimed upward from the tenth floor setback. Special 2000-watt incandescent lamps were developed for the purpose.

mercury vapor as temperature falls, thereby controlling vapor pressure.

Mercury lamps are almost as efficient as fluorescent lamps (about 60 lumens per watt) and somewhat more compact. Color rendition in general is inferior to that of incandescent lighting, although some mercury lamps such as the Westinghouse BOC lamp have relatively good color rendition. The BOC (Best Output and Color) lamp is a new type of additive mercury lamp in which metal halides are added to produce light of daylight color at an efficiency of 80 lumens per watt.

High-pressure lamps have high efficiency —120 lumens per watt for the Westinghouse Ceramalux lamp, which provides a rich warm amber light that renders colors of building materials well.

Projector lamps are developed for particular needs. The 6-volt 120-watt PAR 64 incandescent lamp, for example, produces a thin beam that is very effective for lighting tall buildings, columns, steeples, water towers, and the like. Its beam spread of 4½ degrees in one plane by 7 degrees in the other is achieved by masking critical areas of the reflector to prevent refocusing of light.

Basic Floodlighting Effects

Flat lighting is uniform illumination of a building. It creates few highlights and shadows and little modeling, but it can be the most economical kind because installation usually is simple and little of the light pattern misses the building. Luminaires can be mounted on the ground, on poles, or on the roofs of adjacent buildings or buildings across the street.

Grazing lighting dramatically expresses the character of a building by producing strong highlights and shadows. It is achieved by mounting floodlights close to the facade, so it is often used where mounting space is restricted. The best light source for tall buildings is a clear mercury lamp with its arc tube along the axis of a concentrating specular reflector.

Lighting patterns can be used to emphasize or subdue adjacent architectural elements, strengthen design concepts, or increase the attraction of an otherwise plain surface. The key to success in nonuniform lighting is to create the impression that the effect was planned.

Color lighting can supplement the increasing use of bold colors in modern construction, both in general floodlighting and as a means of establishing highlights and focal points. It can be achieved either by use of color filters or by utilizing the inherent color differences among the light sources. Incandescent lighting produces a natural look, mercury lighting tends to cast a slight greenish color on neutral colors, fluorescent light-

Table II. Floodlight Luminaire Types

Beam Spread (degrees)	NEMA Type	Minimum Efficiency (percent) — Incandescent: Effective Reflector Area (sq. in.) Under 227	Incandescent: Over 227	Mercury: Under 227	Mercury: Over 227	Fluorescent: Any
10 to18	1	34	35	—	—	20
18 to 29	2	36	36	22	30	25
29 to 46	3	39	45	24	34	35
46 to 70	4	42	50	35	38	42
70 to 100	5	46	50	38	42	50
100 to 130	6	—	—	42	46	55
130 and up	7	—	—	46	50	55

Source: National Electrical Manufacturers' Association. Asymmetrical-beam floodlights may be designated by a combination type designation which indicates horizontal and vertical beam spreads in that order; e.g., a floodlight with a horizontal beam spread of 75 degrees (Type 5) and vertical spread of 35 degrees (Type 3) would be designated as a Type 5×3 floodlight.

ing strengthens white or light blue colors, and sodium lighting is rich in amber color and very effective in adding warmth.

Sparkle or glitter, achieved with exposed lamps, also complements modern architecture with its emphasis on line and plane. The lamp size required for a sparkle pattern depends on the brightness of the area and the effect desired.

Choosing a Luminaire

The first step in determining the type, number, and size of floodlight luminaires required to light a building is to choose a tentative floodlight on the basis of type of light source (incandescent, fluorescent, mercury, or sodium), shape and size of beam (round or rectangular; wide, medium, or narrow); and wattage or light output (beam lumens) of the source. As a general rule, if a single requirement must be met, the engineer simply selects the lamp and luminaire best suited for the job. Where there is no clear-cut requirement, he compares the various lamp and luminaire characteristics and weighs the importance of each.

If more than one light source is suitable, an economic study must be made to determine which would be the best choice for a number of years of service. The comparison of light sources in Table I can be effectively used as a quick selector.

With the light source chosen, a luminaire is selected. Floodlight luminaires are usually divided into seven types on the basis of beam spread (Table II). Beam efficiencies (ratio of luminaire output lumens to lamp lumens) vary with the type of beam and lamp, as shown. Specific Westinghouse floodlight luminaires are listed in Table III.

The second major step in choosing a luminaire is to determine the proper illumination level. A helpful guide is the Illuminating Engineering Society (IES) recommendations for minimum maintained levels of floodlighting for various surrounding brightness levels and building materials (Table IV). If a building is located in an area that is normally crowded, it sometimes is advisable to reduce the brightness on the lower portion of the building to prevent possible annoyance to pedestrians and motorists.

The third step is to estimate the coefficient of beam utilization (CBU), which is the ratio of lumens striking the floodlighted surface to beam lumens. The area to be flooded is superimposed on the photometric grid of the luminaire chosen, and the ratio of lumens inside the area to total beam lumens is calculated. A typical CBU value is 75 to 80 percent if the unit is properly chosen. If the value is below 60 percent, a more economical lighting plan probably can be devised by using different floodlight locations or luminaires with narrower beams.

The next step is to calculate the number of luminaires required:

$$\text{Number of luminaires} = \frac{A \times FC}{BL \times CBU \times MF}$$

where A is area of the surface to be

Table III. Floodlight Luminaire Selection Guide

Westinghouse Luminaire Designation	*Incandescent*				*Quartz-Iodine*			*Mercury*				*Fluorescent*		*Projector*
	CAK-14	*CAK-16*	*A*	*AH*	*500-W*	*1500-W*	*AH-16*	*CAK-14*	*CAK-16*	*MFB 4*	*MFB 10*	*Sataliner*	*BSL*	*Bryant C-2100*
Lamps To Be Used	500-W PS-40 500-W G-40	1000-W PS-52 1000-W G-40	500-W PS-40 1000-W PS-52	500-W PS-40 1000-W PS-52	500-W T3	1000-W 1250-W 1500-W T3	400-W Clear Phosphor	400-W Clear Phosphor	700-W Clear Phosphor	400-W Clear Standard White	700-W 1000-W Clear Standard H.O.*	800-ma 1000-ma 1500-ma R.S.*	800-ma 1000-ma 1500-ma R.S.*	120-W PAR 64 500-W PAR 64
NEMA Type	2 3 4 5	1 2 4 5 6	2 4 4 x 3 5	2 4 4 x 3 5 6	5 x 2 5 x 4 5 x 5	6 x 1 6 x 3 6 x 6	3 5 4 x 3 6	3 4 6	4 6	3 x 1 3 x 2 3 x 3 to 7 x 6	6 7 x 6	7 x 7		2 x 1 3 x 2 4 x 3

"H.O." stands for high output, "R.S." for rapid start.

Table IV. Recommended Footcandle Levels for Floodlighting Building Exteriors

Construction Material	*Surface Reflectance (percent)*	*Surrounding Area* *Bright*	*Dark*
		*Footcandles Maintained**	
Light Marble, White or Cream Terra Cotta, White Plaster	70-85	15	5
Concrete, Tinted Stucco, Light Gray and Buff Limestone, Buff Face Brick	45-70	20	10
Medium Gray Limestone, Common Tan Brick, Sandstone	20-45	30	15
Common Red Brick, Brownstone, Stained Wood Shingles, Dark Gray Brick	10-20	50	20

Source: Illuminating Engineering Society.
**Light output maintained over the service life of the light source.*

lighted by the footcandles (FC) desired, BL is beam lumens of the unit, and MF is maintenance factor of the luminaire. Maintenance factor depends on type of luminaire, location, and maintenance practices; it is typically 70 to 80 percent for enclosed units and 85 percent for projector and reflector lamps.

The last step is a geometric check to make sure that the luminaires chosen will cover the surface smoothly. Generally, each beam pattern should be overlapped completely by those on either side (unless pattern lighting is desired). If coverage is not complete, the engineer applies a larger number of lower-wattage units or wider-beam units and recalculates.

Typical Installations

Pan Am Building—The main faces (north and south) of this New York office building are lighted from the tenth floor setback up to the top of the 59th floor, a distance of 550 feet (Fig. 1). To achieve such lighting, special searchlight type luminaires were developed by Kliegl Brothers and a special incandescent lamp by the Westinghouse Lamp Division.

The lamp had to have the most compact filament possible to enable the luminaire mirrors to project narrow but intense beams to the top of the building. At the same time, enough spread was needed to enable the luminaires to cover the lower areas, and a burning life of more than a year was desired. The lamp that was developed, designated 2000 G64/PA2, has a globular bulb of hard glass eight inches in diameter and a special 80-volt filament operating at 2000 watts. A collector grid traps tungsten particles as the filament vaporizes, preventing bulb blackening and thereby assuring good lumen maintenance. The special luminaires have cast aluminum housings with mirrored glass reflectors and clear tempered lenses. Each of the 170 units produces 2,750,000 candelas.

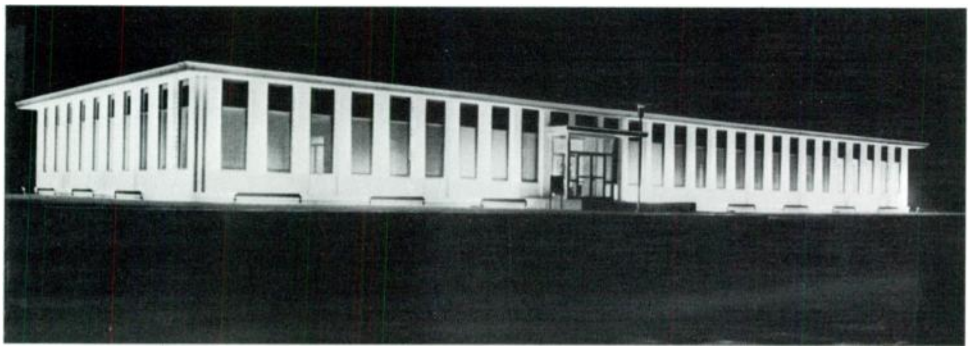
The smaller faces of the building are floodlighted with 1000-watt quartz-iodine lamps in luminaires that supply the same light distribution provided by the searchlights on the larger sides. All together, the luminaires wash the building with some 376 kW of lighting.

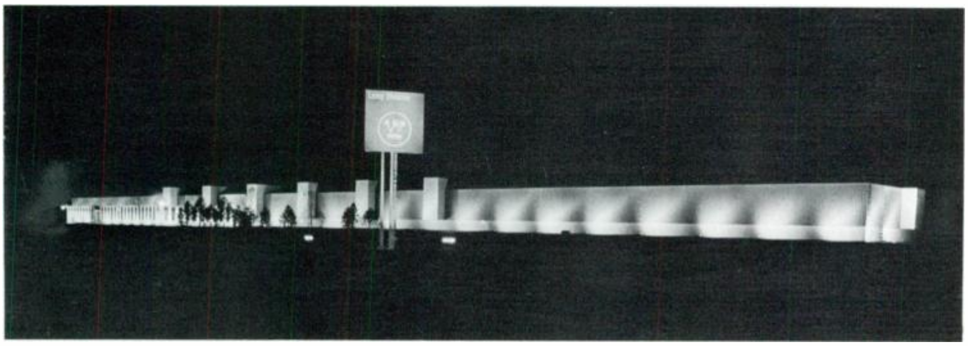
Fluorescent Lamp Plant—An entirely different problem from the preceding example was posed by a modern single-story manufacturing plant (Fig. 2). The objectives were to light the front and ends of the office building brightly and flatly so that it would stand out against the background of the manufacturing building behind it, which, although less brightly lighted, was to have enough illumination to clearly define its mass.

The office building is illuminated to a minimum intensity of 15 footcandles by lighting upward from ground level with weatherproof fluorescent floodlights. SHO-II lamps are used in Sataliner fixtures, which have a low silhouette.

For the manufacturing building, 27 1500-watt quartz-iodine floodlights are located at ground level, 14 feet from the wall on approximately 40-foot centers. They provide a pattern on the building's face and create a "glow" as background for the highlighted office building and the shrubbery. To delineate the pattern of the facade, all floodlights are aimed at 45 degrees from perpendicular to the building face and upward to provide an effect as though the sun were shining on the building at a 45-degree angle. One floodlight is opposite each column and each corner, with the others located as required to give adequate overlapping of patterns. The installation is one of the earliest applications of the recently developed 1500-watt quartz-iodine floodlight luminaires.

The shrubbery surrounding the office building is illuminated by batteries of floodlights on the building roof along both ends. The best lighting color for most shrubs is provided by mercury lighting, so 100-watt PAR 38 mercury lamps are used. They are mounted in heavy-duty cast aluminum outdoor floodlighting luminaires, which are neat and small for good appearance and so aimed that they do not project light and glare toward viewers of the scene.

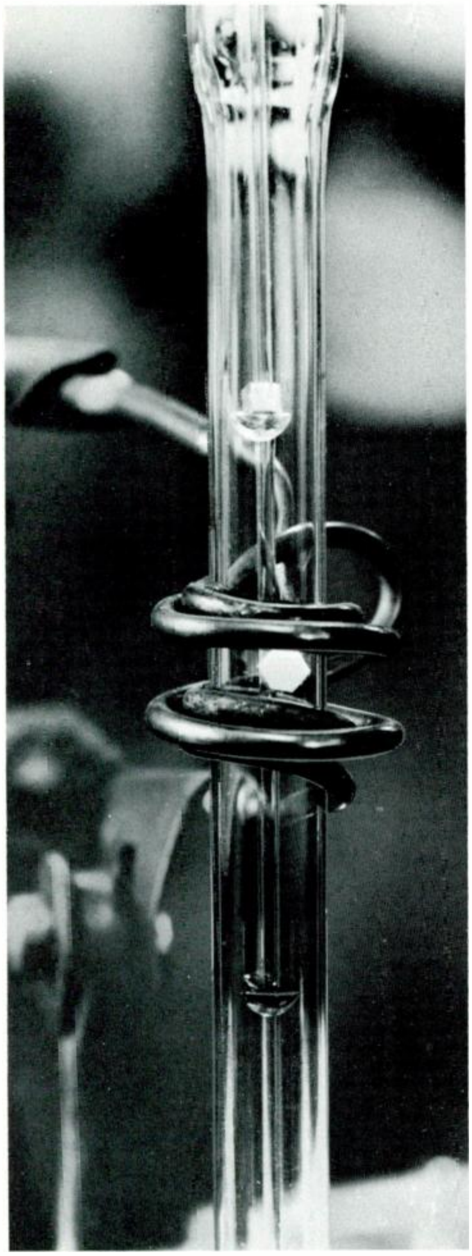




2—Manufacturing building of Westinghouse Lamp Division's fluorescent lamp plant at Salina, Kansas, has pattern lighting to serve as a background for the more brightly lighted office building (shown in upper photo and at left in overall view).

Sampling Method Improves Sensitivity of Analysis for Gases in Metals

J. F. Zamaria
W. M. Hickam



A metal sample floats in space in the gas extraction system, heated white hot. When it melts, it will give up its dissolved gases to the evacuated tube for analysis. The hot zone is restricted to the sample, and the sample is not in contact with any part of the system during heating, so there is little or no contamination from the system. After this sample has been melted, the tube will be moved down through the coil to levitate and melt the sample in the holder just above the coil.

Mass spectrometry and other sensitive analytical methods are only as good as the sampling systems used with them. A new method for extracting gases from metal samples employs electromagnetic levitation and heating to prevent contamination by contact with the system.

The use of "percentage" as a unit of measure in analytical techniques is rapidly becoming obsolete as the development of materials of ultra-high purity increasingly requires such terms as "parts per million" and "parts per billion" to describe impurity levels. Such precise knowledge of the impurities is essential to insure efficient performance of nuclear-reactor fuel elements, semiconductor devices, high-performance structural alloys, and various other components of modern technology.

Metal sputtering, vacuum fusion, and several other gas extraction methods have been used with sensitive analytical techniques for determining concentrations of gases in metals, but it is extremely difficult with them to determine concentrations of less than one part per million. Now, however, a gas extraction system employing electromagnetic sample levitation and melting has been developed for measurement in those low ranges; it retains many of the advantages of other analytical methods while eliminating most of their disadvantages.

Levitation and Heating

A metal sample or other electrically conductive object can be levitated—suspended in space—by placing it in a suitable high-frequency alternating electromagnetic field. The field induces current in the object, creating another electromagnetic field around it. The two fields repel each other, so the object moves from the stronger to the weaker part of the coil's field. For levitation, the field strength must decrease vertically to provide a lifting force equal to the weight of the object; for lateral stability of the object, the field strength must decrease radially toward the field axis to provide a restoring force toward the axis. The electromagnetic field also induces eddy currents along the surface of the object that heat it.

Such a field for levitation and melting is supplied by two coaxial coils designed to suit the power and frequency of the high-frequency ac power supply (Fig. 1). A sample placed within the coil floats in space, becomes hot, and melts.

The concept of levitating a solid with an electromagnetic field was first proposed in Germany some 40 years ago. Since then, various investigators have developed the technique, levitating and melting specimens weighing up to 100 grams.

Levitation and Material Analysis

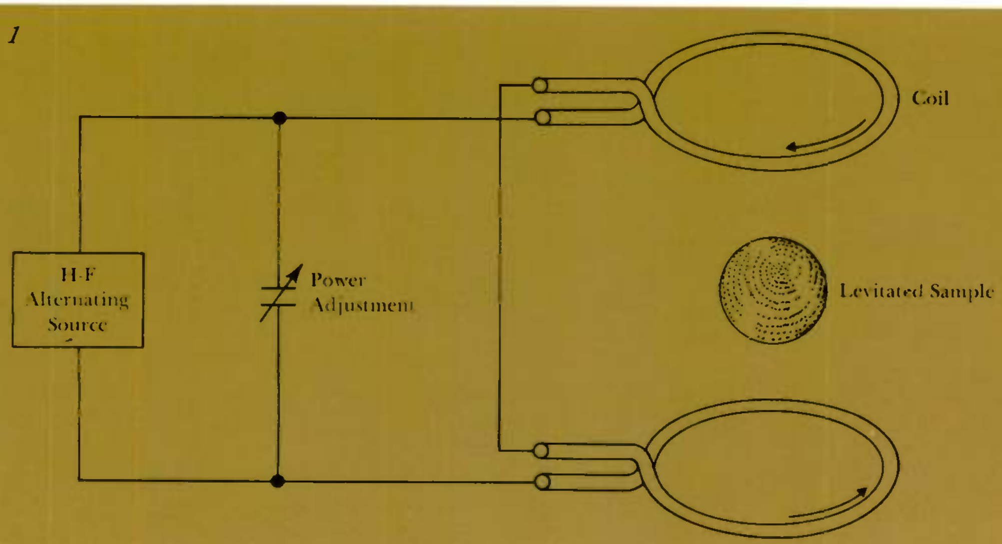
The Westinghouse Research Laboratories began to use the technique in 1949 for melting some of the more reactive high-melting-point metals because it isolates the hot reactive metal from other parts of the system and thus prevents sample contamination. Levitation melting has been used to purify metals, experiment in solubility of gases in metals, make alloys, and study reactions of gases with metals. At least 38 elements have been successfully levitated and melted, including copper, iron, magnesium, tantalum, and zirconium. Now the increasing need for knowledge about gaseous constituents in metals, plus development of the mass spectrometer, gas chromatograph, and other sensitive gas-measuring devices, have promoted analytical use of levitation melting for high-purity metals and space-age alloys.

1—Levitation melting principles are illustrated by this schematic diagram. Two coaxial coils supplied with high-frequency ac power support the sample with their magnetic fields. Current induced in the sample melts and stirs it, causing it to give up its dissolved gases for analysis.

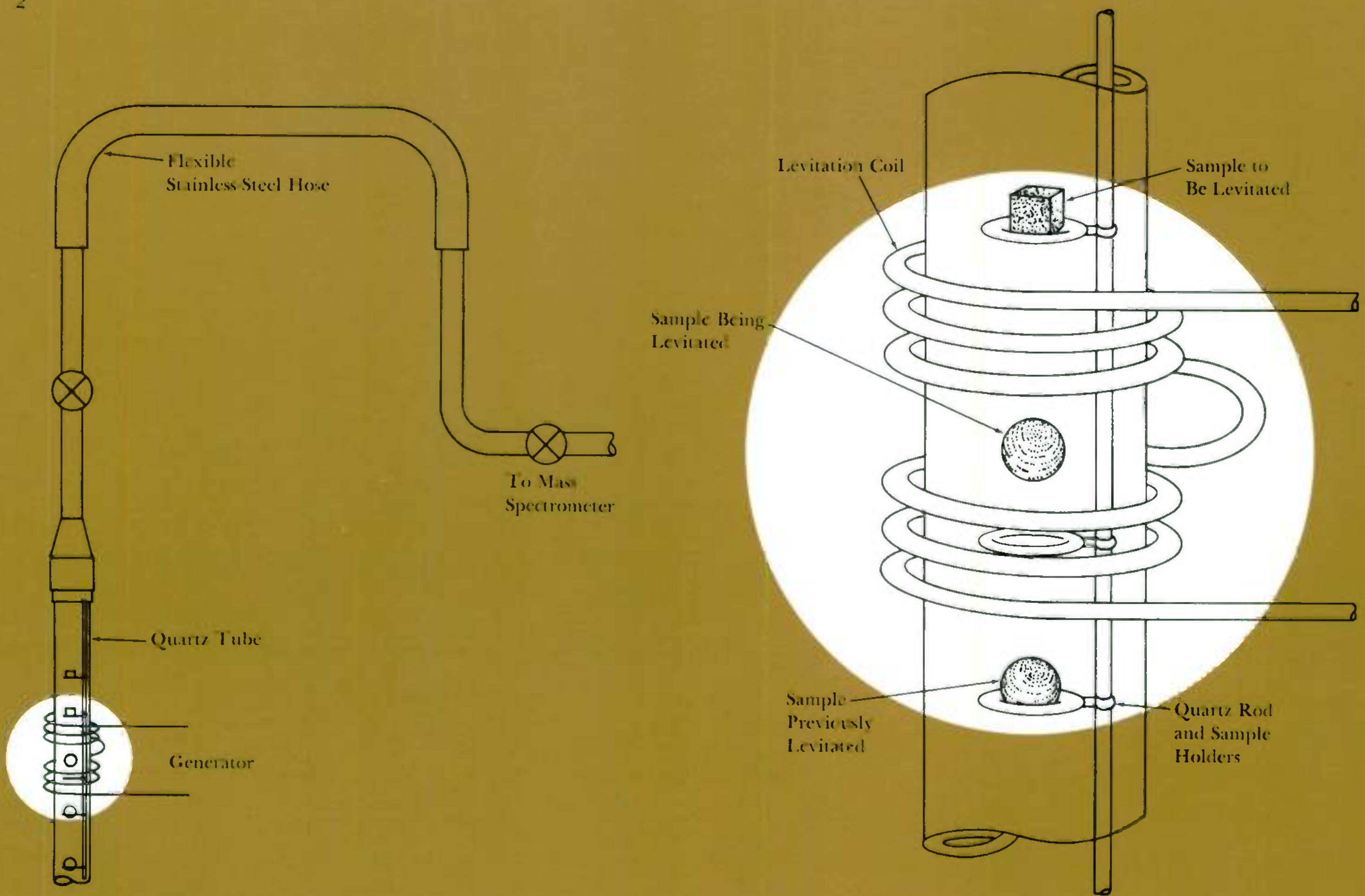
2—Levitation gas extraction system for analysis of gases in high-purity copper melts the samples in an evacuated quartz tube. The tube is moved through the coils to levitate and melt a number of samples in turn. Extracted gases are led to a mass spectrometer for analysis.

J. F. Zamaria is a control development engineer at Hagan/Computer Systems Division, and W. M. Hickam is Manager of Mass Spectrometry at the Research Laboratories, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania.

1


Coil
H-F
Alternating
Source
Power
Adjustment
Levitated Sample

2


Flexible
Stainless Steel Hose
To Mass
Spectrometer
Quartz Tube
Generator
Levitation Coil
Sample to
Be Levitated
Sample Being
Levitated
Sample
Previously
Levitated
Quartz Rod
and Sample
Holders

Levitation melting overcomes or reduces many of the problems encountered in high-temperature gas extraction for material analysis. One of the chief difficulties in other methods is the relatively high "background" problem caused by gas evolution from heated surfaces of the analytical systems; that difficulty is minimized in levitation melting because the hot zone is confined to the sample itself and the hot sample is not in contact with any part of the system while gas is being extracted. Levitation also prevents contamination of the sample and thus permits further analysis (by another levitation or by other methods) without the worry of impurities having been added to the sample by contact with heated surfaces. Moreover, the alternating electromagnetic field stirs the molten sample and thereby speeds gas extraction: levitation, melting, and gas extraction of each sample can be completed in about two minutes.

The system designed at the Westinghouse Research Laboratories is a crucibleless multiple-sample system with an all-quartz miniature reaction chamber (Fig. 2). Its levitation coil is powered by a 5-kW 450-kHz generator. As many as 15 samples can be analyzed without reloading the chamber. In use, the system is evacuated and the quartz tube moved vertically to position a sample in the levitation coil. The sample is picked up by the magnetic field, melts, and gives up its gas. The extracted gas is expanded into a three-liter volume and led to a mass spectrometer for analysis. Then the entire system is again evacuated and the next sample positioned in the coil for levitation. Despite the fact that the sample quantity for this particular system is limited to a weight range of approximately 0.3 to 1.0 gram, hydrogen and oxygen content of samples can be determined to levels as low as a few hundredths of a part per million by weight.

Instruments other than the mass spectrometer can be used with the levitation gas extraction technique. In quality control work, for example, where the *type* of gas impurity in a metal has been well established, a simple pressure measuring device such as a thermocouple gauge can be used to measure the gas *level* in a sample of the metal.

Besides the advantages, there are of course limitations and disadvantages associated with levitation-melting analysis. (Many of them, however, are not unique to levitation melting but are frequently encountered in other high-temperature analytical methods.) The most serious difficulty of electromagnetic melting is that of controlling sample temperature; although it can be controlled within reasonable limits by inserting an inert gas such as helium or argon at appropriate pressures, that reduces the sensitivity of the system. Another disadvantage is that the method is limited to conductive elements with certain combinations of conductivity and density (although that includes most elements of interest in present materials investigations). Moreover, sample shape and size are more restrictive than in some other analytical methods. Finally, adjustments may be necessary to tune the system for maximum coupling to the sample when different elements are levitated, but using an adjustable-frequency generator may solve that problem and also make levitation easier and improve temperature control.

Future Developments

The significant advantages of levitation melting over conventional hot extraction systems is stimulating further development of the technique. In one new approach, novel designs will be developed to try to levitate and melt materials that have thus far resisted the technique—for example, levitating carbon and metal together to encourage extraction of oxygen from the metal oxide in the form of carbon dioxide.

Moreover, the levitation melting technique, coupled with mass spectrometry or another analytical method, lends itself well to isotopic dilution analysis. In that technique, isotopes of the gases being sought are introduced into the reaction chamber before levitation. After levitation and melting, the gas mixture is analyzed; the isotopes in the mixture are easily distinguished from the gases evolved from the sample, and the excess amount of gas over the known amount of isotope is assumed to have been evolved from the sample. This method of analysis has advantages over the evolution of gas into an evacuated system because it does not require complete gas extraction. Isotopic equilibration of the gas followed by isotopic analysis of the gas provides the desired analysis. Moreover, having gas in the reaction chamber aids in controlling sample temperature.

Isotopic dilution analysis has been used to determine the amount of hydrogen in high-purity vacuum-arc-melted copper. The system was evacuated and then deuterium, the isotope used, was introduced in a mixture with helium at a pressure of about one torr. The copper sample was levitated and heated to 1100 to 1200 degrees C for two minutes, and the resulting gas mixture was expanded into an evacuated three-liter volume associated with the inlet system of the mass spectrometer. Typical hydrogen and oxygen concentrations found were 0.12 and 2.0 parts per million by weight respectively. However, the levitation technique revealed that those measured levels resulted primarily from contamination that occurred during machining operations and resisted removal by conventional cleaning techniques. True hydrogen and oxygen concentrations in the bulk copper were found to be approximately an order of magnitude lower. The technique also has been applied for hydrogen analysis of zirconium.

Work is under way to extend the capability of the combination of levitation melting and isotopic dilution analysis. One possibility is use of a mixture of deuterium, carbon-13, nitrogen-15, and oxygen-18 for a simultaneous analysis of a single sample for hydrogen, carbon, nitrogen, and oxygen. Those elements are especially important in materials analysis because they are among the most abundant in nature and therefore are usually present as impurities in materials. More accurate measurement of their concentrations will make possible the development of materials of even higher purity than are available today.

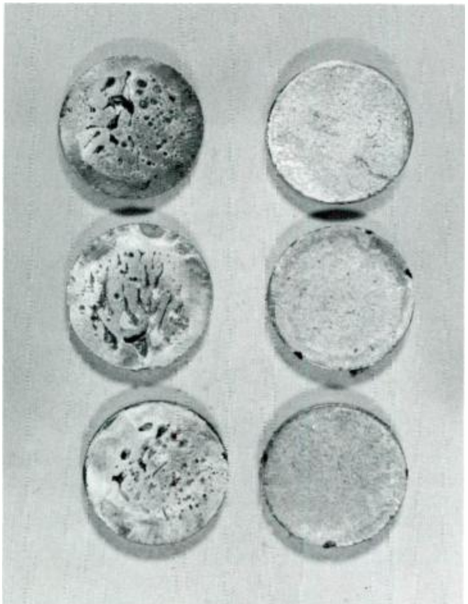
Induction Brazing System Improves Quality of Circuit Breaker Contacts

The brazing of electrical contacts in power switching devices has traditionally involved many variables that justified calling the process an art, since it depended on the judgment of a skilled operator. Now, however, a new production brazing process known as ISO-Braze has been introduced at the Westinghouse Power Circuit Breaker Division to provide controlled conditions. It makes consistent bonds of high quality to meet the increasing service requirements for power circuit breakers.

Because alloyed tungsten contact tips are difficult to wet with brazing alloy, the traditional method included "puddling"—mechanically agitating the parts being brazed. Puddling permitted gases to escape and reduced surface tension, improving wetting and thus reducing voids in the braze zone. However, puddling cannot be automated, so the automatic ISO-Braze process was developed to provide excellent braze wetting by accurate and reproducible control of brazing temperature and pressure.

In addition to overcoming wetting problems, the ISO-Braze process prevents harmful overheating of the copper members to which the contacts are brazed. The special high-conductivity copper alloys used require minimum heat input to prevent the softening overaging phenomenon to which they are susceptible. Brazing should be done at minimum time and temperature, but that has been difficult because brazing temperatures and overaging temperatures are close together; excess brazing heating could cause loss of alloy hardness and rejection of the entire assembly. Past efforts to use automatic temperature control were not successful because of the factors requiring operator judgment for acceptable bonding. The ISO-Braze process, however, controls temperature so well that electrical contacts are brazed with less than one percent rejection rate of the assemblies. Besides preventing overheating, the new process increases the braze bond area by 30 percent or more from that with the previous method.

ISO-Braze provides precise temperature control to simplify production and improves product quality when brazing heat-sensitive materials. Here, contact shunts for power circuit breakers are being tested ultrasonically after brazing.



Former brazing technique produced braze interfaces containing many voids (left); ISO-Brazing bonds more than 90 percent of the interface area (right).

The ISO-Braze process (isothermal and isobaric induction brazing) was developed by engineers of the Westinghouse Headquarters Manufacturing Laboratory and the Power Circuit Breaker Division's manufacturing engineering department. Induction heating generates heat within the material in proportion to the magnitude of the current flow in the heating coil, raising the surface and inner structure of the material uniformly to the melting temperature of the braze alloy. The temperature is kept from going too high or too low by a control system, which includes an infrared optical camera that produces an electrical signal from infrared energy reflected from a small target area on the part being heated.

Constant pressure applied to the parts during heating brings them together as the braze alloy melts. Under those controlled conditions, consistent uniform bonds are produced.

The new technique improves the versatility of induction brazing when applied to heat-sensitive materials, whether for contact devices or other applications. Advantages in the contact brazing application include braze alloy wetting of refractory alloy without agitation, bonded areas exceeding 90 percent, higher shear strength through keeping joint thickness to less than 0.001 inch, and increased part service ratings. Since installation of the ISO-Braze system, thousands of contact assemblies have been joined with it and have met requirements more severe than those demanded by the aerospace industries.

Integrated Electronic Circuits Get New Package Deal

Although integrated circuits save much in size and weight, their main contribution has been a great reliability increase over conventional electronic circuits. For such reliability, however, an integrated circuit has to be sealed effectively against its environment to prevent chemical instability and internal electrical changes. Until recently, protection has been accomplished by putting the silicon circuit device inside a hermetically sealed protective package; now, a new manufacturing process seals the device itself. Consequently, the new integrated circuits can be molded into inexpensive plastic packages and yet be as well protected as though they were in metal-ceramic packages.

The new sealing process begins after the integrated circuits have been made in the conventional manner on a silicon wafer. A thin sealing layer of silicon nitride is deposited onto the wafer; this material is extremely stable and inert and thus gives excellent protection to the silicon surface. Then openings are etched through the silicon nitride and a thin film of aluminum is evaporated on to form the interconnections between the working areas of each circuit. To protect those interconnections, a layer of glass is deposited on the wafer, and then openings for the required electrical contacts are etched through the glass. Finally, thin films of titanium and gold are deposited at the contact points by evaporation. The titanium adheres strongly to the glass layer and seals the contact windows, and it also separates the aluminum and gold layers to prevent their interaction at high temperatures. The gold provides the best possible material for bonding hair-like gold wires that connect the integrated circuit into an electronic system.

The wafer is then electrically tested and cut into its 500 or more individual integrated circuits. The circuits are mounted on bases, wire-bonded, and molded into their plastic packages.

The new process protects the surface of these "Goldilox" integrated circuits from scratches and from moisture and other contaminants, prevents metallurgical interaction between different metals in contact with each other at all temperatures of interest, and prevents internal electrical leakage at high temperatures. The devices are sealed so well that, even with no packaging of any kind, they have been operated experimentally under water for periods of more than an hour. The devices are the result of more than 160 million circuit test hours of study on types of failure in integrated circuits. Test data, plus information from customers' test programs, made possible the Goldilox total approach to reliability rather than a piecemeal attack on some of the problems.

Goldilox integrated circuits have been subjected successfully to more than 120,000 circuit test hours involving such conditions as high temperature, thermal and mechanical shock, vibration, and reverse electrical bias. The Westinghouse Molecular Electronics Division has converted some product lines to the new process and expects to have all standard product lines converted late this year.

Multiple Radar Test Ranges Speed Development and Checkout

As radar systems become more sophisticated, antenna complexity and performance requirements increase continually. Multiple beams, scanning beams, precise beam shaping, polarization diversity, and very low sidelobes have become the rule. To develop such antenna systems rapidly and evaluate them accurately, a complete test-range complex was opened recently by the Westinghouse Surface Division. The facility is one of the most completely instrumented and automated in this country. In addition to its use in Westinghouse programs, its services are leased to other users.

Control building in the radar antenna test complex has receiver mounts on its balcony and roof. The main mount extends 30 feet above roof level and provides ability to test very large antennas. In the background is the range's low-frequency transmitter tower.

The facility includes two major three-axis mounts at receive sites, and a number of smaller mounts. One 40-foot and three 80-foot towers at various ranges provide transmit sites; each is equipped with remotely controlled generator and antenna. Using the sites in various combinations provides 6000-foot, 5082-foot, 780-foot, 724-foot, and 700-foot ranges. The latest is a 1650-foot ground range.

The facility is unusual in its capability for testing very large antennas in the frequency range from 50 MHz to 10.0 GHz. The mile range, for example, allows testing of S-band antennas up to 45 feet in diameter, X-band antennas 15 feet in diameter, and C-band antennas 20 feet in diameter. The 724-foot range allows testing of large low-frequency antennas; it has a 40-foot dual-band phased-array source antenna that allows range operation either in the UHF region or in L-band, maintaining constant illumination of the test aperture across both bands. Instrumentation includes automatic radiation distribution printers, tape recorders and readers, rectangular pattern recorders, and digital readout of angles to 0.01 degree.

The largest single structure is at the junction of the 5082-foot, 724-foot, and ground ranges. (See photograph.) Its large pedestal can carry a 25-ton antenna, measuring up to 38 by 38 feet, in any position. A servo-controlled positioner drive system affords precise speed regulation; it has a 15-bit shaft-mounted encoder on each axis.

The second largest mount can handle a 2000-pound antenna up to 14 by 21 feet in size. The mount is equipped for step cycling, it can be instrumented to punch cards or tape in addition to making standard rectangular chart recordings, and it has 17-bit shaft encoders mounted on the azimuth and elevation axes. Data taken with the positioners of the two major mounts (and with associated recording equipment) can be fed to a computer programmed for immediate data analysis, reducing test evaluation time by 75 percent.

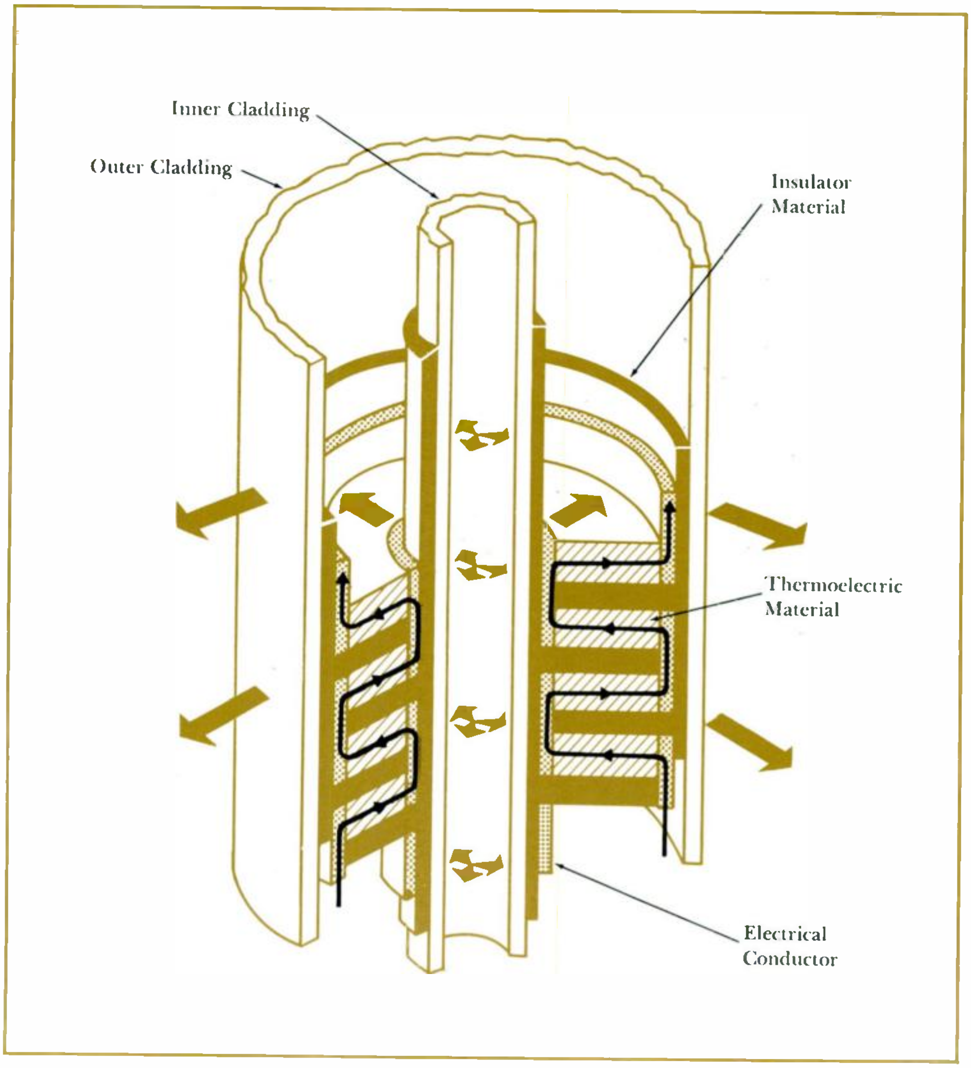
The ground range has a surface 1650 feet long artificially leveled to ±1 inch. The level surface permits accurate control of reflections, which are used to obtain a sufficiently uniform field over the aperture of the antenna undergoing test. The ground range is used mainly for testing high-gain antennas when it is desirable to examine the minor lobe structures down 40 decibels or more from the peak of the main lobe.

Having a number of ranges allows scheduling even special test programs on reasonable notice. Moreover, the new test facility greatly reduces pattern testing time, traditionally the longest period in a radar development schedule, and facilitates certain tests on large multiple-beam systems that would be nearly impossible with simpler equipment. An example of such a multiple-beam system is the three-dimensional type of radar that generates height information about targets as well as azimuth and range: it has a large number of receive beams summed into a single transmit beam through duplexing and phasing. The new test equipment allows simultaneous recording of the multiple beams, acquiring angular interpolation directly and eliminating possible errors due to manual plotting, signal drift, synchro backlash, and reflector deflections in gusty winds. Gain measurements made in the same manner are the most accurate obtainable. The equipment is also used effectively for phasing the transmit patterns and recording phased beam deflection.

Modular Thermoelectric Generator Is Versatile Remote Power Source

A recent advance in thermoelectric power conversion is development of a thermoelectric generator in the form of a tubular module. The module is a mechanically processed standardized device ready for use in space, marine, or terrestrial applications. It is compatible with presently available heat sources, and it can be operated in air, vacuum, inert gases, or even submerged in liquids. The module can be operated as a single unit or as a group of units to produce required power levels. (Some space missions may require 50,000 watts or more.) It was developed by engineers at the Westinghouse Astronuclear Laboratory partly through funding by the U. S. Atomic Energy Commission.

The key technological development is the module's tubular structure. In contrast to other thermoelectric generators, many of which are formed from pellets held in place by springs and fasteners, the new module has a cylindrical and symmetrical form throughout. Washer-shaped thermoelectric elements are stacked on top of each other, with similarly shaped electrical insulators between them and cylindrical conductors connecting them (see diagram). The components are held between inner and outer claddings that prevent internal displacement. The fabrication process keeps the inner cladding in compression and the outer cladding in tension, thereby creating a high compressive loading that prevents separation of the thermoelectric elements from their electrical contacts and thus eliminates a potentially serious cause of thermoelectric degradation.



Tubular thermoelectric generator employs heat differential between inner and outer claddings to produce electric power. Colored arrows indicate heat flow; black arrows show power flow through thermoelectric elements and conductors.

The module is a fully sealed power package needing only a heat source within its core to become a power generating system. The choice of heat source depends on the application; it can be a gas or liquid fossil-fuel burner, a radioisotope capsule, or gas or liquid heated by a nuclear reactor. The heat source for deep-sea space use, for example, probably would be a radioisotope capsule or a nuclear reactor because those applications may require long-time heat supplies that are impractical with fossil fuels.

As heat flows radially through the thermoelectric material to the outer cladding, the temperature drop from the inner to the outer circumference of the module produces a voltage and current. The current flows inward through one thermoelectric element to an electrical conductor adjacent to the inner cladding, through the conductor to the next thermoelectric element, outward through that element, and to the next thermoelectric element by way of the conductor adjacent to the outer cladding. The flow continues through succeeding layers of material to the external power leads.

Tests performed by Westinghouse and Government laboratories have demonstrated that the modules can withstand impacts as great as 10,000 g without being degraded in performance. The modules are insensitive to thermal cycling and to moderate overheating. Longevity tests indicate a capability of producing power for long periods: some modules have been on test for more than 20,000 hours.

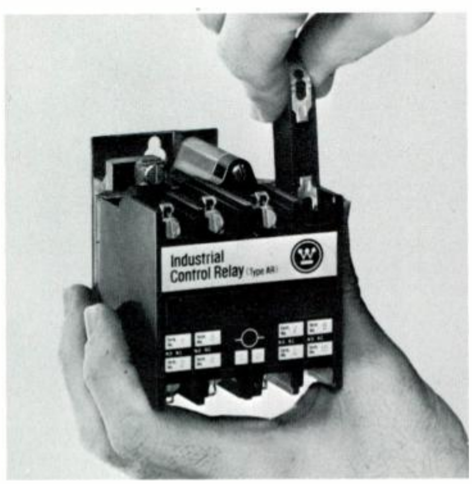
Products for Industry

Numerical machine tool control is designed to make full use of the inherent advantages of integrated circuits, which reduce the number of components and connections and thereby increase reliability as compared with units that use conventional discrete solid-state components such as transistors. Model 40 control provides point-to-point positioning of machine motions, control of straight-cut machining, and automatic control of machine auxiliary functions. Typical applications include vertical turret lathes, vertical boring mills, horizontal boring mills, turret punch presses, and machining centers. The Model 40 can automatically position any practical number of machine tool axes with a programmed accuracy of 0.0001 inch. Its design permits performance requirements to be met at minimum cost by providing only the control features required by a particular machine. Inputs are by EIA standard coded tape or manual dial-in, and the unit can operate from any 115-, 230-, or 460-volt 60-Hz power source. Dimensions are 36 inches wide by 60 high by 30 deep. *Westinghouse Industrial Systems Division, 4454 Genesee Street, P.O. Box 225, Buffalo, New York 14240.*

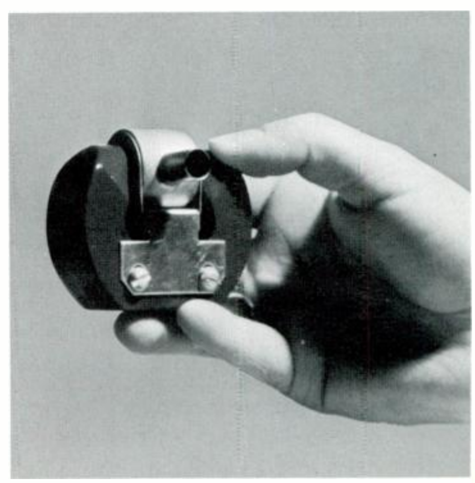
AR relay is a 600-volt electromechanical device that is large enough for easy maintenance access yet takes little panel space. Widely-spaced 600-volt poles simplify installation, contact testing, and maintenance, and contacts are electrically and mechanically isolated. The device is made in four- and six-pole versions. Accessories include a four-pole adder, solid-state timer, and a latch. Terminals are marked to identify normally open and normally closed poles. The fully encapsulated coils are color coded according to voltage and can be used interchangeably with all AR applications of similar voltage. Contact poles can be individually converted from normally open to normally closed position, without disturbing other wiring, by turning the contact cartridge 180 degrees (see photo). *Westinghouse Standard Control Division, Beaver, Pennsylvania 15009.*

Carbon dioxide gas laser can perform cutting and slitting operations that are impractical or impossible with conventional mechanical techniques. Power output is adjustable up to 100 watts, at 10.6-micron wavelength. The Model CO2100 laser cuts many materials, including cardboard, rubber, glass, quartz, ceramics, wood, textiles, and plastics. Since its beam is focused on a very small portion of the workpiece, heating is local and rapid. The resulting cuts are smooth, with no charring or bead formation. Specifications include beam diameter of 1.5 cm, beam divergence of less than 2 milliradians, and focus spot size down to 0.004 inch diameter. *Westinghouse New Products Division, P.O. Box 8606, Pittsburgh, Pennsylvania 15211.*

Electronic vacuum pumps are for applications ranging from basic vacuum process research to industrial thin-film production. They are of the type known as appendage ion pumps, the smallest of a large class of electronic pumps referred to as ion-sorption pumps, ion pumps, or sputter-ion pumps. The three Westinghouse models are for use at pressures between 10^{-4} and 10^{-9} torr; they have speed ratings of 0.15, 0.2, and 1.0 liter per second. *Westinghouse Electronic Tube Division, P.O. Box 284, Elmira, New York.*



AR Relay



Electronic Vacuum Pump

About the Authors

Lisle G. Russell has been designing mechanical systems for environmental control for the past 25 years. He graduated from Pennsylvania State University in 1940 with a BS in Mechanical Engineering. He joined Westinghouse but in 1943 was called to duty in the United States Navy as a training officer at the refrigeration school. Russell was next employed by the Pittsburgh Board of Public Education as an instructor in mathematics, science, refrigeration, and air conditioning. He earned his MS in Engineering Education at the University of Pittsburgh in 1951. In 1953, he became chief engineer with W. J. Keist and Son, a Pittsburgh firm, where he was responsible for designing and supervising installation of air conditioning systems. Russell then joined Koening, Inc., in 1961, where he continued as a specialist in evironmental control. He returned to Westinghouse in 1962 as Manager, Mechanical Systems Engineering, where he initiated and set up a computer engineering service. He was later assigned as a consulting and liaison engineer to the Air Conditioning and Lighting Divisions. Since 1967 he has been a mechanical systems engineer in Major Projects and Urban Systems, Construction Group.

William S. McIntyre earned his BSEE from Virginia Military Institute in 1947, joined Westinghouse as a sales correspondent in Industry Sales, and in 1954 became a sales engineer in the Pittsburgh district sales office. He transferred to the Systems Control Division in Buffalo in 1956 as Assistant Manager, Control Equipment. Two years later he was made Sales Manager, Metal and Paper Section, and, in 1964, Product Manager, Single-Stand Metal Mill. When the Industrial Systems Division was formed in 1964, McIntyre was made Manager, Metals Industry Systems Department. He became Division General Manager the following year.

C. A. Meyer, G. J. Silvestri, and **N. R. Deming** all have been involved in development of standards for power-plant development and testing, including the new steam tables.

Meyer graduated from Villanova University in 1933 with a BSME degree. He joined Westinghouse at the Steam Divisions and spent two years supervising development of three experimental diesel engines. He then moved into the steam- and gas-turbine area to work in experimental development, including design of the first locomotive gas turbine and the first axial-flow turbojet engine. In 1953, he was made manager of a design section. He next headed a group that carried out computer programming of the division's steam turbine engineering calculations. He was named an Advisory Engineer in 1963 and has since carried out design studies of new types of vapor power plants. Meyer is a member of the International Formulation Committee of the Sixth International Conference on the Properties of Steam and a coauthor of the *1967 ASME Steam Tables*.

Silvestri earned his BSME at Drexel Institute of Technology in 1953. He joined the Steam Divisions, where he has served as a project engineer in low-pressure turbine model tests, development of the generalized performance and heat balance program, and cycle performance and evaluation studies. He also helped develop the computer package for the new steam tables. Silvestri earned an MSME at Drexel in 1956.

Deming graduated from the University of New Hampshire in 1944 with a BS in Mechanical Engineering, and he has since taken courses there and at the University of Pennsylvania in mechanical engineering and business management. He joined Westinghouse on the graduate student course in 1947 and was assigned to the thermodynamics section of Large Turbine Engineering. Deming has since been involved in all phases of performance testing all over the world, and he helped develop the procedures and techniques used to determine performance of electric utility steam turbines. He was appointed Supervisory Engineer in 1957, responsible for the power plant economy test program.

R. W. Griffith and **Fred J. Bertoldo** team up to describe aerospace electric motors.

Griffith graduated from Ohio State University in 1950 with a Bachelor of Industrial Engineering degree. He served two years as assistant sales manager with the Lynch Corporation, Par Compressor Division, and then joined the Westinghouse Aerospace Electrical Division as a negotiation engineer. Since then he has progressed through the marketing ranks to his present post of Customer Service Manager.

Bertoldo joined Westinghouse on the graduate student course in 1953 after graduating from Utah State University with BS degrees in Civil Engineering and Business Administration. He went to the Small Motor Division the following year as a sales engineer, and in 1955 he became a field sales representative in the division's York, Pennsylvania, office. In 1961, Bertoldo transferred to the Aerospace Electrical Division as a senior sales engineer in the Utilization Systems Department. He became Sales Manager and is now the department's Marketing Manager.

K. Chen and **E.B. Karns** combine long and varied backgrounds in lighting.

Chen earned his MEE degree at Harvard University in 1948. He worked first as a relay specialist with American Foreign Power Company and then as a project engineer with Ebasco Corporation. He joined the Facilities Department of the Westinghouse Lamp Division in 1956, where his major responsibilities have been in development of plant power distribution and lighting systems. (He designed several of the floodlighting examples cited in the article.) Chen is a senior member of the Illuminating Engineering Society and the IEEE, and he serves on the latter's Industrial and Commercial Power Systems Committee.

Karns graduated from the University of Kentucky in 1928 with a BSEE degree. He joined Westinghouse on the graduate student course and then served in the Indianapolis district sales office, electric utility department. He transferred to Lighting Division headquarters in 1936 as an engineer in the design and application engineering department, where he was responsible for developing and applying products for street lighting, floodlighting, and aviation and marine lighting. Karns was appointed manager of the Outdoor Lighting Section in 1956, and in 1966 he became Product Communications Manager with responsibility for communications for all outdoor lighting product activities. He has contributed to development of mercury street lighting and floodlighting, special lighting for several world's fairs, and airport lighting equipment.

John F. Zamaria and **William M. Hickam** join forces for the second time.

Zamaria joined the Westinghouse Research Laboratories in 1951 as a technician while attending University of Pittsburgh evening classes under the Westinghouse educational program. He received his BS degree in Natural Science in 1966 and started work on development of solid-electrolyte oxygen gauges (a development he described in an article with Hickam in the July 1967 issue of the *Westinghouse ENGINEER*). He has also worked in analysis of high-purity helium, analysis of gases dissolved in transformer oil, and development of a technique for analyzing gases from hermetically sealed units. Zamaria transferred to the Hagan/Computer Systems Division last year, where he has worked mainly on development and application of oxygen analyzers for automatic furnace control systems.

Hickam got his BS in Physics at Randolph-Macon College in 1941 and his MS in Physics at Virginia Polytechnic Institute the following year. He has since taken graduate work at the University of Pittsburgh. Hickam joined Westinghouse at the Research Laboratories in 1942 to work with commercial mass spectrometers, a field that evolved into 15 years of research in mass spectrometry and ionization and 10 years of development and application in mass spectrometry. Other developments he has been responsible for or contributed to include the solid electrolyte oxygen gauge, mass-spectrometry helium leak detectors, the Westinghouse analytical mass spectrometer, instrumentation for fast breeder reactors, and research on liquid metals.

This full-scale mockup of the supervisory and control office for the Bay Area Rapid Transit (BART) system being built in the San Francisco area was constructed to evaluate the room's visual displays, traffic flow, and other engineering details. The room will be located in BART's Oakland headquarters and will be the control center for the three-county transit network; its display panels will show the condition of the system's electrification and support facilities and the locations and movements of trains. The Westinghouse Transportation Division is supplying automatic train control and communications equipment for the system. Initial lines of the system are expected to be in operation in 1970.