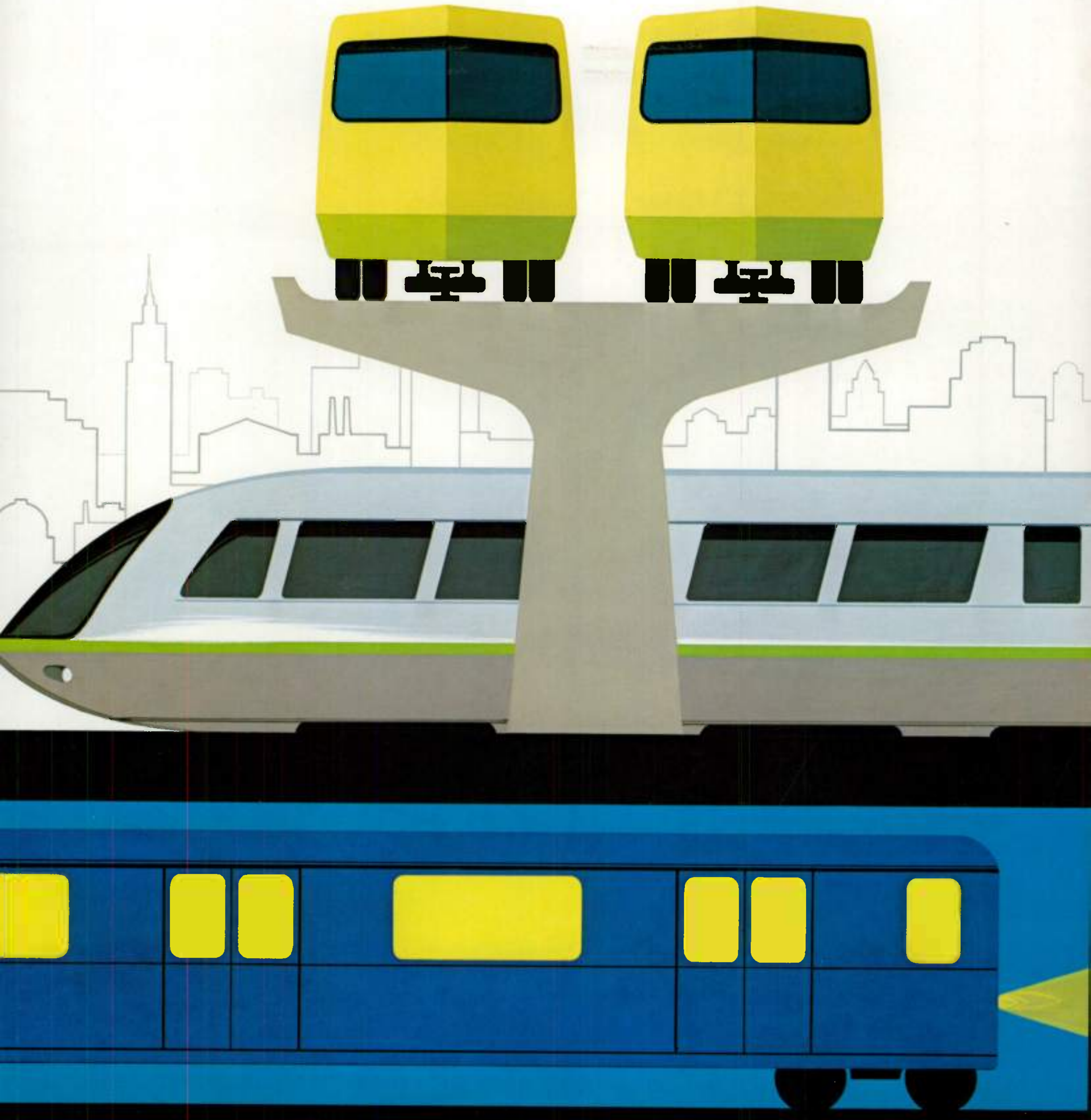
Westinghouse ENGINEER

July 1972



Shirley Highway Gets Brighter Look

New lighting gives Shirley Highway, the recently rebuilt segment of Interstate 95 south of Washington, D.C., a day-like appearance in the middle of night. Nearly 1000 lighting fixtures illuminate the 7-mile stretch. They provide maintained illumination of about 1.1 footcandles in the outer lanes and 0.6 footcandle in the reversible center express lanes. The lighting is sufficient for future nighttime television surveillance as an aid to traffic control.

Standard Westinghouse mercury lighting fixtures are used; 450 of them are 1000-watt OV-50 units, 453 are 700-watt OV-50 units, 63 are 400-watt OV-25 units, and 10 are 100-watt VB-15 units.

To minimize collision hazards, the poles are placed three feet behind the guardrail and are of breakaway construction. This off-shoulder location also allows easier servicing. Brackets 8 and 12 feet long are used to extend the fixtures over the outer traffic lanes. The fixtures are mounted at heights of 50 feet on the main roadway and 40 feet on the access ramps and overpasses.

All the lights operate at 277 volts on a three-phase four-wire system. Ballasts are regulated output types, and lamps are of the "clear" variety. The consulting engineer for the project was Howard, Needles, Tammen and Bergendoff of New York.

Westinghouse ENGINEER
July 1972
Volume 32, 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
Westinghouse Building, Gateway Center
Pittsburgh, Pennsylvania 15222

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

Front Cover: Modern rapid transit and other people-moving systems are depicted on this month's cover. An article on the automatic train-control techniques that make such systems feasible begins on the following page. The cover design is by Tom Ruddy.

Design Techniques for Automatic Train Control

R. C. Hoyler

Automated control and communication systems presently available provide safe and efficient train operation.

Modern rapid transit, and other people-moving systems for such facilities as airports, rely on automatic train control to achieve today's objectives in service, safety, reliability, and economy. Full automation provides faster response time, greater safety, more frequent service, and lower operating costs than would be possible with human control; fail-safe design protects the passengers in the event of equipment malfunction; and modern technology provides both those benefits within a reasonable size and cost.

Although each installation is different, many of the general design considerations discussed in this article apply. The equipment that has been developed to implement the designs will be discussed in a following issue of the *Westinghouse ENGINEER.*

R. C. Hoyler is Manager, Negotiations Support, Transportation Division, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania.

System Requirements

Passenger Comfort—The important quality of smooth ride depends on train control as much as on the wheels and running surface. Certain limits on acceleration, deceleration, and jerk (rate of change of acceleration) have been found over the years to be acceptable. They are affected by velocity around curves and by such track characteristics as "banking" and spiral into curves, so those considerations must be taken into account by the train control system, which then limits propulsion and braking as required.

Service and Safety—Trains should be operated as frequently as possible to provide the best service. More important than service, however, is safety under all conditions, including equipment failures. Safety considerations include how closely trains in a system may run without danger of collision, so they affect the minimum safe headways (time intervals between trains). (See Fig. 1.)

The distance needed to stop depends on train speed and acceleration, system reaction time, braking effectiveness, and jerk limits (Fig. 2). The worst case exists if a lead train stops suddenly, as a result of an equipment or right-of-way failure, and the following train is accelerating just as it receives information as to the problem ahead. For full safety, moreover, reaction time and braking rate must be assumed to be at their worst-case tolerances. Reaction time is the time it takes the control systems to interpret and react to the stop signal; it is on the order of one second for the control equipment in the Bay Area Rapid Transit (BART). Braking rate is determined by the brake system, and it generally varies with wet or dry conditions. The BART system has a nominal rate between 2.7 and 3.3 mi/h/s on straight level track.

Design for the closest practical headway must also take into account the definition of the detection system, i.e., its ability to determine the positions of the leading and following trains. To establish the minimum guaranteed headway, the separation distance must include the total detection uncertainty for each train as well as the safe

Automated Transportation Systems

Systems built, or being built, with some or all of the Westinghouse Transportation Division's automatic train control techniques are the Bay Area Rapid Transit (BART) in the San Francisco area, the Transit Expressway Demonstration Project at Pittsburgh, the passenger transport systems at Tampa International Airport and Seattle-Tacoma International Airport, and the São Paulo, Brazil, rapid transit system.

Bay Area Rapid Transit will be the world's first fully automatic transit system. It is a double-track 75-mile railroad with trains of two to ten cars that will run automatically at speeds up to 80 mi/h with rush-hour headways of 90 seconds. Overall average speed, including 20-second station stops, is 50 mi/h. The first section, 23 miles long, is scheduled to go into service late this year; the entire system is expected to be in operation about a year later. The system is fully automatic and does not require an attendant, although one will be on each train to provide passenger assistance and to operate the train at reduced speeds in the event of a breakdown.

The Transit Expressway Demonstration Project was built and operated for the Port Authority of Allegheny County. It has demonstrated completely automatic operation, with no attendant on board the vehicles. The facility consists of a 9340-foot loop, a 1050-foot spur, two stations, and three 70-passenger rubber-tired vehicles that run singly or in trains at speeds up to 50 mi/h. The rubber-tired vehicles run on a guided roadway that includes both at-grade and elevated construction, a switch, and a 10 percent grade. The facility was used principally for test and demonstration purposes. Between the beginning of tests in 1966 and their conclusion early this year, it carried more than 250,000 passengers.

The Tampa International Airport Passenger Transport System minimizes the typically long walking distances for air travelers.[1] More than 10 million people have ridden it since it went into service early in 1971. The airport consists of a central terminal building with four (expandable to six) outlying satellites, each located approximately 1000 feet radially from the terminal. Each satellite is connected to the terminal by two 100-passenger rubber-tired vehicles on their own elevated roadways. The system operates completely automatically to carry more than 5000 people an hour on each leg, with a total travel time of 40 seconds.

The Seattle-Tacoma International Airport Satellite Transit System consists of three underground systems linking various points in the main terminal and outlying satellite terminals.[2] Two are approximately 4000-foot loops, each linking two legs of the main terminal with an outlying satellite, and the third is an 1100-foot intraterminal shuttle linking the two loops. Each loop has three trains consisting of one to four rubber-tired 106-passenger vehicles, and the shuttle has a single vehicle of the same type. The automatic system has a total capacity of more than 30,000 people an hour, with a departure every 2 minutes or less. It is scheduled to go into operation this year.

The São Paulo Metro will begin as a 17-km north-south line, the first segment of a planned 200-km rapid-transit system serving South America's largest city. Its automatic train control will be patterned after that in the BART system. It includes a central control computer, local control units at passenger stations and train yards, car-mounted control packages, and data communication equipment required to tie the system together. In addition to the train control and communication system, Westinghouse through its subsuppliers will provide closed-circuit television surveillance equipment for stations, a system of coordinated clocks to synchronize operations, public address equipment, mobile radios, and a teleprinter system. The first segment is scheduled to be in operation in 1974.

stopping distance. For a system in which the route is quantized into defined lengths (called blocks) in which a train is either detected or not, the uncertainty consists of twice the length of a block plus the distance corresponding to any time delay in indicating a vacated block as unoccupied. The time delay is less than 1 second in the BART equipment.

Block length can be reduced for better definition, but that increases the amount of block equipment required and therefore raises costs. Maximum block length on BART is approximately 1000 feet, which is somewhat more than the length of the longest train (700 feet) but sufficient to provide the required 90-second headways. Train length also enters into the determination of headway as related to stopping distance, because headway is measured from the front of one train to the front of the next; stopping distance is measured from the rear of one train to the front of the next. Physical spacing of trains is closest at stations, where dwell time and the acceleration time needed to clear the station are critical factors affecting a following train.

Typical stopping distances from various speeds, and the resulting minimum possible headways, are shown in Table I.

Headways can be shortened by providing parallel paths at stations, either by multiple parallel tracks or by switching off the main line to the station, so long as switching time does not become a significant factor. However, the problem of safe merging onto the single path comes up after station departure, the time of which can be perturbed by passenger loading problems such as blocking of doors. The BART system has all its stations on the main line but, even so, rush-hour headways are as close as 90 seconds for a given station platform having a 20-second dwell time.

Closer headways can also be obtained by running at lower speed to lessen the stopping distance, provided more and shorter blocks are used. More blocks are needed because lower speed increases the travel time for a given distance and so requires better definition in the detection system to prevent loss of the headway advantage in traversing the uncertainty distance. Table I shows such a headway improvement between 150 and 100 mi/h, but with a degradation for speeds below 80 mi/h because of the transit time through the 1000-foot blocks. Further headway improvement in that example would require use of shorter blocks.

Control Implementation

In general, each passenger station contains control equipment that determines the allowable speed for each train in its area as a function of the locations of other trains in the area. Occupancy information is brought to the station logic from wayside detection points at block boundaries, the logic determines safe speeds for the trains and encodes speed commands, and the speed codes are sent back to their respective block transmitters for transmission to the trains. On-board control equipment interprets and applies the commands as required, and it also stops the trains accurately at stations.

BART trains are designed for high speed and high passenger volume. Although an operator is present in the head car, operation normally is completely automatic.

Tampa International Airport Passenger Transport System connects a central terminal building with satellite buildings. Similar vehicles and technology are used in the Transit Expressway system designed for public transportation in smaller cities and for feeder service in large cities.

In large systems, a central computer monitors system operation and calls up various corrective strategies to optimize the operation of the entire system.[3,4] The corrective strategies consist of such actions as modification of speeds and accelerations of trains to change their run times between stations, modification of station dwell times, addition or deletion of trains, selection of alternate routes, running through a station without stopping, and changes in schedules.

Design Techniques

Reliability—An occasional failure is inevitable in components, subsystems, and systems, but failure should disrupt the system as little as possible by causing degrees of gradual degradation. Furthermore, plans for operating the system around any failure should be predetermined to minimize system disruption.

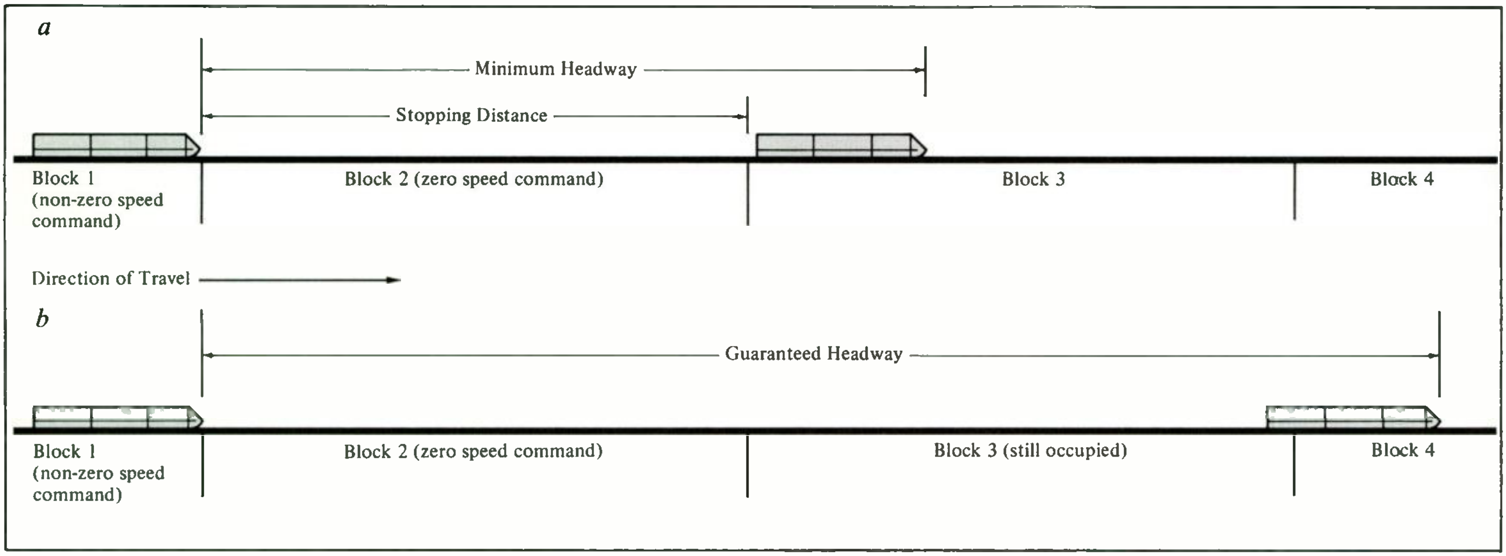
It is inefficient to design a highly reliable subsystem to operate with a subsystem of lower reliability, because failure of either subsystem has the same effect on system availability. Instead, failure rates should be distributed evenly over all subsystems. For example, it would be wasteful to require that the complex on-board control system have a very high mean time between failures (MTBF) but to allow the much simpler coupler contacts carrying the control information to each car of a train to have a relatively low MTBF. It is much more reasonable and economical to allow a lower MTBF on the control system and bring that of the coupler contacts up to the same level, by using redundant contacts for example.

Another important factor affecting system availability is the time required to repair a failure. To achieve a short mean time to repair (on the order of half an hour), Westinghouse equipment is so designed that a malfunctioning unit is quickly identified and easily replaced with an operable unit.

Equipment design also allows multiple usage and maximum interchangeability, thus minimizing the number of spare units that must be kept on hand. For example, only a few different types of transistors and integrated circuits are used on all equipment: they make up multipurpose boards such as a transmitter board used for detection, control, identification, programmed stopping, door control, and other communications. A wayside control box can be used for train detection, train control, identification, or programmed stopping with only slight changes in the combination of printed circuit boards used (Fig. 3). Where the equipment must operate on predetermined frequencies and time slots according to location, a selector plug permanently attached to the enclosure provides the appropriate control connection.

The box's total power dissipation is only a few watts, with a net output signal of approximately 4 watts. As a result, all components operate in an environment of low electrical and thermal stress.

Minimizing the number of field adjustments required during installation and periodic maintenance also improves system reliability. Moreover, equipment not requiring adjustments or special installation



1—In automatic train operation, train positions are determined by dividing the route into "blocks" and continuously informing the control system whether each block is occupied or not occupied. For safety (a), *the standard block length is the maximum stopping distance required; therefore, the block immediately behind a train always has a zero speed command for the following train. The closest guaranteed headway (time between trains) must be based on the assumption that the two trains are located at the most remote points of the uncertainty resulting from block length* (b).

procedures can be replaced by maintenance personnel of lower skill in much the same way a light bulb is replaced, thereby achieving system availability at lowest cost. A digital system requires fewer adjustments than does an analog system because, in general, the equipment either works or doesn't work. Thus, isolation and repair of failures is simpler in a highly digital system. This feature also allows simple diagnostic testing on the equipment, each time a train enters service, to detect potential failures before they affect system operation.

Fail Safety—Any failure that occurs must not cause an unsafe condition. A failure that causes the system to revert to a more restrictive condition is considered to be a safe failure; a failure that results in a less restrictive condition is an unsafe failure. Examples of more restrictive failure modes are indication of occupancy whether or not a train is present and control at a lower speed limit than otherwise required. The term "fail safe" does not imply that a failure will not occur, but rather that the effect of a possible failure is unidirectional to a more restrictive mode.

The basic philosophy of fail-safe design is to rely on known characteristics that do not change or that can only fail in one direction. For example, the force of gravity is always present to release vital relays, carbon contacts in vital relays cannot weld together, brass cannot become magnetic, pressure cannot become a vacuum, and a fixed length of tungsten wire cannot have a resistance lower than a predetermined value.

Similarly, operational characteristics can be employed to guarantee fail safety. To name a few, constant direct current cannot be transferred by induction, a dc signal cannot be inverted in a passive circuit, and a dynamic signal can only be reproduced by a properly operating active circuit.

System characteristics must also be chosen to insure fail safety, such as utilization of unidirectional failure modes in the information transmission techniques used for signals that affect safety.

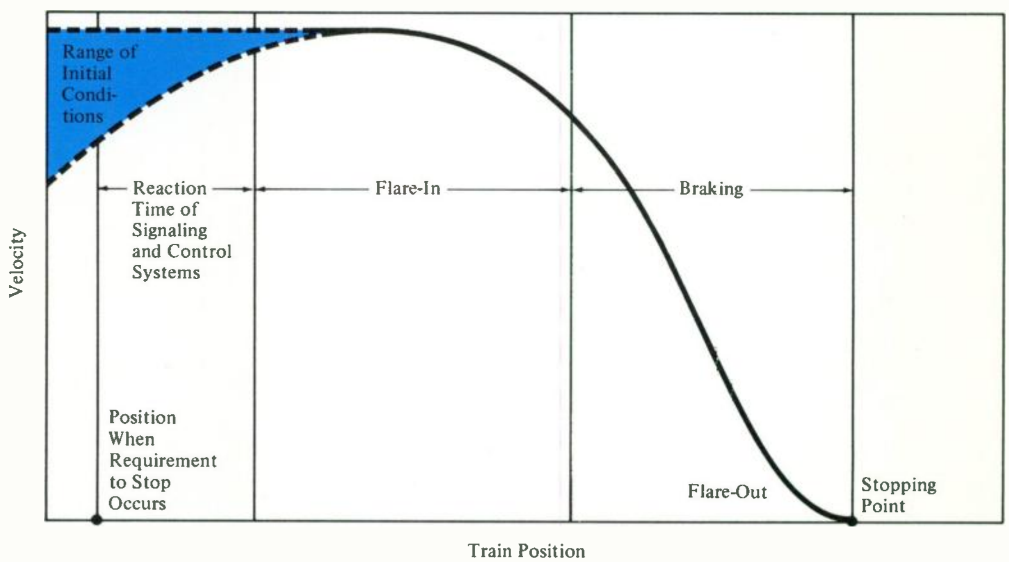
Information Transmission Techniques—Train-control information must be transmitted in the form of commands and indications between each train and the local control centers and between each control center and an overall supervision system. Information transmission channels for automatic train control on an electric railroad are generally characterized by a severe electrical noise environment due to switching of the high propulsion currents and sparking of current collectors, brushes, and contactors; by fairly low data rates due to the characteristic controls and responses of a transit system; and by various degrees of reliability and safety requirements depending on the purpose of the particular channel.

The basic types of signaling requirements are: continuous signaling for speed control and train detection, requiring low data rates but well defined reaction times; "one-shot" signaling for train identification and performance modification, where only one chance is available to receive correct data; occasional low-rate signaling for programmed stopping and door opening, requiring minimal information at certain

Table I—Typical Calculated Stopping Distances and Headways on Straight Level Track

Maximum Speed (mi/h)	*Stopping Distance* (feet)*	*Minimum Headway† (seconds)*
20	190	110
40	580	65
60	1170	61
80	1960	51
100	2950	51
150	6300	59

*Includes 3-second total reaction time and deceleration at 3 mi/h/s.
†Includes provision for stopping distance, 1000-foot blocks, 700-foot train length, and 20-second dwell time at stations.



2—Stopping distance is the distance between the train's position when a requirement to stop occurs and the final stopping point. It depends on train speed and acceleration at the time the requirement to stop occurs, reaction time, flare-in (transition to braking) required to prevent excessive jerk, braking effectiveness, and the flare-out (transition to final stop) again required to prevent excessive jerk.

points of the system; wayside control multiplex for speed, safety, and control information to and from wayside equipment and local control centers; and supervisory data links for system optimization.

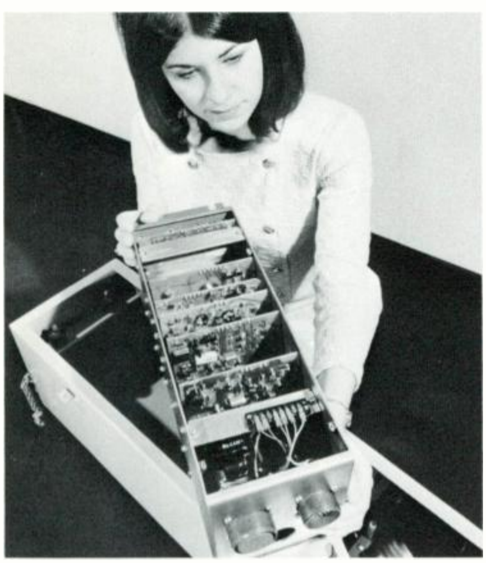
Reliable signaling techniques are especially necessary in a system using chopper propulsion, because the system has rail currents with high transients at harmonics of the chopper frequency—especially during acceleration when current flow is greatest. Reliability in this environment is ensured by using crystal control for the chopper and by signaling at crystal-controlled frequencies between chopper and other power-frequency harmonics. In addition, narrow-band crystal filtering at the receiver separates signals from noise. Frequency-shift keying at a crystal-controlled rate provides the added signal-to-noise advantage inherent in an FM system over the AM systems classically used for railroad signaling.

The choice of frequencies to transmit the codes is a function of operating requirements and safety. The propulsion noise envelope falls off fairly rapidly above 1 to 2 kHz, but practical crystal filters are not available below approximately 5 kHz. Track attenuation and federal licensing are problems above 10 kHz, so signaling in Westinghouse train control systems is contained in the band of 5 to 10 kHz. Frequencies are chosen that avoid harmonics of commercial power frequencies and can be obtained by simple integer division from a single master clock. To provide a unidirectional mode of failure, the higher of the two frequencies represents binary 0 and the lower represents binary 1, thereby avoiding possible generation of binary 1's due to harmonic excitation.

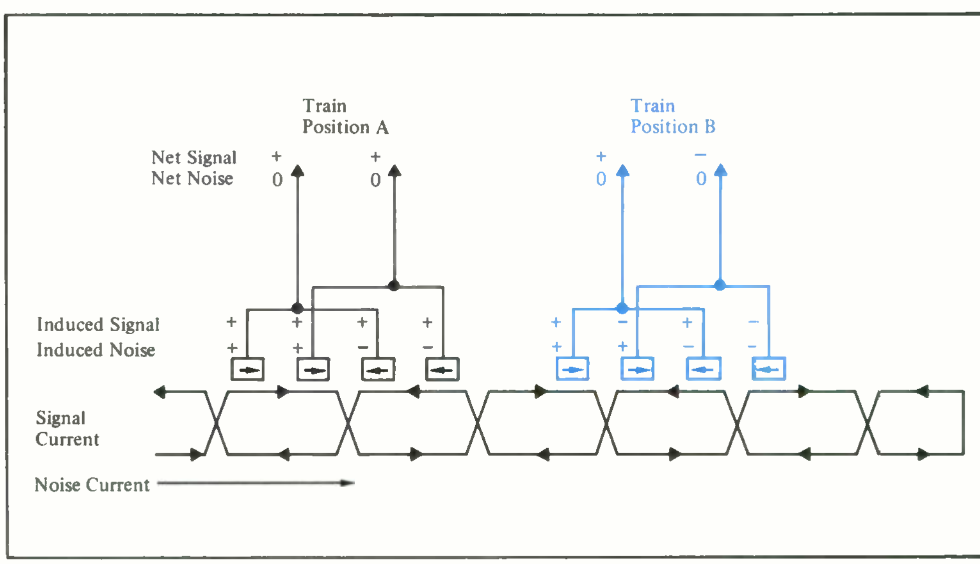
Digital coding provides accurate speed code and occupancy information with built-in safety features where required. Speed commands are transmitted continuously in the form of six-bit codes of the type known as comma-free, formed by selection of only those combinations of 1's and 0's that are unique for all cyclic shifts of any code. This form of coding distinguishes one continuously repeated code from any other regardless of which information bit is used as the starting point; hence the somewhat cryptic but commonly used term "comma-free."

For example, a continuous transmission of the code 101111 is . . . 101111101111 01111 . . . , and any consecutive group of six bits from it is unique to that code regardless of starting point (101111, 011111, 111110, 111101, 111011, or 110111). The same applies to such cyclic shifts of all the other codes. As a result, they can be transmitted without need for code synchronization between wayside and train, the loss of which might cause safety problems if it were needed. Six-bit coding is sufficient to provide nine unique dynamic codes: 101111, 100111, 101011, 100011, 100101, 101001, 100001, 101000, and 100000. They are dynamic in that all contain at least one change of state between 1 and 0, which is needed for proper operation of the associated fail-safe circuitry.

Since the codes are used with equipment designed to fail selectively only to the zero binary state, those at the head of



3—One wayside control box can be used for various purposes. It contains a power supply, transmitter, receiver, multiplex decoder, multiplex encoder, and lightning protection equipment.



4—Position information for programmed stopping at stations is acquired by counting phase changes as the vehicle moves past a transposed continuously energized cable. Electrical noise pickup is reduced by providing two antennas in each of the two receiving channels, with polarities and spacing such that they aid for the transposed signal and oppose for unidirectional noise. In this diagram, signals and noise induce a voltage of relative positive phase when currents and antenna polarity are in the same direction, and one of relative negative phase when they are in opposite directions. Summation of the signals between the two antennas on each channel causes the signals to add and the noise to cancel.

the list correspond to higher speeds and those at the end to lower and zero speeds. Loss of signal and invalid codes, including all 1's or all 0's that may result from total failures, also result in a zero speed interpretation.

Furthermore, for safety as well as operation, the circuitry is so designed that the proper crystal-controlled bit rate must be present in the code, even for successive 1's or 0's. Therefore, the information is transmitted by reversing the phase of the carrier at the bit rate, and that rate must be detected in a narrow-band filter before the decoded output can be accepted. This method provides an additional safety factor for the entire data link in that no data is transferred if the proper frequency is not present.

Certain information sent to and from the vehicle, such as train identification and performance modification, can be transmitted or received only once because it passes to or from fixed wayside antennas as the train goes past. Therefore, it must be transferred correctly. Errors do not involve safety in this instance, but they could cause inconvenience and so are highly undesirable.

Such errors are reduced by parity-check error *correction* codes (which actually correct up to a predetermined number of transmission errors) rather than by the simpler error *detection* codes that would be useful only if retransmission were possible. A particular code can correct errors so long as other codes are sufficiently separated as to be recognizable even after some transmission errors occur. The number of errors that can be tolerated is determined by the amount of separation of the codes.

For example, if either the code 01 or 10 is to be sent, a single error yielding 00 or 11 completely destroys the information because it is not known which code was intended. If, however, the codes are lengthened to 011 and 100 respectively, then a single error in the former could yield 111, 001, or 010, all of which are identifiable from any of the single-error results of the alternate code (000, 110, or 101). Similar methods are well known for use with longer codes, and they are used in the Westinghouse system to provide much more extensive error protection than is indicated in this simplified example.

The train identification system transmits train number, length, and destination from the train to the wayside equipment. It requires several words of the six-bit coding format that provides a timing reference between train and wayside signals. Therefore, additional synchronization information must be sent to ensure that the individual words are properly aligned within the total information block. This is particularly necessary because the information can be received in any cyclic order depending on when a train happens to arrive at the wayside antenna, which is located in advance of the station or divergence point at which the information will be used.

This alignment within the information block ("framing") can be accomplished in several ways, but basically it sets down a constraint in the format of one word that is prevented in the others, so that the word which satisfies this constraint is then the lead word. Such constraints can exist in one word only or can be interspersed throughout all of the words of the message. Framing the information is of no use if errors have occurred in its transmission; therefore, error correction is again used.

In such places as yards or turnbacks where identification information is originally assigned or completely modified, a feedback checking system is also used to ensure correlation between the information intended for the train and the information actually received and stored by the train. This checking is done by transmitting the new information put onto the train back to central, where it is compared with what was sent. If it agrees, the information on the train is assumed to be correct. (It is unlikely that an error in retransmission would exactly cancel an error in transmission.) If it does not agree, the information is transmitted again and another check made.

For programmed stopping at stations, position information is provided by phase changes received as the vehicle moves past a continuously energized wayside cable, which is transposed every 12 inches (Fig. 4). Each of the two phase-comparing receiving channels on the vehicle, which are separated by 6 inches, contains two series-opposing antennas placed 12 inches apart. Since the wayside cable is transposed every 12 inches, the two receiving antennas for a particular channel are actually aiding for the signal and opposing for common-mode noise. This arrangement improves signal-to-noise ratio significantly, although full noise cancellation would require perfect antenna balance and homogeneous noise across the antenna assembly.

The same principle is used for the speed command receiving antennas. Propulsion return currents flow in the same direction in each rail, whereas the control currents flow in opposite directions in each rail. Thus, by providing a properly phased receiving antenna above each rail, the train receiver obtains a signal that is series-aided for the control signals and series-opposed for the noise.

The wayside control multiplex used at BART is designed to avoid transmission errors that could occur due to failures. In the event of a reset failure in the synchronization system, it would be undesirable to have one channel receive the information intended for another channel. The multiplex circuitry is so designed that such a situation is never possible, even under failure conditions.

The supervisory data links used to transmit control and indication information between stations and central control for overall system optimization do not operate within the same restraints of noise environment and safety as does the direct train control equipment. As a result, conventional data transmission techniques are used.

REFERENCES:

[1]E. E. Hogwood and R. B. Maguire, "Passenger Transfer System Will Take the Long Walk Out of Air Travel," *Westinghouse ENGINEER*, Jan. 1969, pp. 9-15.

[2]Ralph Mason, "Automated Transit System Reduces Walking in Expanding Airport," *Westinghouse ENGINEER*, Jan. 1971, pp. 8-14.

[3]Thomas R. Gibson, "Bay Area Transit System Will Have Automated Central Control," *Westinghouse ENGINEER*, March 1970, pp. 51-4.

[4]Albert F. Harsch, "Systems Modeling and Simulation Help Develop and Test the Logic for BART Train Control Strategies," *Westinghouse ENGINEER*, March 1970, pp. 55-61.

Illustrated Answers to the Ten Most Common Questions About Industrial Design

Ed Izzi
Ralph Caplan

Considering its effect on American industry, industrial design has never been well understood. This is unfortunate, for the industrial designer has talents, skills, and knowledge to complement the engineer's role in industry. We live in a society whose economic mainspring is the movement of machine-made goods. As the relationship between maker and buyer grows increasingly complex and increasingly remote, the designer looms as a figure of major importance.

The following article addresses ten of the questions most commonly asked about industrial design.

Can you define industrial design?
Yes. "It is the process of shaping goods to be made by mass production." (Except that many products of industrial design are not mass produced.) "It is a plan for arranging elements to accomplish a particular purpose." (But so is a concerto.) "Design is the communication of the function and quality of an object, or the character and integrity of its makers, by visual, nonverbal means." (But before quality can be communicated, it has to be designed into the product.)

And so on. There are hundreds of definitions, many of them good, none of them adequate. Although it may seem like going around in circles to say so, industrial design really is the process of designing what industry makes. Of course industry can, and does, make products whether industrial designers are involved or not. The designer's contribution is to relate the product to the people who will use it.

Ed Izzi is Manager of the Industrial Design Department, Westinghouse Corporate Design Center, Pittsburgh, Pennsylvania. Ralph Caplan is a writer and editorial consultant.

One reason industrial design is so hard to define satisfactorily is that it overlaps so many other disciplines. Yet, elusive though its definition may be, industrial design exists. So do industrial designers. Perhaps the most helpful definition lies in the answers to other questions and in the products that illustrate them.

What does an industrial designer do that an engineer doesn't do?
Let's put it this way: suppose that the product is an electric fan. The engineer is responsible for making sure that the fan will work. The designer is responsible for making sure that someone can—and will—work the fan.

That is of course a gross oversimplification, but it does accurately reflect a difference in emphasis, in professional discipline, and in expertise. An engineer's problems are usually limited to the interaction of components and materials. His job is to make the best product consistent with the state of technology and the anticipated market price range. The designer's

What does an industrial designer do that an engineer doesn't do? Industrial designers working in close partnership with engineers of the Oceanic Division constructed a mock-up of the seven-foot-diameter capsule interior for the Deepstar underwater vehicle. Within these small quarters a three-man crew of scientists would be making critical decisions. The mock-up was used by the design team to work out human factors problems. To minimize operator fatigue, designers specified proper angles for body support during extended periods in the prone and sitting positions. Controls, monitoring equipment and support equipment are positioned within easy reach of the operator, and data is displayed clearly, consistently, and concisely.

job is to assure that the product is one that people can use and will buy.

To put it that way may suggest that these are discrete steps in a creative assembly line—with the engineer first doing his part, then turning the job over to a designer for polishing. Design, in such a case, would be merely laid on. And, as a matter of fact, a lot of products do get "designed" in just this way. It is a wasteful process. Precisely because engineering and design responsibilities are not wholly separable, engineers and designers have to work in close partnership to be most effective.

Like engineers, industrial designers need restraints. They need to be working against something. A responsible design concept solves a problem within certain given and irreducible restrictions.

Design restraints vary. The most important—and the most desirable—of them is the fact that the product is to be used by a human being. The designer, more than anyone else, is concerned with the man or woman who sits in the chair, reads by the lamp, or operates the sewing machine, the computer console, or the golf cart. He is, in this sense, the consumer's advocate, sharing the engineer's concern for safety and reliability and translating the engineer's mechanism into something that is convenient and pleasant to use.

To the extent that an industrial designer represents the consumer, his presence on the scene is especially urgent today. The so-called "consumerism" movement will not go away, nor should any reputable manufacturer wish it to go away. It is in large measure a reaction to the lack of thoroughness of design thinking in the production process.

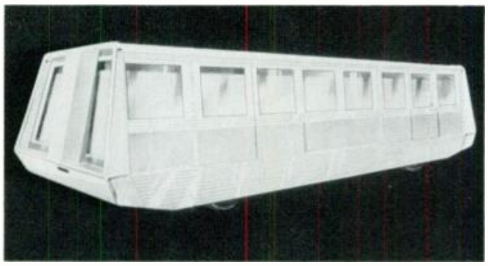
The designer has to know what people want and need. He also has to know what they are like physically: sizes and shapes, extent of peripheral vision, musculature and bone structure, reaction time under stress, arm reach while seated, etc. Research into such characteristics is the basis for "human engineering," the systematic consideration of factors that make up the relationship between man and machine. Human factors design research began during World War II, when it was applied to situations—the design of altimeters, for example—in which a product's efficient human use was critical. Since part of the designer's job is to relate things to people, some human factors information is needed in almost every design problem.

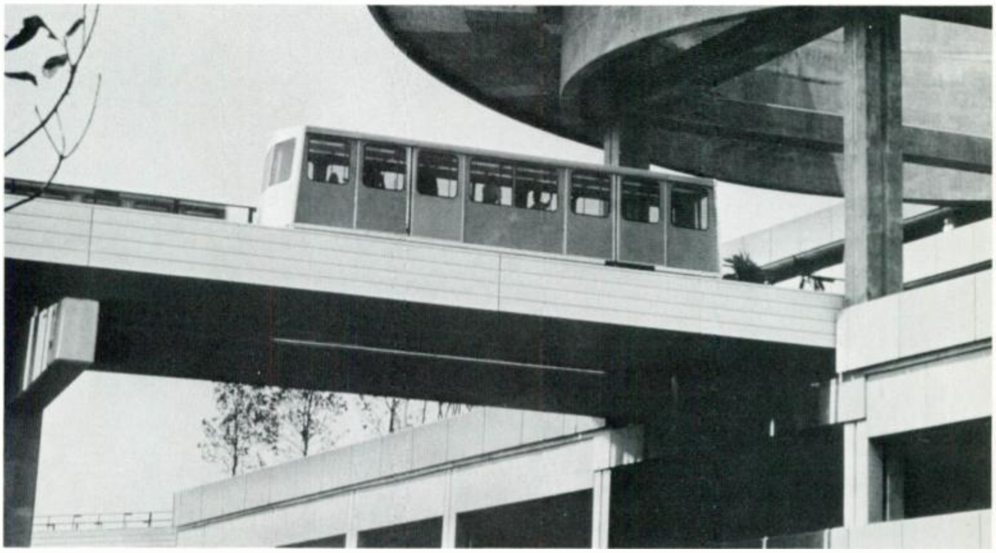
Isn't industrial design really a matter of "styling"?

"Styling" is superficial design, and it would be nice to think that industrial designers are never superficial.

Nice, but not true.

In some industries design is regarded as an instrument of fashion, and the problems a designer works on in those industries are superficial problems. But "styling" is a derogatory term in the minds of most industrial designers although, ironically, industrial design would never be where it is today without it. American industrial design was first officially recognized when the Government sent a commission to the Paris exposition in 1925, with the aim of alerting American industry to foreign de-





Isn't industrial design really a matter of "styling"? Two design solutions for the Tampa passenger vehicle are shown above. The earlier more heavily "styled" solution (*top*) employs extra trim panels and strips on the vehicle sides, and arbitrary forms and trim on the vehicle ends. These unnecessary details add to initial costs, and costs for cleaning and maintaining.

The final design* (*bottom and right*) treats the exterior metal panels as structural skin reinforcing the integrity of the structural frame. Elimination of arbitrary forms and details from the vehicle ends resulted in full width windows, providing more light inside the vehicle and better viewing for the passengers. Thus, the final solution focuses on practical, functional problems.

*Tampa vehicle industrial design by Eliot Noyes & Associates, Westinghouse Corporate Consultant of Design.

sign competition and to the problems of mass production techniques. American design's big chance came a few years later, with the depression. Industrial designers were summoned in the early 30's to stimulate sales by making products more attractive.

It seemed to work, and industrial designers got a good deal of credit—very likely more than they deserved—for reviving industrial production. So the reputation of the professional was built on the premise that "styling" sells merchandise.

Yet it is a testimony to the astuteness of the early designers that, although their method was largely intuitive, they did not stop with styling. While manufacturers frequently wanted nothing more than a "prettification" of what the engineers had devised, the designers from the beginning consistently rejected this objective. Their attitude was typified by the experience of a designer named Walter Dorwin Teague, who was selected in 1927 by the Eastman Kodak Company to design two cameras. Teague replied that he knew almost nothing about cameras and would take on the assignment only if he could do the work in the Eastman factory, with Eastman engineers. Such an arrangement today is simply taken for granted.

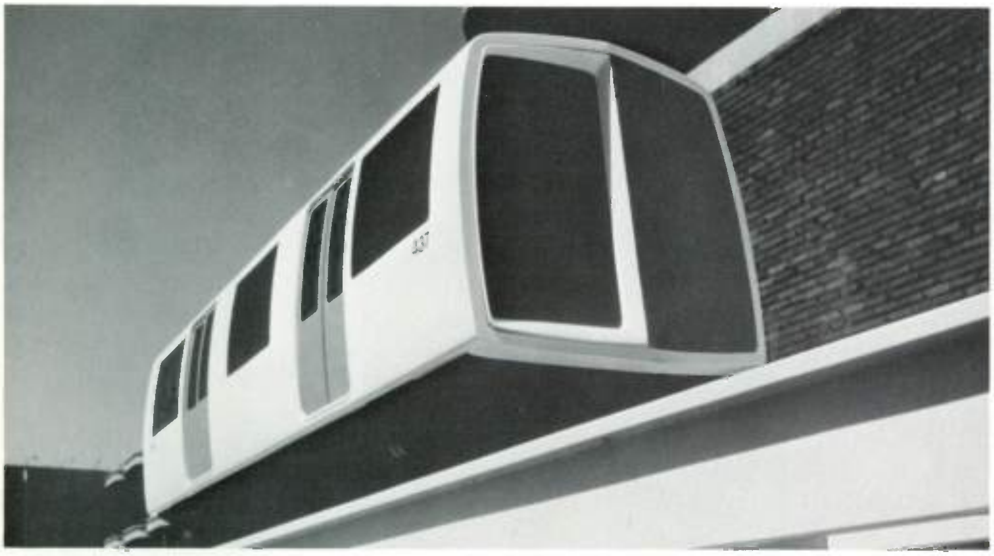
At what stage in the development of a product should an industrial designer be called in?

As early as possible. The reasons for this are implicit in most of our answers to the other questions. Design cannot be applied to a product on the way to the production line. Rather, it is an organic process. To call a designer in at the end is not useless; he can still make some contribution. But his greatest contribution is likely to come before the problem is defined, for that is when the industrial designer's unique approach can best be exploited. Don McFarland, a practicing industrial designer who is an engineer by training and background, points out that an engineer customarily works from the inside out—that is, he is trained to solve problems by thinking first in terms of technical details. The designer is trained to think from the outside in—starting with the complete product as it would be used by someone, and working backwards into the details required to make the concept work. To an engineer, McFarland observes, this may seem like beginning at the end. And in a way it is. Paradoxically, this is why it is important for the designer to be involved in a product at the very beginning. If he is called in after the details have been worked out, only the unlikeliest coincidence would permit him to link his concept with them.

Doesn't an industrial designer invariably add to the cost of the product? If so, how is that cost absorbed or justified?

Design services, like any services, cost something, although often it is less than expected. But industrial design also contributes greatly to cost reduction—indirectly by increasing sales; directly by making manufacturing more efficient.

Design increases sales in two overlapping ways. First, by helping to make a product better—safer, more convenient to



At what stage in the development of a product should an industrial designer be called in? This concept for Pittsburgh Transit Expressway Revenue Line (TERL) (*above*) was developed during the early stages of a proposal and in conjunction with a preliminary engineering study. Early involvement in the project insured that the designer's unique approach would be used more effectively in determining vehicle form, seating arrangements, certain equipment locations, and window sizes and arrangements (*right*). Another benefit was the use of the conceptual model as a communications tool for the product group and as a public relations tool for the Port Authority of Allegheny County.

use, easier to store. Second, by making it more appealing in the marketplace.

Design makes manufacturing more efficient through simplification of components, choice of materials, and use of particular manufacturing processes. The truck refrigeration unit (XMT) shown in the accompanying illustration demonstrates the value of including an industrial designer on the project team. He can contribute toward a better mechanical design within cost restraints and help provide a more appealing product in the marketplace.

Do good things get designed without industrial designers?

Certainly they do, and they always have. After all, 50 years ago there were no products that *had* the benefit of an industrial designer. And today many of the manufactured objects designers themselves most admire were created without benefit of professional industrial design.

The axe, the kayak, the suspension footbridge are early examples. And some of the most stunning products of contemporary design are technological products that have had no appearance design treatment as such. An airplane is a popular example. Its beauty is often assumed to have been dictated purely by the requirements of aerodynamics and the restrictions of materials and cost. Certainly it would not fly if it were shaped like a shoe. But in fact a variety of forms are possible. Choices were made in the context of certain restrictions—function, materials, tooling, costs, fabrication techniques—which are precisely the restrictions within which any industrial designer makes his choices.

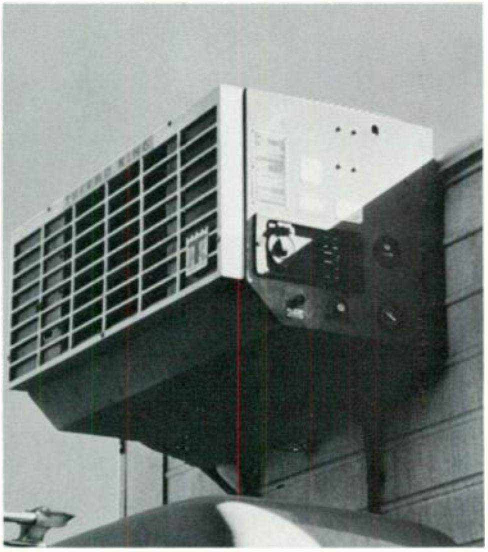
In addition, the designer is aware of restrictions that the engineer is less likely to think about, such as marketing goals, distribution patterns, user habits, shipping practices.

While individual products may be well designed owing to the discrimination and taste and common sense of engineers and others, the effective design of an entire program is much less likely to occur without someone whose primary professional responsibility is design.

How can an industrial designer make contributions in areas in which he has no specialized knowledge?

In a way, he can make them *because* he has no specialized knowledge. Design affects an astonishing diversity of items, and the industrial designer's specific contribution to them is not the same in every case. The designer is a generalist, not a specialist. Obviously the same person cannot be technically knowledgeable about computers, can openers, transformers, packaging, office arrangements, typography, point-of-sale displays, and corporate imagery. With the exception of furniture and a few other products, probably no industrially manufactured product is designed by one man. Product design is a team process. Industrial designers are significant members of that team, but no more than that. Their collaborators include engineers, management, marketing experts, scientists, technicians, advertising men, and other designers.

To solve the kinds of problems he regularly faces, the engineer must be equipped with a great deal of technical knowledge



Doesn't an industrial designer invariably add to the cost of the product? If so, how is that cost justified? In the XMT truck refrigeration unit (*right*), as compared with the earlier MWC unit (*above*), the industrial designer, working with Thermo King Corporation engineers and marketing personnel, was able to contribute to an overall cost reduction achieved in the development of the basic structural frame, external panels, and grill. A major design objective was to keep the unit simple and easy to manufacture. The design team eliminated angular forms and kept everything at right angles. They simplified the grill configuration and provided better access to parts. The control area was redesigned into two larger nameplates, replacing seven smaller ones. Operating and monitoring devices were organized according to their relative importance and order of use in the startup procedure.

and specialized skills. The designer, on the other hand, comes equipped with what may appear to engineers as technical ignorance. In many cases, it *is* technical ignorance. But the designer's ignorance may in fact be productive, for it frequently includes ignorance of what cannot be done. He may therefore suggest doing it, with the result that a skeptical but inventive engineer discovers a way in which it *can* be done.

I can see why consumer products should look nice. But what difference does appearance make in capital equipment?

While design is by no means confined to appearance, there is no question that appearance matters, even in capital goods. Nor is there any reason it shouldn't. We live and work in a world that we look at, and it might as well be good to look at.

Each man-thing relationship begins with appearance. Because objects cannot speak for themselves, they ought to look like what they are and what they do. The problem of making them look this way is a modern one. Primitive implements are likely to have a design integrity that comes from the fact that designer, engineer, manufacturer, and consumer are one. In a more complex age, that quality has to be consciously designed into the product and into everything else that represents the maker.

The artist Saul Steinberg says, "You always find good design in work things." Well, you don't always. But you do have a far better chance of finding it there. Power transformers, laboratory instruments, medical instruments, data processing devices, lathes—such things tend to be better designed as a rule than the stuff we fill our houses with. The reason probably is importance. These things count, and so the design has to count, too. The human factors aspect of a lounge chair is not crucial: the worst that bad design can inflict is a sore back. But the design of an undersea vehicle is a matter of life and death.

The designer has to be tuned to the public wish. But there are several publics, and design plays a significant role in "nonconsumer" goods as well as in consumer goods. A physician, for example, is a man before he is a doctor. And, all other things being equal, he will select the medical equipment designed to appeal to him.

People keep quoting, "Form follows function." What does that mean? Is it true?

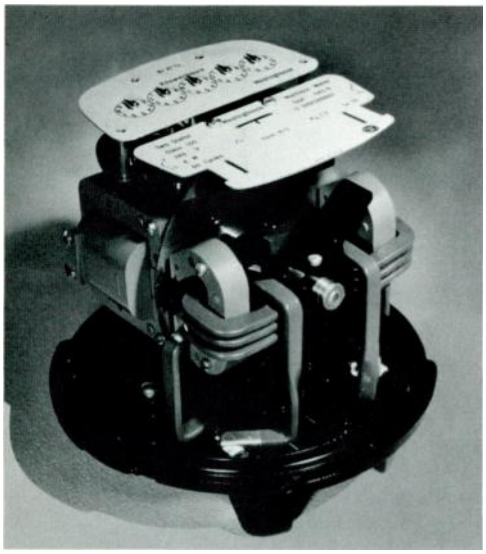
As a profession, industrial design can be traced to the German Bauhaus of the 20's, a school of design that quickly came to have international influence. "Form follows function," the most succinct and certainly the best known statement of design philosophy, is associated with the Bauhaus, although its origins go much further back. The statement is perfectly logical as far as it goes, but it does not go nearly as far as designers used to suppose. "Form follows function" is still a necessary guideline for order of concern, but it is no more than that.

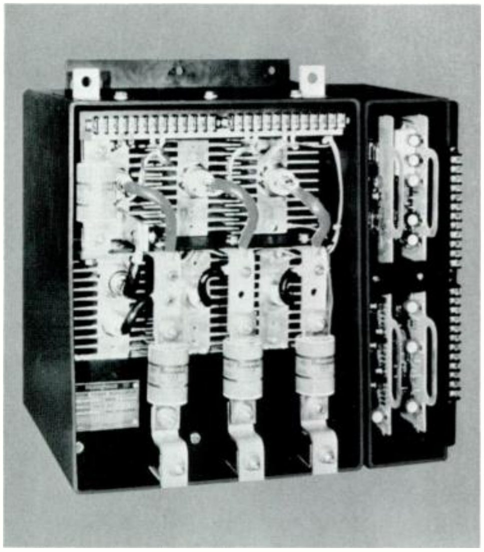
Of course, you do not first choose a form for a product and then try to make it function adequately. But the phrase has unfortunately been taken to mean that if a product is designed to function well mechanically, the inevitable "best shape" will result. This is wishful thinking for mechanical function is no guarantee of good design (although obviously you cannot have a good design without it).

However, "function" can also be understood to consist of all the separate "functions" that satisfy the user's need, including his need for convenience, for safety, and for sensory pleasure. Function in that sense (which is not the original sense) includes form, and to solve the problems of function is inevitably to solve problems of form.

How can I tell whether or not a product is "well designed?"

Unfortunately there are no absolute criteria. Nevertheless, designs *are* judged and have





How can an industrial designer make contributions in areas in which he has no specialized knowledge? Items such as the polyphase watthour meter components (*above*) and the thyristor power module internal components (*right*) would not typically be considered an area for industrial design input. In the first instance the designer simplified many of the complex multipiece internal elements to produce a simpler looking device with more apparent quality.

In the second case, the designer set all the components back into the module and arranged them and the wiring to produce a better organized product. This design effort results in easier access to the components for maintenance and also enhances the equipment's appearance.

to be. Here is a checklist of criteria we have found useful. These are not rules; there are no rules. It is possible for a product to meet every one of the criteria below and still fail as a design. But it is not possible for a product to fail to meet all of them and still be well designed.

1) Does the design express the function? Part of the designer's job is to make things look like what they are and like what they do.

2) Does the design take advantage of available fabrication techniques to improve the product, simplify manufacturing, reduce costs?

3) Are the materials appropriately used, and do they look it?

4) Is the product as simple and pleasant to use as it can be made?

5) Is it easy to maintain? Or has the designer, for example, made cleaning difficult and servicing awkward?

6) Is it safe? Or has appearance or economy been introduced at the expense of safety?

7) Can the designer explain what he has done? Designers should be accountable for design, so do not hesitate to ask a designer why he did what he did. But don't be distressed if he can't give rational arguments for every curve. Some aspects of design are necessarily subjective. That is not bad, but it ought to be clear which aspects they are.

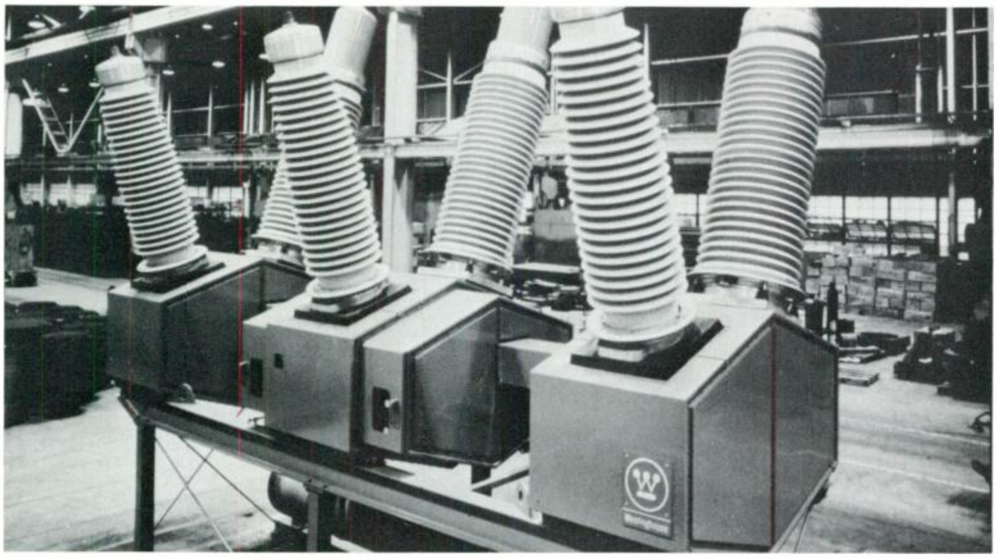
8) Do you like it? This may seem too obvious to be worth mentioning, but it isn't. Some people take design criteria so seriously that they are intimidated into suppressing a personal response.

9) If you don't like it, is it because it looks "too different?" Don't be put off by the unfamiliar. All products were unfamiliar once.

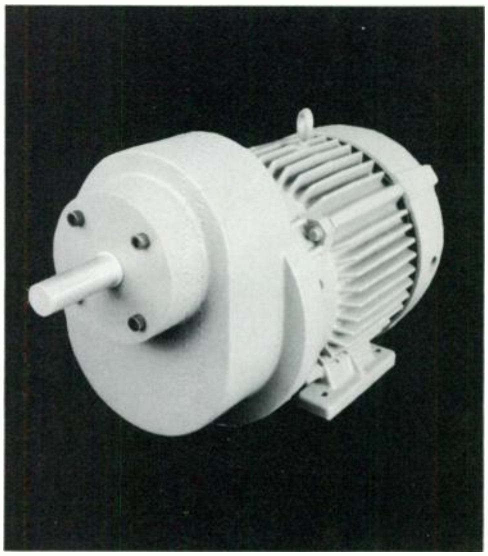
10) Does it communicate a context? A design should anticipate the environment in which it is to be used, including the kind of objects likely to surround it. It ought to look as though it belongs somewhere in particular. This is partly a matter of scale.

11) Does it have unity? That is, does it look like "a thing" or like an impromptu assembly of things? Since many contemporary products are arrangements of many components, often using several materials, it is all the more important that they be integrated—brought together in a way that suggests a single idea.

12) This is purely for symmetry. We have never found a twelfth item that wasn't really covered by one of the first eleven. That doesn't mean that *you* won't think of one, however. Or a thirteenth, fourteenth, and fifteenth, too. We hope that if you do you will tell us about them.



I can see why consumer products should look nice. But what difference does appearance make in capital equipment? The appearance of the SFV circuit breaker reflects simplicity imposed by design restraints. The circuit breaker was to be manufactured with simple tools, panels to be installed from the outside only, pieces to be handled by one man, and joints to be held to a minimum. The resultant geometric form embodies a sense of strength, confidence, and reliability and incidentally, is good to look at.



"Form follows function." This prototype study model of a motor-mounted single-reduction gearbox was planned as a minimum envelope and reflects the presence of bearings and gears. The "functional" form, although following very closely the configuration of the mechanical parts, was also influenced by other important factors such as manufacturing process, the need for a simple moldable form, mounting techniques, motor size, and weight.

A Developer/Builder's View of the Housing Market

R. S. Garrett

Because housing is a social product, its ultimate market is the community. Each community has its unique living patterns, social attitudes, and economic potential. The developer/builder must adopt a problem solving approach in designing new housing to satisfy that potential market.

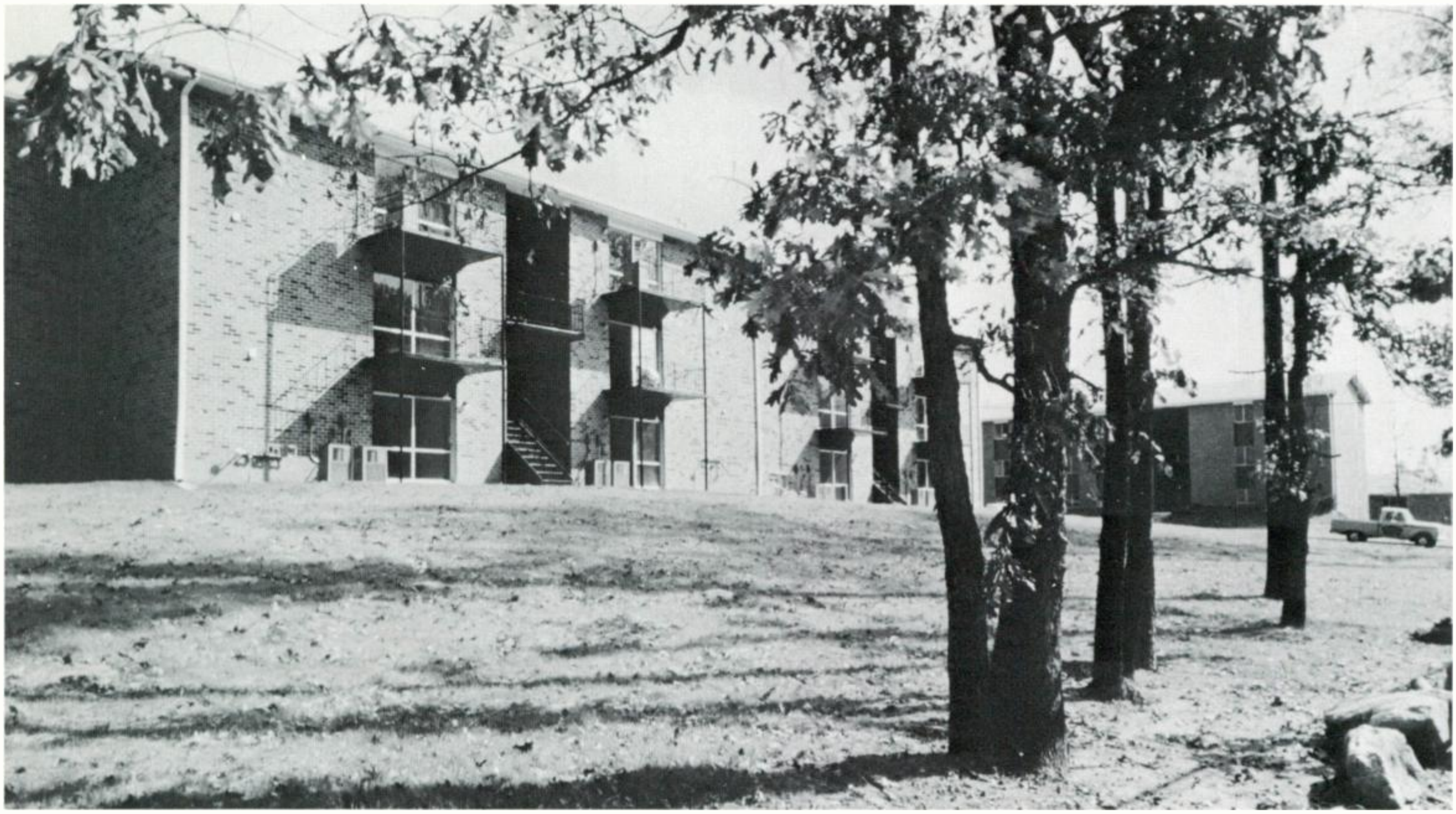
The multifaceted market for residential housing offers a variety of challenges for the developer/builder. Underlying all those challenges is the problem of escalating costs, which has both industry and government searching for solutions.

R. S. Garrett is President of Urban Systems Development Corporation (a subsidiary of Westinghouse Electric Corporation), Arlington, Virginia.

During the 50's and 60's field labor rates climbed rapidly, land and land development costs increased, and interest rates rose. On the other hand, residential construction methods differ little from those of a half century ago. Field labor productivity has been improved somewhat by the increasing use of partially assembled components that are faster to install, but the resulting improvement in overall on-site productivity has generally not kept pace with the increasing costs. The result has been a steady rise in the average cost of single-family units, from about $14,000 at the end of World War II to about $28,000 today. Over this same period, growth in the nation's gross national product has been fairly constant, about three percent per year, and average take-home pay has increased at about the same rate. Housing starts have averaged a relatively steady 1.5 million units per year over the total period, although yearly rates have ranged from one million to slightly over two million units started per year.

In contrast, the prime first-home buyers (the 30- to 40-year age group) had a net loss of nearly two million people in the 1960's while the young renters (20- to 30-year group) had a substantial increase of nine million people.* By 1965, the increasing rate of new household formations,

*Dept. of Commerce, Population Estimates and Projections Series P-25, No. 448, Aug. 6, 1970.



One of USDC's first ventures in the low- and moderate-income housing field was Central Methodist Gardens, a 240-unit project of conventional construction in Atlanta, Georgia. Under the Builder/Seller Program, USDC designed the project and applied to the FHA to build under contract with a nonprofit sponsor, the Central United Methodist Church. The sponsor took over the project at the completion of construction. The Builder/Seller Program is one of several federal subsidy programs available for low- and moderate-income housing. All federal subsidy projects require feasibility analyses, similar to that tabulated on p. 113, to qualify for FHA approval.

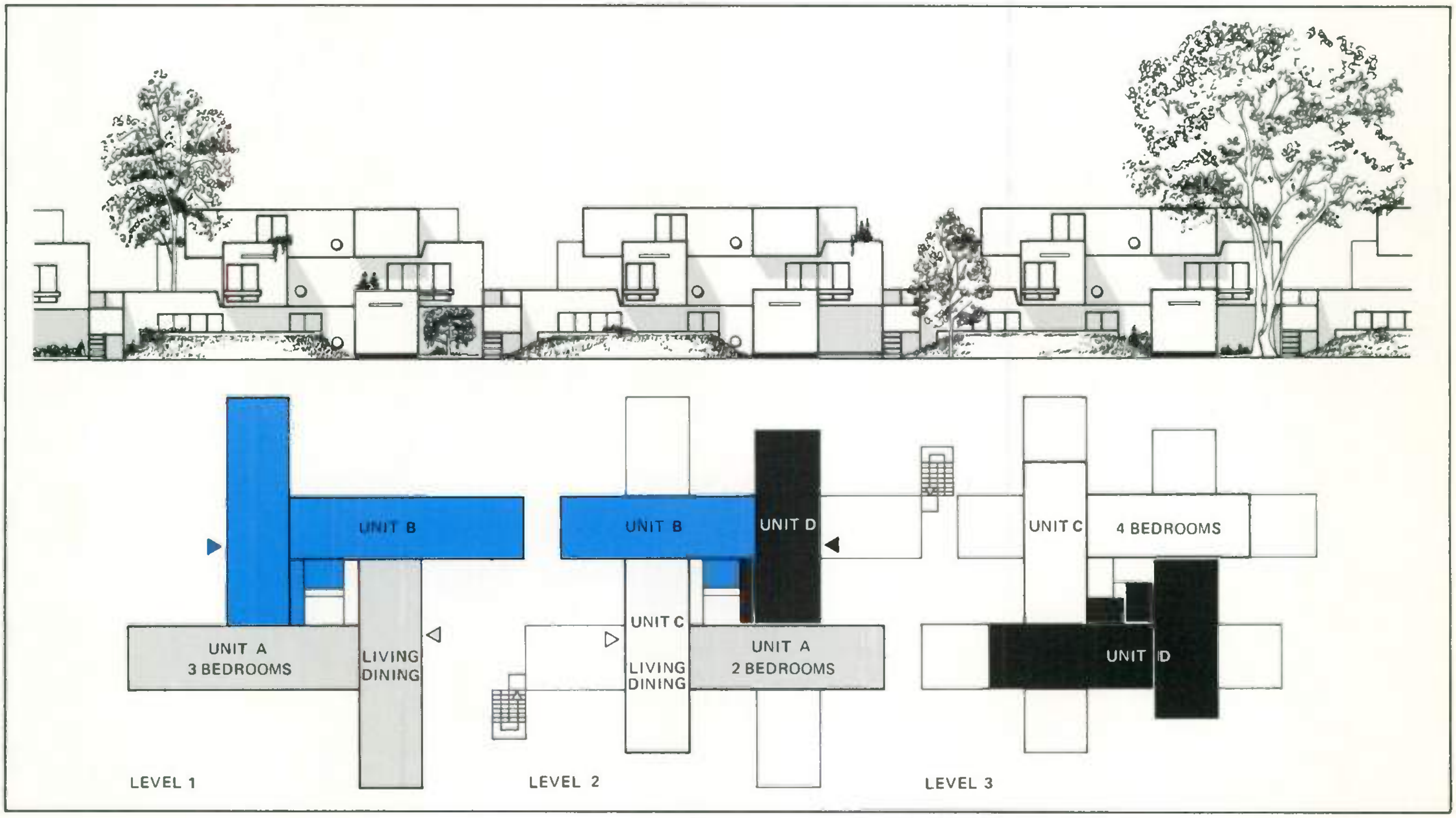
superimposed over a relatively constant building rate with increasing costs, foretold a serious housing shortage, particularly for low- and moderate-income families. The situation was aggravated by a changing mix of available housing in the late 60's as builders moved toward more expensive houses that had more profit.

The relatively new Department of Housing and Urban Development (HUD) was well aware of the growing problem, and was encouraging major U. S. industrial companies to become involved in housing. It realized that industrialized production techniques would be necessary to produce the large numbers of units required. To stimulate industry's interest, HUD initiated such major programs as the In-City Program in 1968 and Operation Breakthrough in 1969, both designed to encourage industry to develop industrialized techniques that would increase housing production and reduce housing costs. In 1968, partly in response to these programs, Westinghouse formed the Urban Systems Development Corporation (USDC), a wholly-owned subsidiary that had the initial assignment of entering the low- and moderate-income housing market.

The Need for a Stabilized Low-Income Housing Market

While the growing need for low-income housing is readily apparent, too often *need* is confused with *market*—because there is need, it is assumed there is also a market. But, in fact, the market is created only by consumers with the ability to buy or with access to some form of subsidy programs that can help them buy. HUD has attempted to bridge the gap between need and market with a variety of low-income housing subsidy programs.

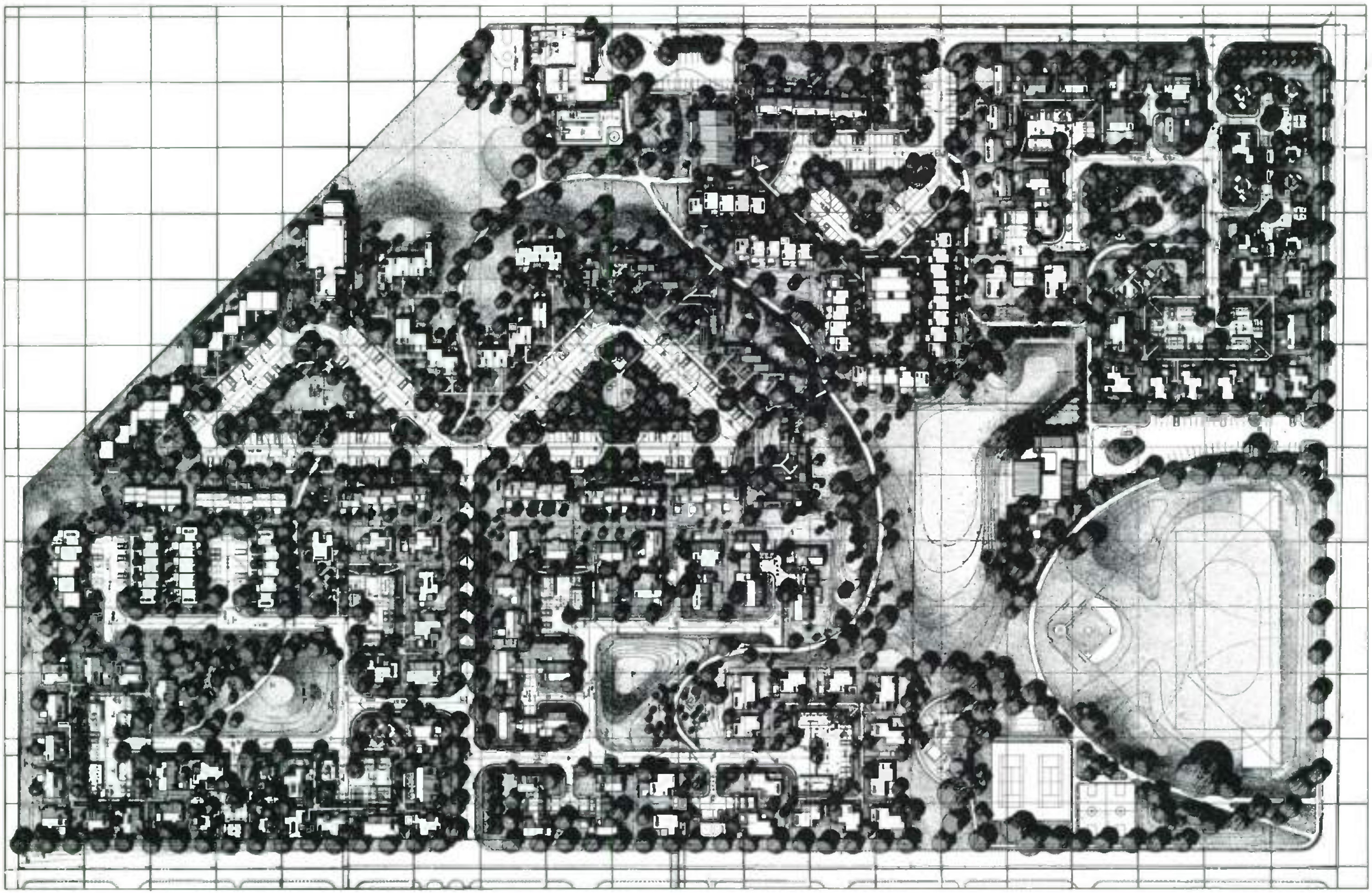
The basic benefit from the various Federal programs results from the subsidization of interest rates on money. For example, when a nonprofit organization sponsors a low-income housing project with a federal subsidy, the sponsor can obtain a 100-percent mortgage with no equity capital. Then, to minimize rents—and that's



Initiated in early 1968, the In-City Program was HUD's first effort to stimulate development of innovative building systems that could provide mass-produced housing for low- and moderate-income families. HUD asked for innovative proposals to include technical and architectural designs, financing methods, labor action programs, and social programs.

Of the 22 firms that responded to HUD's request for proposal, Westinghouse was one of three awarded development contracts. Westinghouse proposed 13 different building systems. One of the more innovative designs was based on a modular unit of steel-frame stressed-skin construction. Modules stack around a central utility core that contains kitchen and bathroom units. By interconnecting modules between floors, various bedroom combinations can be provided. The arrangement shown contains four living units on three floors.

Although Westinghouse did not win the single construction contract that was awarded, the experience provided a valuable study of the housing field and led to the formation of the Westinghouse subsidiary, Urban Systems Development Corporation (USDC), in mid-1968.



Under contract to the U. S. Department of Housing and Urban Development, USDC is site developer for the Indianapolis Operation Breakthrough project, coordinating the work of eight prototype housing systems builders. Site planner is Skidmore, Owings & Merrill.

Operation Breakthrough was launched by HUD in 1969. That sponsored competition involved a broad segment of private industry in the design of innovative building systems for volume production. Although USDC's design was among the 37 finalists, it was not one of the final 22 awarded construction contracts.

On the basis of that effort, however, USDC later proposed and was selected by HUD as site developer for the prototype Operation Breakthrough project in Indianapolis. The Indianapolis site is one of nine Operation Breakthrough projects located throughout the U. S. for the purpose of demonstrating new techniques in planning, zoning, construction, and marketing of family communities. As site developer, USDC has been responsible for land acquisition, financing, licenses, fees, and preparation of the land to receive units from the HUD-selected builders. The 295 homes on the site will be marketed under Section 213 of the National Housing Act as a market cooperative under USDC's direction.

the whole purpose of the arrangement—the sponsor's mortgage money is provided at what is called BMIR (below-market interest rates—as low as one percent). There are also other federal programs that permit individual consumers with low or moderate incomes to buy housing at BMIR. Depending upon the program, those mortgages can be obtained at interest rates as low as one percent.

The Federal Government doesn't actually make low-interest loans, but it does provide subsidy funds to the mortgagor. By this mechanism, low-interest money provides much lower rents or monthly payments than possible with normal mortgage interest rates.

All low-income housing programs begin with a comprehensive feasibility analysis. In the case of low-income rental housing projects, the feasibility analysis starts with a survey to determine normal rents for the area, which in turn provides an estimated yearly income for the project. From that income is deducted a vacancy allowance (usually 5 to 10 percent) and estimated expenses; the remaining income must support the mortgage. The land cost, taxes, insurance, and fees are all fixed and deducted from the available mortgage. The architect's fee, builder's general overhead, profit, and interim financing costs are also deducted. The balance is the amount available for construction. The builder then figures his costs. If the project can be built for a mortgage that can be supported by projected income, and if the FHA approves the project, then the builder contracts with the sponsoring organization.

This procedure is backwards from the process normally used in industry; instead of establishing prices based on product costs, the builder must work in reverse to determine if he can recover his costs plus profit from a predetermined price.

There is no problem finding sponsors for low-income housing projects, or investors who are willing to invest in housing for the return they receive via the depreciation allowance. The main problem areas are in processing procedures and federal funding.

The problems, both federal and local, are mainly political—tremendous delays in processing paperwork, zoning delays, building permit delays, sewer and water availability, etc. Processing delays of one to one and one-half years in obtaining project approvals from the various federal and local government agencies are not unusual. The funding problem exists primarily because Congress makes *appropriations* for the various federal support programs but, when the time comes to actually *fund* the project, it fails to vote the funds that have been previously appropriated.

In summary, the need for low- and moderate-income housing continues to grow, but the market will remain sporadic until sufficient federal funds are made available and the tremendous delays in processing procedures are overcome.

Hope For Factory-Built Housing

Industrialized (factory-built) housing has the potential of becoming a major factor in satisfying the need for housing during the next decade. Although this form of housing has not provided an immediate economic solution to low-income housing, the potential remains. A real cost breakthrough will probably require major design breakthroughs, with sufficient demonstration of the benefits of those new designs to attract people who will want and accept new forms of housing. On the other hand, those consumers who want homes that look conventional also do not want to live in a development of *identical* conventional homes. In attempting to satisfy that consumer demand for conventionality with variety, experience to date has shown that the cost of labor and materials for factory-built housing is about the same as that required for conventional construction. Therefore, today's factory-built housing must compete with conventional housing on merits other than labor and material costs.

Basically, people look for three things in a house: they look for a style or design that they find attractive, they want amenities for living comfort, and they compare dollar cost with living space. The house must be large enough to accommodate family needs but be within the income range of the buyer. Thus, the builder must attempt to anticipate the consumer in terms of the accommodations he is looking for, the price he is willing (or able) to pay, and the design that will be acceptable to his lifestyle. The acceptability of industrialized housing presently depends on the builder's ability to provide an attractive house that can't be labeled "factory built" and at a price competitive with conventional housing.

Typical Feasibility Analysis for a Low- or Moderate-Income Housing Project

Rent Schedule		
8—1 BR units @ $75/month	$ 600	
92—2 BR units @ $87/month	8,004	
20—3 BR units @ $95/month	1,900	
	$ 10,504	
Annual income	$126,048	
Income at 93% occupancy (7% vacancy allowance)		$ 117,225
Expenses (45%)		53,035
Annual income available to support mortgage		$ 64,190
From Annual Constants Table		
$64,190 will support mortgage of		$1,419,500
Land	$ 94,000	
Taxes, insurance fees	$104,600	198,600
		1,220,900
Architect's fee		44,400
		1,176,500
Builder's general overhead		18,000
		1,157,500
Builder's profit		51,900
		1,106,600
Interim financing (7½% on $709,750 for 15 months)		66,600
Balance available for construction		$1,040,000

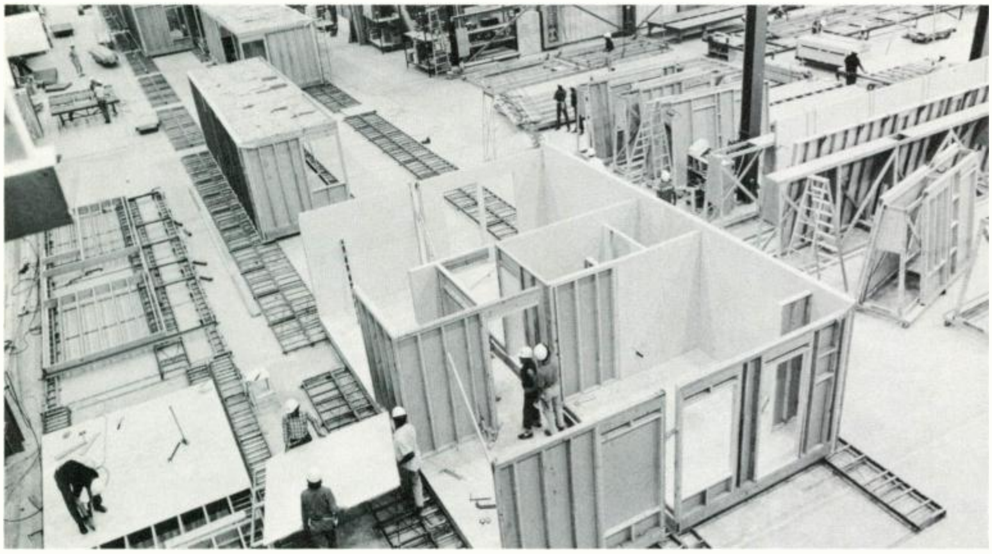
From a competitive standpoint, industrialized housing has two major advantages over conventional construction. First, it is of generally higher structural quality, if for no other reason than to withstand the rigors of moving units from factory to foundation. Many of the structural advantages only impress the consumer when pointed out since the added quality is not visible. In gaining consumer acceptance, manufacturers must also point out how industrialized housing differs from the low-quality prefab housing that appeared during and immediately after World War II. Actually, a degree of industrialized construction is now common for most residential building, including some of the more expensive luxury homes. Today, most so-called conventional housing built on site is substantially "industrialized": roof trusses are prefabricated, windows and doors are prehung in frames, and a great deal of wall panelization is done off site. Those types of prefabricated components can be manufactured in small plants with low overhead, making field construction with prefabricated components very economic. Industrialized housing, however, carries prefabrication to the fullest extent possible, and in so doing uses much more sophisticated plant facilities.

A second major advantage of industrialized housing is the potential reduction in interim expenses incurred during construction—especially interest expense because of the shorter time period required from start to completion. Instead of taking weeks or months to get a building enclosed and ready to finish inside, multiroom components are built and finished in the factory, moved to the site, and set in place on a prepared foundation. All that is required in the field is the hookup work between components and the service connections.

Another advantage of industrialized housing over field construction is that a factory can work year round, regardless of weather, while conventional construction field personnel can't. In fact, from an economic standpoint, factory production *must* be continuous.

In the usual housing project, about half the total cost to the consumer is in the structure itself. The remaining 50 percent covers all the other things required to deliver the product to the consumer—land, land development, amenities, financing charges, etc. Thus, a construction approach that saves six months in getting the project to market should help reduce some of those non-structural expenses.

On the other hand, site development is not easily accomplished. It remains the developer/builder's greatest challenge. Starting with a piece of raw land, it must be zoned, planned, and developed. With a planned unit development, a year may be consumed just for land acquisition, zoning approvals, feasibility analysis, land planning, and engineering. Another year may be required for getting the site ready for construction, depending upon how much development is required. Actual construction may not begin until the third year. Thus, it can take as long as three years from start to completion for a project that may require less than a month of factory production. But getting houses on the mar-



Component modules for townhouse and single-family detached homes are in production at USDC's Fredericksburg, Virginia, plant. Component parts for the module are fed into 10 main assembly-line work stations. Many of the components are subassembled or prefabricated prior to reaching the main assembly line. Shown in the photographs are the first main assembly station (left) *where fabricated end, plumbing, bearing, and fire walls are erected on preassembled flooring, and the final station* (right) *where each module is weatherproofed and packed for shipment.*

About 80 percent of the home construction is completed when the modules leave the plant. At the job site, workmen secure first-floor modules to the foundation; join adjacent, upper, and lower modules; erect and attach the roof; and make water, sewer, heating, and electrical connections. A minimum amount of interior finishing is required on site.

ket six months earlier gives the developer/builder a faster return on his larger investment in actual construction.

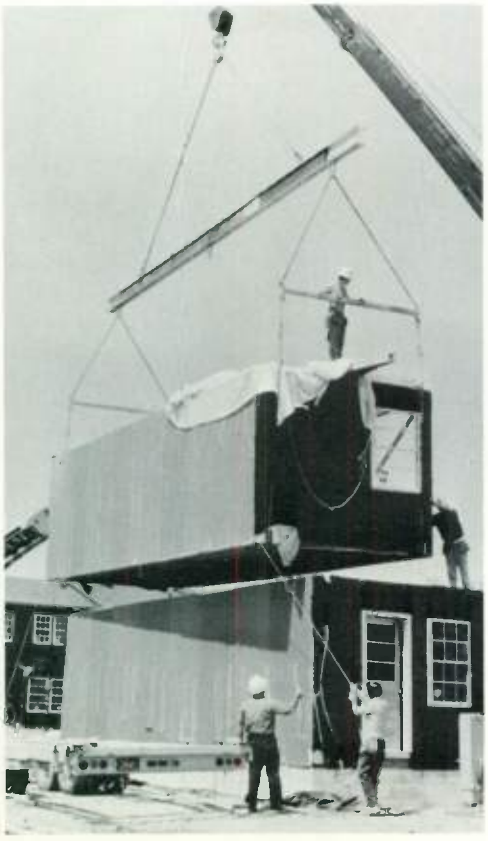
Shipping considerations require that industrialized housing plants be located to serve specific markets. The effective market that can be served from a given plant is essentially limited to major urban areas within a 150- to 200-mile radius of the plant. Urban sites are generally required because factory-built housing must be clustered to make its on-site assembly economic; market radius is limited economically to distances that a tractor transporter can reach in one day. Although barges and railroads have been used for transportation in a few instances, the tractor transporter is usually the most feasible method.

A problem of site development that applies today to almost all housing whether industrialized or conventionally built is sewer and water availability. In many urban areas, developers are restricted by sewer moratoriums and must either help the community provide these facilities or wait until new facilities have been installed. Sewer moratoriums will continue to increase and become more severe in crowded urban areas because of the growing concern for the environmental problems that attend inadequate sewage treatment. A further limitation that must frequently be considered is the availability of highway transportation. Most communities require adequate highway capacity before permitting construction of large developments. As a result, many large housing projects are now being built near interstate highway connections.

Trends in the Middle-Income Housing Market

In the past, middle-income housing has been mainly single-family detached units. But because of the rising cost of land, the single-family home is becoming increasingly expensive, a situation that is stimulating a growing acceptance of townhouses and condominiums. Townhouses can be reasonably priced because 10 to 15 units can be clustered on an acre of land, compared with only two or three single-family detached homes. Furthermore, carefully planned clustering can make open space available for desirable amenities. The owner of a single-family detached house on a ⅓-acre lot usually has all his amenities self contained within his own living unit; in the townhouse development, recreational and social accommodations are usually exterior to the living units. In typical USDC townhouse developments, a community building is provided for holding various social functions, such as dances, meetings, or teenage gatherings. There is usually a swimming pool and, if the development is large enough, tennis courts, badminton courts, pitch and putt courses, bicycle paths, or walking paths may also be provided. These additional features are seldom provided in land-consuming developments of single-family detached homes.

Today's middle-income housing, whether conventional or factory built, townhouse or single-family home, must be more specifically oriented to the customer's desires. This consumer is relatively affluent and is no longer willing to settle for just a house



This new community of 148 factory-built homes is under construction at Virginia Beach, Virginia. Known as Lynn Meadows, the development will include 112 traditional style townhouses, 12 two-story duplex homes, and 24 single-story duplexes. All units are being built at USDC's Fredericksburg, Virginia, plant.

The USDC system is approved under Virginia's industrialized housing code passed in 1971, and each unit carries a Commonwealth of Virginia numbered registration seal. The units meet all FHA and VA requirements.

or apartment. He now puts more emphasis on the surrounding environment. He wants such things as recreational facilities, convenience of transportation, and various other social embellishments. To satisfy those desires, the developer/builder must become involved in planned urban developments, some of them of a scale large enough to be considered "mini towns." These large developments must contain a desirable mixture of high-density and low-density housing with open areas reserved for community use. The consumer must be able to clearly identify the benefits to him that have resulted from a good job of urban planning.

An urban development that illustrates this comprehensive approach to planning is now under construction by USDC at Stuart, Florida, about 60 miles north of Fort Lauderdale. It will consist of 1032 condominium units and is planned to include a marina, convenience shopping, recreation facilities, and an 18-hole golf course. For every acre developed, one acre will remain open for community use. Although building construction is conventional, complete amenities are being provided to assure consumer acceptance.

For example, one new concept designed for a specific type of consumer is called a "holiday" condominium. It amounts to multiple ownership of a condominium, each owner having possession for a limited period of time—such as one month of the year, in which case there are 12 owners each having a 1/12th ownership in the condominium. Thus, for a $36,000 condominium, in this case each owner would pay only $3,000 plus his share of the upkeep. This form of condominium ownership is designed for the vacationer who would like to limit his investment in proportion to his anticipated use.

New Look in Military Housing

Military housing is an expanding market, which has grown rapidly during the last few years. It is primarily the result of the U. S. Government's effort to encourage an all-volunteer military force, and the effort now extends through all the services. USDC has completed housing projects at Fort Meade, Maryland, at Andrews Air Force Base, Maryland, and at Vint Hill Farms Station in Warrenton, Virginia. All of these family housing projects resemble any other townhouse or apartment project except that they are located on a military base. They have many of the amenities of conventional civilian housing including air conditioning. USDC also has under construction several other military housing projects—Fort Leavenworth, Kansas, Redstone Arsenal in Huntsville, Alabama, Keesler Air Force Base in Biloxi, Mississippi, the Newport naval complex in Rhode Island, Homestead Air Force Base, Miami, Florida, and Fort Hood, Texas, to name a few.

(Left) *This townhouse community known as Harford Square in Edgewood, Maryland (near Baltimore) was developed primarily for the middle-income market. However, under FHA programs, qualified buyers are paying as little as $700 down and $180 per month, which includes membership in the community swimming-tennis club. The builder/developer must work with the community from the beginning because community preferences in housing vary widely. Baltimore happens to like townhouses; in a USDC project in Minneapolis, the community preferred a mix of garden apartments and a high-rise apartment building.*

(Right) *A country club, proposed yacht club, tennis club, and fresh-water swimming pools are amenities offered the buyer of a condominium in USDC's Miles Grant development at Stuart, Florida. The Stuart development is designed for the upper range of the middle-income housing market.*

Housing Market for the Developer/Builder

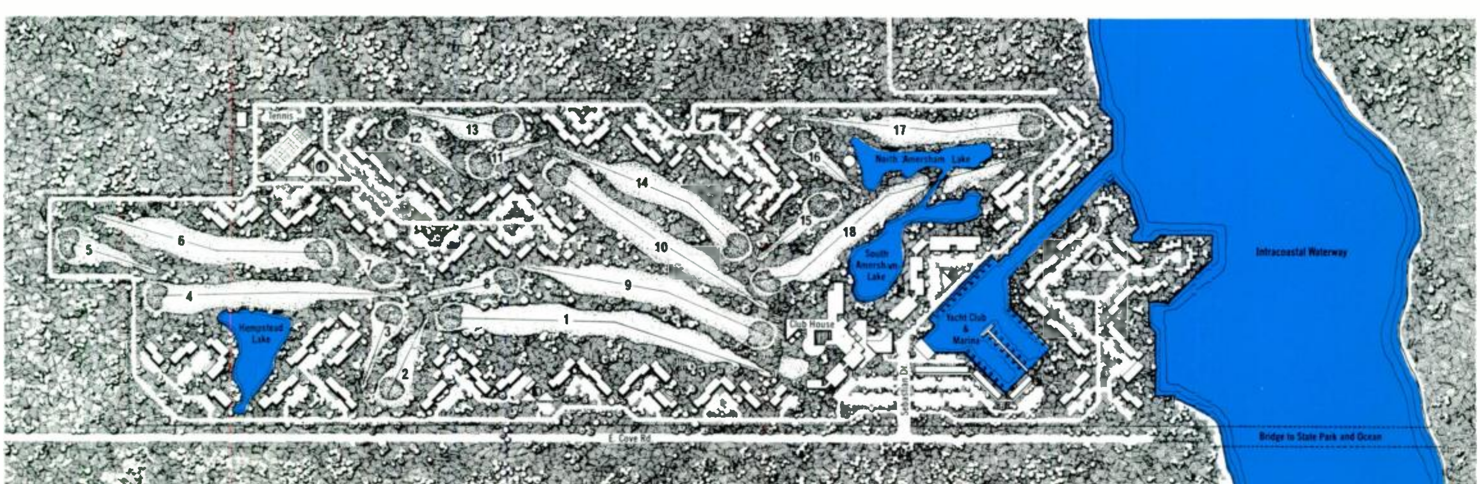
Any given developer/builder's view of today's housing market depends on his range of participation. Therefore, the comments that follow reflect the experiences of USDC, which is presently involved in three general residential market segments: low- and moderate-income housing, middle-income housing (which may range to semi-luxury and includes industrialized housing), and military housing.

USDC's efforts began in the low- and moderate-income market, and over half of its housing projects are still in this segment. That experience enables USDC to provide professional guidance and counsel to new project sponsors, and help them coordinate their efforts with local and federal government agencies. However, because of the sporadic nature of the low-income housing market, it has been necessary to expand for a broader business base.

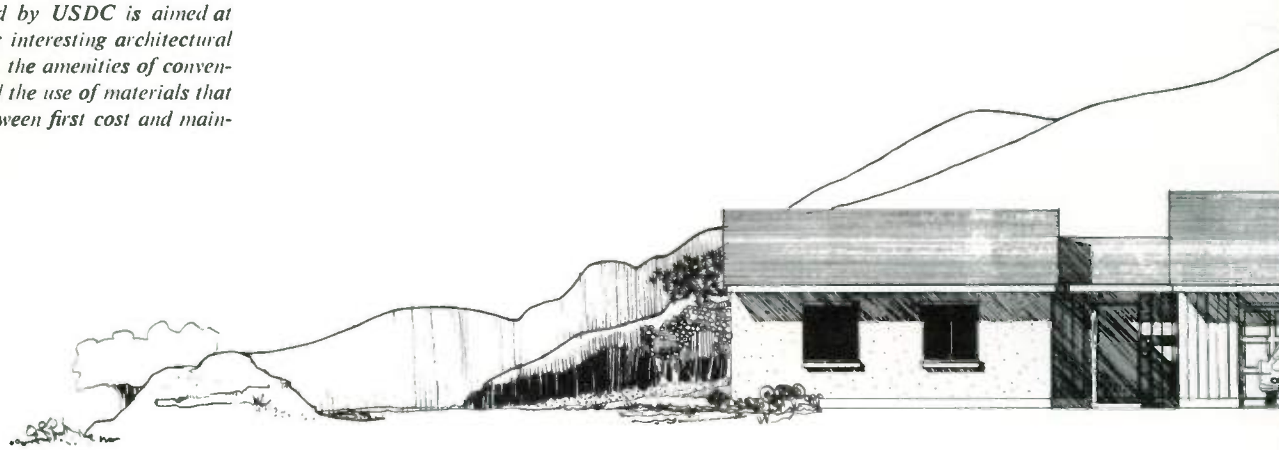
The USDC market segment with the greatest potential is middle-income housing, primarily because financing is conventional and it does not depend upon federal subsidies. Another reason is that prime first-home buyers (the 30- to 40-year age group) will increase by the highest percentage in the 70's—over 50 percent, or 8.9 million people.* Here, the developer/builder must carefully interpret the consumer's wants and must respond more than innovate to be successful. This approach requires the developer/builder to adopt a vertically integrated total approach—feasibility studies, economic analysis, market analysis, land acquisition, land planning, site and building engineering, and construction. The initial marketing analysis and its interpretation are particularly important in large planned residential developments.

Market interpretation begins with a feasibility analysis of each particular piece of ground that is under consideration for development. The analysis includes a study of its location and the types of activities in the surrounding area, the population base

*Dept. of Commerce, Population Estimates and Projections Series P-25, No. 448, Aug. 6, 1970.



Military housing proposed by USDC is aimed at satisfying basic objectives: interesting architectural design to enhance the site, the amenities of conventional civilian housing, the use of materials that maximize the tradeoff between first cost and maintenance cost.



Design Flexibility with Modules

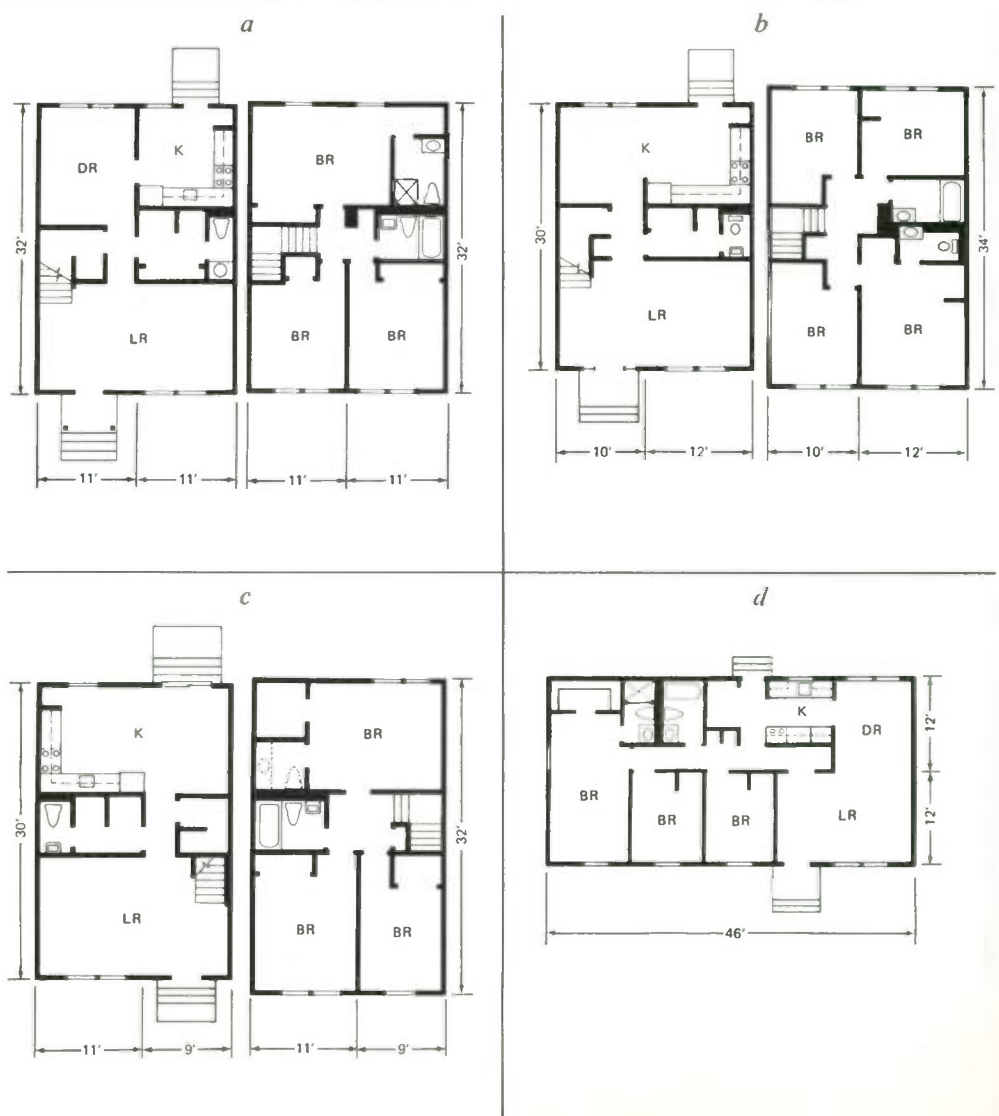
Factory-built modules for townhouses currently in production at USDC's Fredericksburg plant range from 9 to 12 feet in width, 28 to 34 feet in length, and weigh 4 to 5 tons. Four modules make a two-story townhouse.

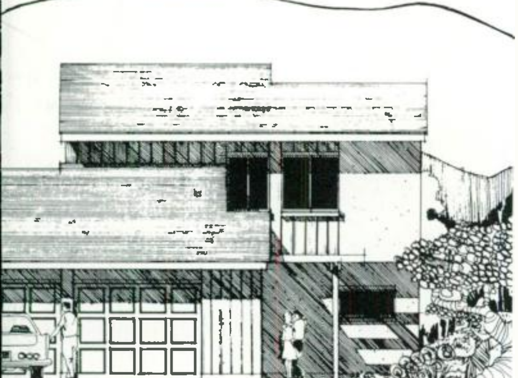
One of the basic advantages of modular construction is the variety of townhouse arrangements that can be built with standard modules. An example of the flexibility provided by this approach is illustrated by the townhouse units being constructed at Virginia Beach, Virginia.

Three- and four-bedroom units (*a*, *b*) use the same basic first-floor arrangement, but different second-floor layouts. Both townhouses have similar structural front elevations (with variations in trim), but several units have a second-floor overhang in front and rear. The three- and four-bedroom townhouses are the right and left units respectively in the four-unit cluster.

The two middle townhouses in the cluster (*c*) use the same modules, but variety in front and rear elevations is achieved by offsetting units and changing trim. By changing unit combinations, alignment, and trim, a variety of townhouse arrangements and facades are obtained. Such techniques are essential to minimize construction costs and gain consumer acceptance.

The single-family detached homes being erected at Virginia Beach consist of two factory-built modules. This three-bedroom unit (*d*) is built with two 12- by 46-foot modules; a larger four-bedroom single-story design is built with two 49-foot modules.





a, b, c

d

that will support it, the environmental considerations including problems of obtaining utility services, soil and topography and their bearing on allowable density, and any other considerations that could affect the marketability of housing built on the site.

Once a project's feasibility has been established it becomes necessary to make more detailed studies to determine what approvals are necessary, the duration of the approval cycle, the overall cost of developing the land, the potential market, and the competition.

Then comes site development planning and the related architectural program for designing the housing. These are usually strongly dependent on the available market and the competition. For example, if a condominium package is to be marketed, will it be necessary to sell an interest in marina accommodations or a golf course? If a townhouse project, are the architectural design and price level acceptable to the area? These kinds of considerations must be studied for each area where a project is contemplated because they differ from one location to another. For example, USDC's mid-Atlantic region, although relatively compact geographically, actually consists of many different market areas. The metropolitan Washington, D.C., housing market is characterized by consumers who are often transient and from both national and international locations; furthermore, housing costs are frequently 10 to 15 percent higher than in nearby areas such as Baltimore. Similarly, the housing market in southern New Jersey is much different from the Philadelphia market even though it serves as a "bedroom community" in close proximity. The Norfolk-Virginia Beach market is unique because of its isolation and its proximity to military establishments with a generally transient population. Thus, it is necessary to examine each community individually to be sure that the site plan and architectural approach will be acceptable.

The third basic market segment in which USDC is involved, military family housing, approximates middle-income architectural considerations. It is presently a relatively steady market but limited in total potential. Congress appropriates funds to the military services, and one way they procure is to invite technical proposals from builders for housing that will satisfy their needs. Although the evaluation of proposals by the individual military services differs somewhat, all basically select the builder's proposal that offers the best advantage to the government. Military housing that is family oriented usually requires certain special features in addition to being economically priced. Maintenance, for example, is particularly important because of relatively high tenant turnover. In this respect, proposals consider the tradeoff between first cost and maintenance cost.

Narrowing the Gap

The ultimate goal in housing is to narrow the gap between what is available and what is affordable, but much ingenuity will be required to overcome the economic problems of housing. Federal subsidy programs for low-income housing must continue if the market is to survive. Industry must also contribute by developing a strong business base in housing that will permit it to internally subsidize to some extent its low-income housing efforts where potential profits are either low or nonexistent.

Technological contributions are the long-range hopes and are eagerly sought. Presently, industrialized techniques contribute primarily to improved efficiencies in management and operation. The factory-built house has not yet contributed significantly to lower construction costs, but its value to the middle-income market is being tested, and its potential for satisfying a wider spectrum of the housing market will be pursued.

Future hopes are for new and imaginative housing systems that can help overcome the economic problems of housing. But even when these unconventional solutions appear, time will be required for their acceptance. Ten years ago, consumer acceptance of townhouses and condominiums was rather limited. Today, the economic advantages of this type of housing, combined with the social desirabilities of the amenities offered, make it the fastest growing market in housing.

Improving the Performance of Lamp Dimmers

George A. Kappenhagen

Use of integrated circuits and feedback technology provides easy, accurate, and stable control of the light output from incandescent lamps.

Dimming control for incandescent lamps has been steadily improved through the years and its applications broadened. The latest improvement is a dimmer that compares actual light output with desired output and makes the required correction to regulate light level accurately over all levels from full bright to fully dimmed.

The original application for dimmers, and still a large one, is in complex switchboards for theater stage lighting. A large installation has several hundred dimmers with sophisticated programming. More and more smaller installations appear as high schools and colleges build new stage facilities or upgrade existing ones. In any theater, accurate light regulation is important because visual effects constitute a large part of a performance.

Light levels also are important in television and photographic studios. The response of the camera to light is quite specific and does not adapt like the human eye; for good pictures, light levels must be easily adjustable and remain set where they are supposed to be.

Intensive-care areas in hospitals have dimmers to dim the lighting at night. It is important that the area not get too dark due to drop in line voltage or to normal temperature rise in the dimmer. Other applications are in conference rooms and demonstration areas, where special lighting effects are often advantageous.

Dimmer Requirements

Dimmers have to overcome three main adverse effects—fluctuations in line voltage, loading, and temperature.

Line voltage can vary considerably in the far reaches of a power system. The variations cause light level to fluctuate, and a *high* line voltage in the full-bright control position causes lamps to run over rated wattage and burn out quickly. Hub Electric Company's new dimmer can take a line voltage change of ± 10 volts and typically allow a change of only ± 0.1 volt at the load. For a ± 20-volt change, which is very rare, typical regulation is ± 0.25 volt.

Loading also causes line voltage changes. All of the wiring, reactors, transformers, and so on have resistance. When only a few lamps are on, a small current flows and the voltage drop across this resistance is quite low. When all the lamps are on, however, a very large current flows and the voltage drop across the resistance is very high. Consequently, lamp voltage tends to fluctuate. The new dimmer typically allows only a 0.5-volt total change from full lamp load to minimum lamp load.

Temperature changes tend to cause drift in control circuits. Most dimmers do not always track with each other (dim their lamps uniformly and together). The reason is that one may be hot and another cold; the lamp voltage changes, in turn, and different lamps supposedly at the same light level are actually at different levels. Drift is especially a problem at low light levels, where it is very obvious. Dimmer racks give off heat of their own and are usually tucked away in out of the way places that are not air conditioned. The new dimmers are so designed that they are thermally stable.

Development

In the early days of lighting control, dimmers were variable autotransformers. They provided smooth flickerless control at low cost and are still supplied for small simple systems, such as those usually found in elementary schools. In moderate to large systems, however, they are cumbersome and unwieldy in physical size and in control methods. Average dimmer rating is 6 kW apiece, and an autotransformer of that size is a 90-pound mass of iron and copper with a large directly coupled handle. An average installation may have 30 dimmers. If more than a few need to be changed at one time, motor drives must be used. Several dimmers can be operated at once from the same master control, but, to have different initial and final light levels for many dimmers, considerable electromechanical control is needed.

A new type of dimmer came into being during the 1960s with the development of power thyristors. It is compact and easily controlled by gating a thyristor bridge to control output voltage. Its use led to development of large lighting systems with efficient low-level dc control systems having simple slider potentiometers for complete control of as many dimmers as needed (Fig. 1). The adjustable dc control signals from the potentiometers are converted by the dimmer's control circuitry into gating

Use of Dimmer Control

In the simple example illustrated in Fig. 1, both preset *A* and preset *B* light values are set initially on the individual dimmer control potentiometers. At the beginning of Scene 1 on stage, the master fader handle is in preset *A* position and the grand master handle is at minimum. Bringing the grand master handle to maximum illuminates Scene 1 with all the preset *A* levels. To start into Scene 2, the master fader handle is gradually moved to the preset *B* position, and all the light levels gradually change to the preset *B* values. Preset *A* is then deenergized, and the light levels for Scene 3 are set into its potentiometers. At the next movement of the master fader handle, the new values in preset *A* light up the stage. Preset *B* is then deenergized, the light levels for Scene 4 are set up, and so on until the first act is over and the grand master handle is again moved down to minimum, blacking out all the lights on stage. There are further levels of sophistication, but this example shows how simple the control can be.

G. A. Kappenhagen is a Senior Engineer in the Design and Development Department at Hub Electric Company, Inc. (a subsidiary of Westinghouse Electric Corporation), Elmhurst, Illinois.

The author acknowledges the contributions of James B. Tabor, Hub Electric Company, Inc., to the development of the new lamp dimmer and the contributions of William D. Allardice, Westinghouse Corporate Design Center, to the general appearance of the dimmer and its enclosure.

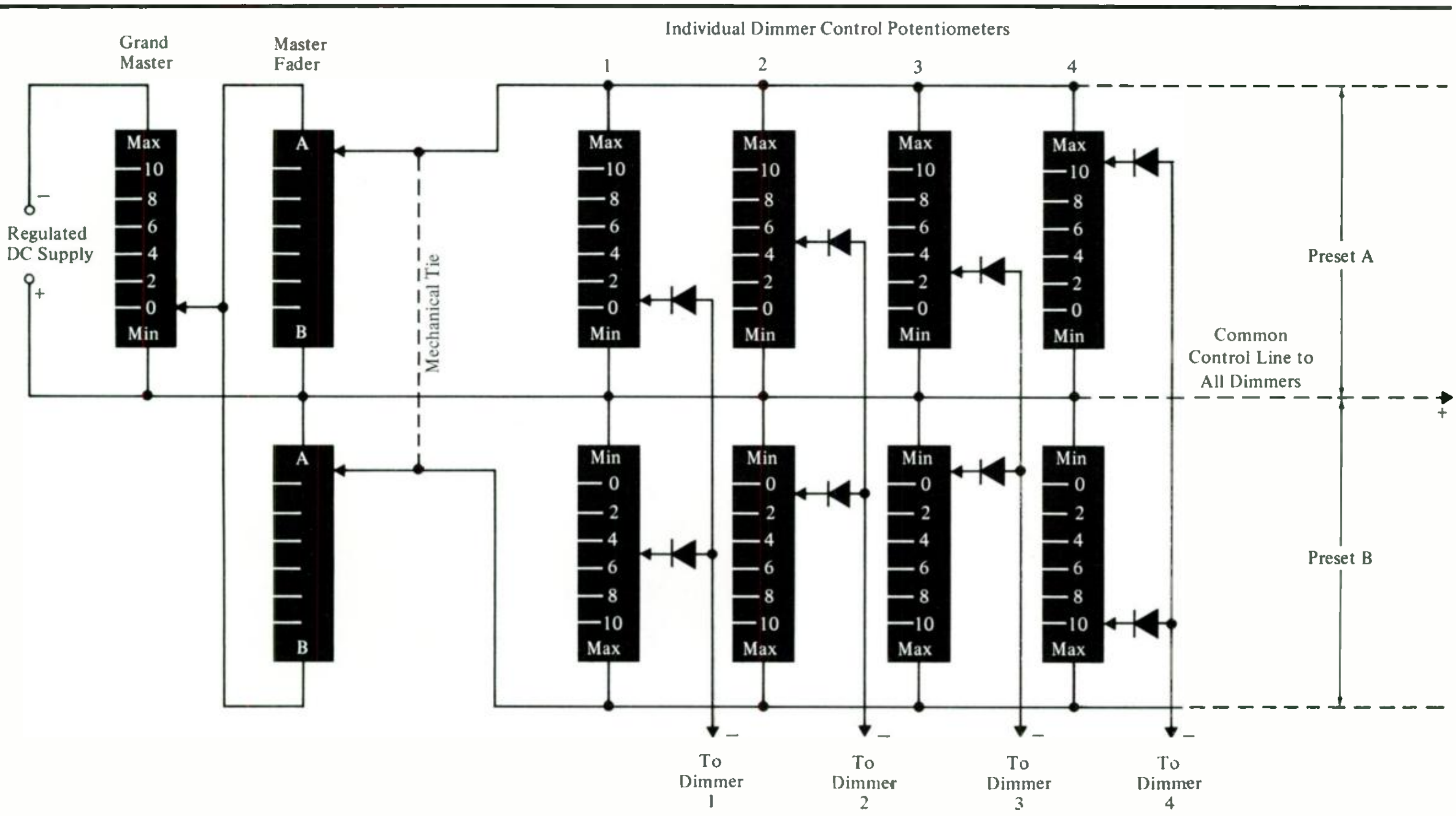
signals for the thyristors. A maximum potentiometer setting provides the full 24-volt dc control voltage to the dimmer's control terminals, producing maximum dimmer output voltage and thus maximum light output from the lamps.

Each group of dimmers, called a "preset," is given a totally independent set of desired initial and final light levels, and the dimmers change proportionately between those levels depending on the position of the master fader control potentiometer. This proportionate changing is called "fading"; the whole sequence is called a "fade." (See *Use of Dimmer Control* at lower left.) Submaster potentiometers can be used to control smaller groups of dimmers by appropriate auxiliary switching.

A new advantage that came with thyristor dimmers was the ability to adjust dimmers for an apparent linear change in light output with a linear control change. It was too cumbersome to mechanically provide that feature with autotransformer dimmers because the relationship between apparent light and dc control level is an exponential function. With thyristor dimmers, almost any control curve can be developed electronically at low cost and in very little space without requiring moving parts or mechanical linkage. The relationship between control setting, actual light, apparent light, and lamp voltage is shown in Fig. 2. An apparent linear change to the human eye is an actual change following a square-law curve. Most manufacturers have standardized on this dimmer response because it is recommended by the Illuminating Engineering Society.

New Dimmer

The new dimmer employs modern solid-state technology to improve the performance of the conventional thyristor dimmer. Integrated circuits provide the required close matching of resistors and transistors because the devices are made at one time on the same chip. Use of sensing circuits and feedback loops adds the function of voltage regulation. The dimmer is not merely line voltage compensated, it actu-



1—Control system for thyristor dimmers consists of interconnected potentiometers that regulate the level of the dc control voltage going to the dimmers. Potentiometers for individual dimmers are arranged in two or more groups that are called "presets" because, while one group is controlling light levels, the desired light levels for the next scene can be preset in the other group. With the master fader in position A *all diodes in preset* B *are reverse biased, so preset* B *has no effect on the dimmers; with the master fader in position* B *all diodes in preset* A *are reverse biased, so preset* A *has no effect on the dimmers.*

ally senses true rms output voltage, compares it with the control setting, and maintains the desired output regardless of loading, line voltage, and temperature.

The power circuit consists of lamps (the controlled load), current transformer, reactor, thyristors, and circuit breaker (Fig. 3). The current transformer senses any overload condition and sends a signal into the control circuit. The circuit breaker serves as an on/off switch and as backup overcurrent protection with fast all-magnetic trip. The thyristors control lamp voltage by conducting or blocking ac power at such points in the applied waveform as to provide the desired rms voltage on the load side. Their switching action must be carefully timed and regulated, and that is the function of the blocks in the control logic portion of the diagram.

The new light dimmers are modular, made in several standard sizes to supply different amounts of lamp wattage. Each has a circuit breaker used as an on-off switch. Standardized cabinets hold as many dimmers as needed.

The main function of the reactor is to prevent lamp filament noise. A voltage rise time less than 300 to 400 microseconds causes an incandescent lamp's filament to "sing"; the shorter the rise time, the louder lamps sing. We design for a rise time of 800 microseconds under full load conditions when phased back to a turn-on angle of 90 degrees. At 90 degrees, line voltage is switched on at its peak instantaneous value, giving a worst-case condition. Voltage rise time decreases as a dimmer is unloaded, so full-load rise time is made considerably higher than the minimum to prevent audio pickup into stage microphones. An adequate reactor causes approximately 5 volts drop in dimmer output at full load, but the consequent reduction of light output is negligible. Other reasons for including the reactor are that it reduces radio-frequency interference and limits thyristor di/dt.

The close response of the logic circuit made it possible to build in the dynamic square-law response shown in Fig. 2, so no curve adjustment is needed and all dimmer outputs automatically match and track with each other. The shaped curve is produced by a transistor network with excellent low-current response.

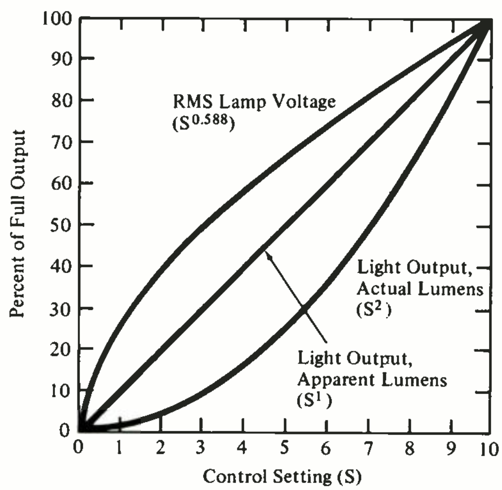
The shaping circuit provides a reference current signal from the 24-volt dc control voltage (Fig. 3). At the same time, a feedback reference current is provided by the lamp voltage sensor. Both signals are fed into the rms comparator, and the resulting low-level output corresponds to the proper turn-on phase angle plus or minus any error. A small trimming potentiometer balances the feedback signal into this network.

The rms comparator feeds into a high-gain error amplifier stage and then into a network that limits the output lamp voltage to whatever value is wanted at the top end of the square-law curve. The signal then goes into a ramp generator and trigger that produces a pulse when the ramp voltage equals the trigger voltage. The pulse is amplified by the gate drive amplifier and applied for thyristor gating.

To provide a time reference, a reset is provided at each line voltage zero point. Thus, the whole circuit is timed and sampled every half cycle. It is very important to keep both positive and negative sides of the waveform balanced and perfectly symmetrical to prevent a dc current from being impressed on the power line and to prevent generation of all the even harmonics.

Having the square-law curve built in means that there are no adjustments to play with, a feature that is especially important in schools. The setting is tamper-proof. Furthermore, the design eliminates errors in adjustment giving nontracking lights. All lamps actually dim how and when they are supposed to.

The new dimmers are available now in



2—The inherent relationships between lamp voltage, apparent light output, and actual light output enable the new dimmer to electronically convert a linear control change to an apparent linear change in light output. The apparent change is an actual change following a square-law curve.

3—(Right) *The dimmer's basic elements include power circuitry, shown in colored lines, and control circuitry. Input to the latter is a regulated dc voltage from a control system such as that diagrammed in Fig. 1. Arrows indicate information flow.*

two basic models to cover a wide power range. All 120-volt styles have been tested by Underwriters' Laboratories and are component listed. Other styles in 240 volts and 277 volts with power capabilities in excess of 24,000 watts will be available late this fall.

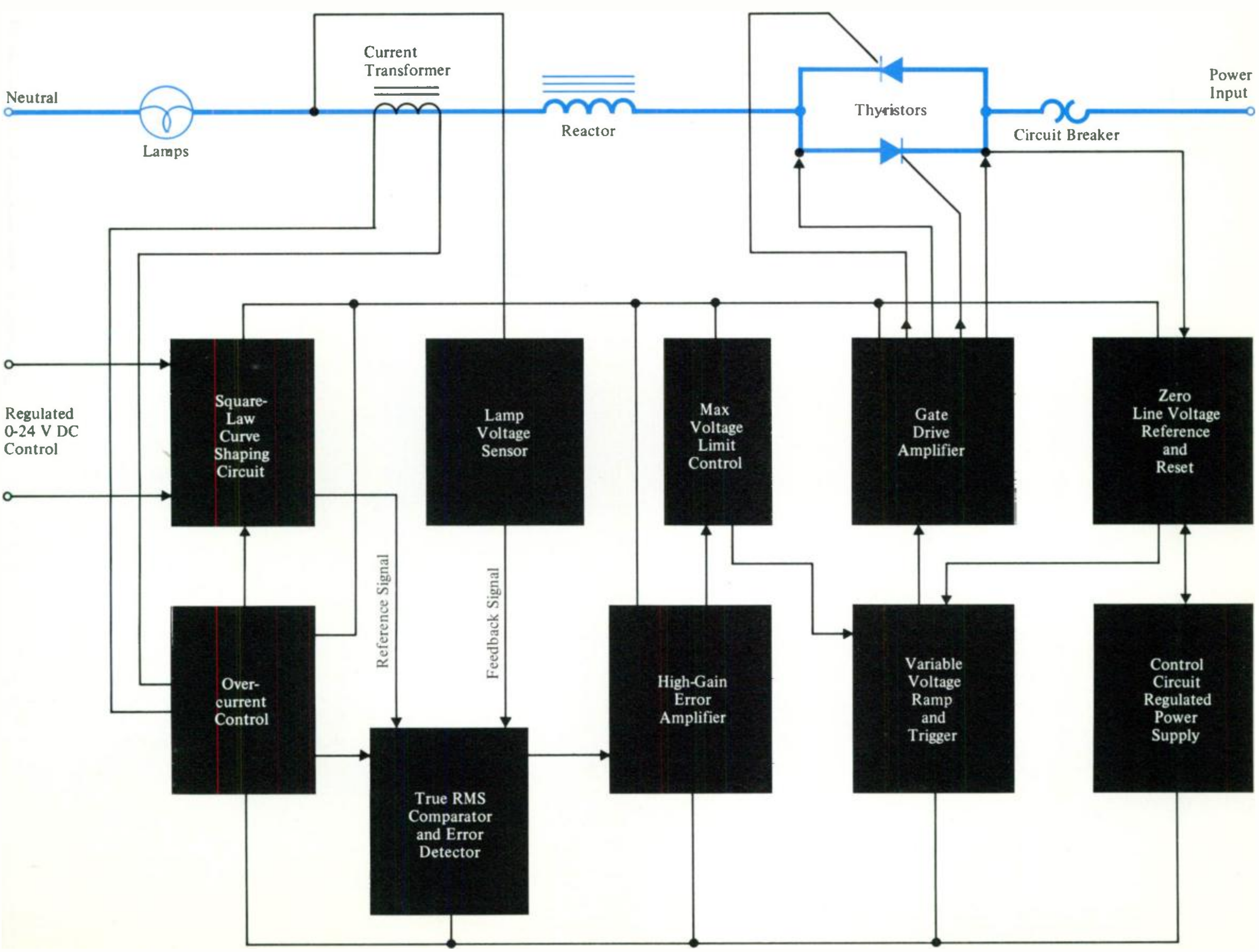
The KAPP-2 model comes in 1800-watt and 2400-watt ratings. It is intended for use with a low-voltage cross-connect system having one dimmer for each branch circuit.

The KAPP-1 model comes in nine different power ratings from 3000 to 12,000 watts. It is intended for use with power cross-patch switchboards where one dimmer is connected to more than one branch circuit. These dimmers have the additional feature of a built-in overload circuit.

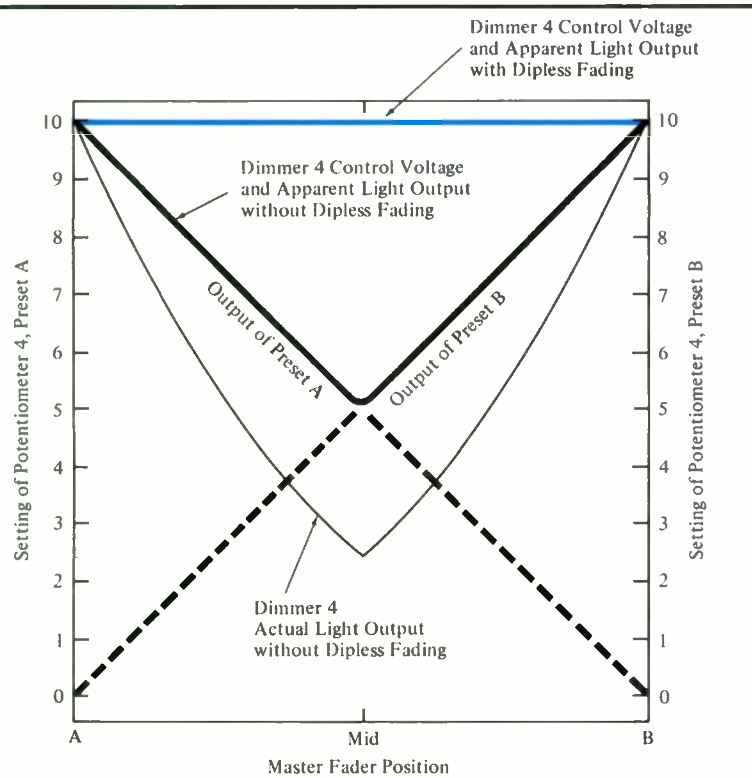
The overload circuit is a peak current sensing system designed to allow a dimmer to tolerate approximately 200 percent of rated load without exceeding its current rating. We do this not to condone overloading but to eliminate nuisance tripouts that may occur when a power panel is being hot patched and the new load is accidentally patched to the dimmer before all of the old load is unpatched. A generally unrecognized fact is that the voltage-current relationship of an incandescent lamp as it is dimmed is not linear. The relationship depends on the temperature (and therefore the resistance) of the lamp filament. This fact must be taken into account in the protective system, since cutting voltage output in half does not protect a dimmer running into twice its normal maximum lamp load. The KAPP-1 overload circuit automatically phases back and reduces dimmer output when output current exceeds maximum rating. Then current gradually rises again until it trips the circuit breaker at about 200 percent of rated load.

Dipless Fading and Pile-On

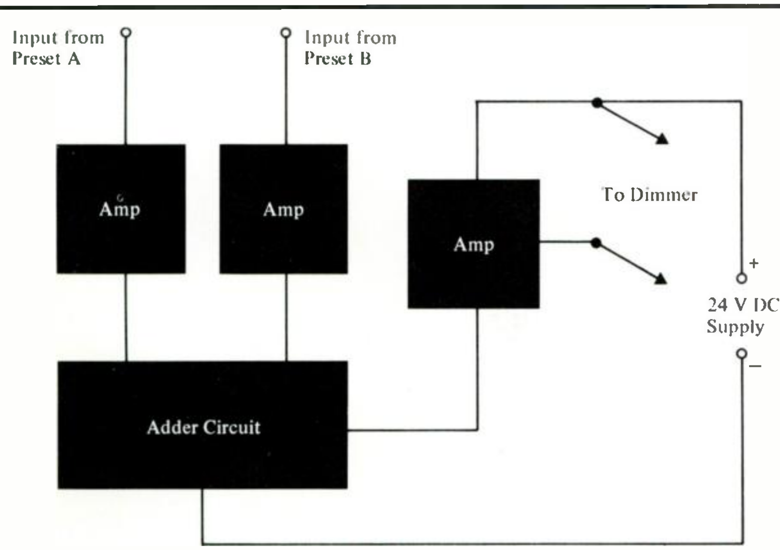
An optional circuit card allows fading between presets without an unwanted dip in light intensity during the fade. Another provides dipless fading plus what is commonly known as pile-on. Both can be added



a



b



4—Conventional dimmer control circuit shown in Fig. 1 causes light output from dimmer 4 to dip when fading from preset A *to* B, *even though both are at maximum setting* (a). *The dip can be prevented, as shown by the colored curve, by modifying the circuit with an optional dipless-fading card* (b). *The card's power supply is the same one shown in Fig. 1.*

to existing systems, but it is more economical to specify them initially.

To understand dipless fading, consider Fig. 1 again. The potentiometers for dimmer 4 in presets *A* and *B* are both set at 10, so the lights controlled by dimmer 4 should not vary in intensity as the master fader is moved from *A* to *B* or vice versa. Unfortunately, with the conventional circuit shown, light level does dip severely because the highest output from either preset *A* or *B* controls the dimmer (Fig. 4a).

To eliminate the dip, the sum of the *A* and *B* settings should control the dimmer rather than the highest setting. As an example, if *A* is added to *B* at the worst part of the dip shown in Fig. 4a, the result is $5+5=10$ which is the desired value. Adding at any other point would also give 10 and the desired linear relationship. Briefly, the dipless fader card causes all dimmers to follow their own paths independently and linearly from any *A* setting to any *B* setting and vice versa. The card's basic circuitry is shown in Fig. 4b.

"Pile-on" means retaining the lighting from one preset and, in addition, fading in all the lighting from the other. The circuit card for dipless fading with pile-on is similar to the one for dipless fading, with the addition of two amplifier blocks and a block that tells the adder circuit when it should add and when it should not. It takes advantage of the fact, mentioned earlier, that the highest output from preset *A* or *B* ordinarily controls the dimmer. All dimmers with settings in either *A* or *B* stay on, and those with settings in both *A* and *B* go to the higher of the two settings. To implement pile-on, the mechanical tie on the master fader (Fig. 1) is broken; the upper potentiometer is left in position *A* and the lower one is moved to position *B*.

Summary

The new dimmers are easily controlled and accurately regulated. By use of modern solid-state circuit technology, they provide light levels that do not vary, low light levels that do not dip to a blackout condition, longer lamp life, and tamper-proof and uniform curve settings.

Training Center Prepares Personnel for Nuclear Power Plants

A training center for personnel of PWR nuclear power plants around the world has been opened at the Zion Nuclear Power Station on Lake Michigan some 40 miles north of Chicago. It is a joint venture on the part of Commonwealth Edison Company and Westinghouse Nuclear Energy Systems, with Commonwealth Edison supplying the land and 30,000-square-foot building for the training center. Westinghouse supplied the equipment and staff, and it operates the facility.

The Zion station includes two 1.1-million-kW nuclear units supplied by Westinghouse. It is nearing completion, with one unit scheduled to go into operation this year and the other next year.

The key training aid is an electronic nuclear-plant simulator that includes three computers. The simulator can be programmed to duplicate the unique features of most nuclear plants for which operators will be trained; its versatility permits the training of more than 200 persons a year. The simulator was designed and built by the Westinghouse Computer and Instrumentation Division.

Each of three control rooms has an instructor's console from which the instructor observes performance of three-man trainee groups. Display and control equipment in the control room responds to the simulator, and governs it, much as such equipment responds to and governs the systems in an actual nuclear plant. The instructor can introduce more than a hundred simulated malfunctions in plant operation, and the nature of the trainee's responses helps determine what additional instruction they need. Much of the instruction is individual.

Another major feature of the center is a training reactor that achieves criticality but produces no power. (See back cover.) Other facilities include a television studio for producing videotaped lectures, three classrooms, a library, training materials unit, and administrative offices.

The great advantage of the simulator over use of an actual plant for training is that most of the abnormal or malfunction drills that are desirable for training purposes could not be allowed to interfere with actual power generation. Moreover, the simulator can be allowed to go on operating if a trainee makes a mistake, thereby enabling him to see the consequence of his mistake and thus reinforcing good operating techniques. Finally, a simulator can be changed immediately from one operating condition to another; the inflexibility of a real plant would slow the training pace intolerably.

The center's training programs range from 2 weeks to 8 months in length. Most are designed to prepare prospective plant operators for the rigorous written, oral, and practical examinations required for USAEC operator licenses. In addition, the center offers courses in nuclear technology for nonoperating utility personnel. Other special courses are provided for plant engineering staffs, instrumentation technicians, and health physics technicians.

A typical operator student is taken back to the fundamentals of algebra and pro-

Instructors use this console to introduce simulated plant malfunctions into the program of the nuclear plant simulator. They observe the student's reactions in the control room.

Much of the training is on a one-to-one basis between student and instructor. Here an instructor works with a student from Kyushu Electric Power Company of Japan.

gresses through trigonometry to calculus and basic physics. From there he goes into nuclear physics and then reactor physics, radiation physics, and reactor safety.

He moves from theory to practice by using the zero-power training reactor. This reactor has no auxiliary systems to hinder its use as a basic training tool, and its core design, control instruments, and essential components are similar to those the trainee will encounter in his own plant. The reactor has 28 fuel elements and 9 control rods. A trainee performs core loadings to become familiar with the various geometrical and material considerations of handling fissionable materials in a reactor. He also starts it up and operates it to get the feel of how a reactor "reacts," and he experiments with control rod programming.

Next comes a series of lectures on design and operation of the systems and components of the specific plant the trainee will operate. The lectures are given by Westinghouse design engineers who are closely associated with the plant.

Approximately 6 months before the initial fuel loading of his plant, the trainee begins a course of intensive training with the simulator. The simulator realistically simulates all modes of PWR operations: startup, shutdown, load follow, abnormal and emergency conditions, and transient responses. Once the trainee achieves proficiency in normal operation, emergency shutdowns and various malfunctions are simulated to give him the feel of handling the plant under abnormal conditions.

The trainee spends close to 100 hours on the simulator and sees more nonequilibrium or abnormal operation than the average operator of a real nuclear plant experiences in many years. In addition, he learns to react properly to malfunctions and emergencies that he probably will never experience in the life of the plant he will later operate.

Once qualified, operators must maintain their operating proficiency. Therefore, the center also provides retraining programs that are flexible and readily adaptable to meet specific operator requirements. Such a trainee spends most of his time on the simulator, performing exercises designed to sharpen and update his techniques and knowledge.

Services in addition to initial training and retraining programs for plant operators include programs to give nonoperating personnel a thorough understanding of nuclear technology and the systems, components, operating techniques, and safety procedures of a nuclear power plant; special design lectures to acquaint attendees with the design and operating characteristics of a Westinghouse reactor; programs to provide instrumentation technicians with an understanding of electronic theory and radiation detection, with emphasis on safety and troubleshooting techniques; instruction for health physics technicians in the various forms of radiation, Atomic Energy Commission exposure limits, proper handling of radioactive materials, and plant safety procedures; and replacement-operator training programs tailored to the individual's specific needs.

Skylab's Portable Light Units Combine High Output with Safety

Special fluorescent lamps in portable high-intensity light units will be used in Skylab, the orbiting laboratory scheduled to be launched next year. The lights will supply local illumination for various work and photographic tasks connected with Skylab's scientific experiments, and they will also serve as back-up for the general lighting system. Consequently, their lamps were designed and built to meet stringent performance and safety requirements.

Skylab is an experimental space station that will be put into earth orbit by the National Aeronautics and Space Administration. It will consist of a cluster of spacecraft, the core of which is an Orbital Workshop with an Apollo Command and Service Module docked to it. The Workshop is a modified S-IVB stage. It and other elements of the cluster (airlock module, multiple docking adapter, and solar observatory) will be launched by the Saturn V vehicle, which develops 7,600,000 pounds of thrust. The Command and Service Module will be launched separately and will be used to transfer crews to and from Skylab.

Skylab program objectives include advancement of the sciences, determinations of the durability of men and systems in space, improvement of space flight technology to develop capabilities for long missions, and "practical" applications such as the development of gravity-free manufacturing techniques and the perfecting of sensing and data systems for use in agriculture, forestry, geology, communications, and other pursuits that benefit man.

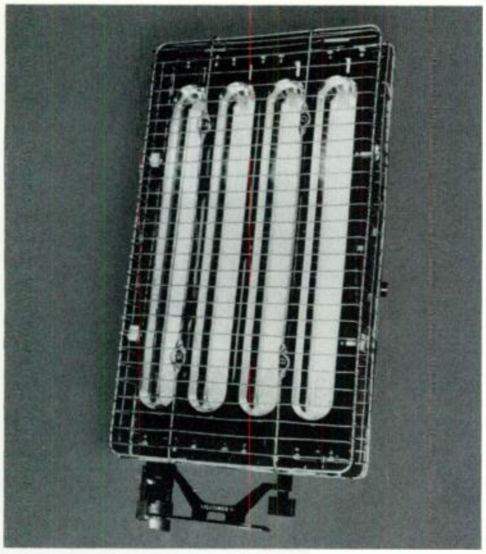
Each portable light unit will have four lamps (Fig. 1). The special lamp developed for the light unit is about 15 inches long and 1 inch in diameter.* It has a clear lengthwise window, half an inch wide, and a built-in reflector to direct light out through the window (Fig. 2).

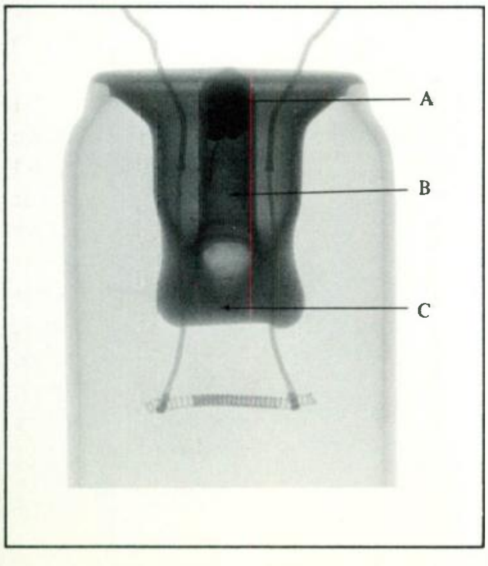
Power will be 28 (+2, −4) volts dc and will be changed from direct to alternating current by an inverter in each light unit. The lamps operate on 20,000 hertz at 800 milliamperes. The high frequency was chosen to maximize efficiency of the lamps and circuitry.

The basic requirement for the lamp is high light output in spite of high operating temperature. Ordinary fluorescent lamps have maximum output when the temperature of the coolest part of the glass bulb is about 40 degrees C. Mercury vapor condenses at the coolest part of the bulb, and the temperature of that condensed mercury determines the vapor pressure in the lamp. If the vapor pressure is excessive (i.e., if the temperature of the condensed mercury is too high), light output diminishes. The Skylab lamps will have to operate at bulb temperature of about 100 degrees C because there is no apparent gravity in orbit and therefore no convection to help remove heat. An ordinary fluorescent lamp could lose up to half its light output at that temperature because of excessive mercury vapor pressure.

Vapor pressure is controlled in the special lamp by using an amalgam of mercury, indium, and tin instead of the droplet of liquid mercury used in ordinary lamps (Fig. 3). The amalgam's composition and its

*R. W. Bushroe, G. S. Evans, and W. A. Wall, "High Intensity Portable Light Unit for NASA Skylab Project," prepared for presentation at the Annual Conference of the Illuminating Engineering Society, Tulsa, Okla., July 23-28, 1972.





position in the lamp are such that light output stays near maximum, and nearly constant, over a wide range of operating temperature (60 to 100 degrees C). Constant output is important because the lights will be used for photography and television. Light output reaches 90 percent of maximum in less than 2½ minutes after turn-on when the lamp is operated at full power in a simulated Skylab environment (ambient pressure of 5 psia and temperature of 50 to 90 degrees F).

Use of the amalgam instead of free mercury also greatly diminishes the potential personnel hazard of mercury escape from a broken lamp. For further protection, each lamp is enclosed in a sleeve of high-temperature Teflon shrunk on by heat.

The lamp's phosphor coating has five components blended to give a distribution of light wavelengths (known as spectral power distribution, or SPD) that approximates the visible portion of noonday sunlight. The SPD matches the requirements of the photographic film that will be used, and it provides the excellent color rendering needed for such medical purposes as judging the condition of an astronaut's health by skin color.

The special lamp was developed by the Westinghouse Fluorescent and Vapor Lamp Division for Iota Engineering, Inc., prime contractor for the light units, under the direction of the Marshall Space Flight Center.

1—Portable lights will be used in Skylab for photography and other local illumination needs. They have special fluorescent lamps recessed in an aluminum housing. A wire barrier surrounds the metal enclosure to protect the astronaut's hands from hot surfaces.

2—The lamp has a lengthwise window and an internal reflector to make its light output directional. The phosphor does not cover the window area.

3—X-ray photograph of lamp end shows how mercury amalgam is retained at the end of a glass tube (location A). Use of amalgam instead of free mercury provides high and constant light output even at unusually high temperatures. A barrier of nickel mesh (B) keeps the amalgam from being dislodged. An auxiliary amalgam, not visible here, is located at C; it warms up rapidly and thus shortens lamp starting time.

Fast and Versatile Elevators Will Serve Sears Tower

When the world's tallest building, the Sears Tower, is completed in 1974, visitors will be whisked in less than a minute from ground level to a 103rd floor observation deck 1350 feet above Chicago. The ride will be the longest nonstop elevator trip in the world. It will be provided by two high-speed express cars supplied as part of a contract that includes manufacture and installation of 88 elevators and 18 electric stairways.

Sixty-three of the elevators will be Mark IV computer-controlled high-speed gearless units. The two that will provide express service to the observation deck will each be capable of carrying about 40 people at 1800 feet a minute.

Double-deck elevators will operate as shuttles from the Franklin concourse and Wacker plaza levels to "sky lobbies" at the 33rd/34th floors and the 66th/67th floors. Each will be capable of transporting about 54 people. The 8 serving the 33rd/34th floors will travel at 1400 feet a minute; the 6 serving the 66th/67th levels will move at 1600 feet a minute. Six freight elevators and 63 passenger units will provide local service in the building's three elevator zones. They will travel at speeds from 500 to 1000 feet a minute.

Fourteen electric stairways will connect the lower levels, two will connect the 33rd and 34th floors, and two will operate between the 66th and 67th floors. They will travel at 120 feet a minute.

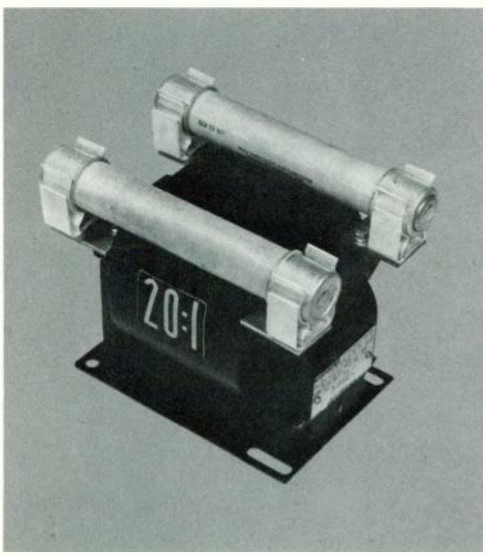
The 110-story building, national headquarters for Sears, Roebuck and Company, will rise 1450 feet from a site facing Wacker Drive in downtown Chicago. It will have a gross area of 4.5 million square feet and a population of 16,500, including 7000 Sears employees.

The building was designed by Skidmore, Owings & Merrill of Chicago, and the mechanical and electrical engineering design was by Jaros, Baum & Bolles. General contractor is Diesel Construction, a division of Carl A. Morse of Illinois, Inc. The elevator and electric stairway systems are being manufactured and installed by the Westinghouse Elevator Divisions.

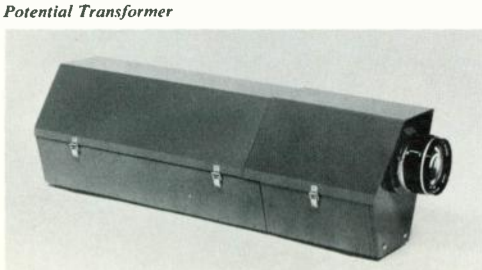
Products for Industry

Potential transformer, Type PC-60, is an indoor 5-kV unit for use in metering and relaying systems. It has octagonal core design to reduce required floor area by 20 percent and weight by 30 percent under previous designs while providing high thermal rating—1000 VA. Its high-voltage coil is wound directly over the low-voltage coil, and the entire core and coil assembly is cast in epoxy. On fused units, a clamp-type terminal for wire connection is provided on the line end of each fuse. *Westinghouse Sharon Transformer Division, 469 Sharpsville Avenue, Sharon, Pennsylvania 16146.*

TV cameras in the new TEM line are for low light levels, as low as 5×10^{-7} footcandles. All necessary power and control circuits are in one package with the camera tube. Features include automatic gain control, random interlace or 2:1 fixed interlace, and all solid state circuitry (except for the tube). The cameras have either an EBS (electron bombarded silicon) or SEC (secondary electron conduction) camera tube, with or without an image intensifier. Models TEM 101 (with SEC tube) and TEM 101-E (with EBS tube) measure 5¼ by 19 by 7½ inches high and weigh 15 pounds with removable lens. Models TEM 201 and TEM 201-E are larger to accommodate an image intensifier; they measure 6 by 25 by 8 inches high and weigh 24 pounds. All operate from 120- or 220-volt 50- or 60-hertz power. *Westinghouse Electronic Tube Division, Box 284, Elmira, New York 14902.*



Potential Transformer


TV Camera

D4S watt-hour meter is a single-phase unit developed in response to requests for meter overload surge protection above the 2000-ampere short-circuit current prescribed by common industry test standards (AEIC-EEI-NEMA). It can withstand short-circuit current of 5000 amperes through the current windings for 0.1 second. Repeated surges of that magnitude have negligible effect on performance or on the magnetic bearing system. Calibration changes due to such surges are limited to plus or minus one percent. Other features of the 240-volt 30-ampere meter are the same as those of the existing D4 meter line. *Westinghouse Meter Division, P. O. Box 9533, Raleigh, North Carolina 27603.*

Mine transporters are battery-powered vehicles for carrying personnel underground. They are made in three models: a low-seam three-passenger maintenance and supervisory car, a low-seam nine-passenger personnel carrier, and a high-seam vehicle with 13-passenger capacity. The chassis is welded steel plate. A dc series wound traction motor provides speeds up to 12 mi/h. The transmission is fully enclosed to resist dust and moisture, and all four wheels have hydraulic brakes. *Westinghouse Electric Vehicles, P. O. Box 712, Redlands, California 92373.*

Dry-type transformers are now available in three new ratings: 333- and 500-kVA single-phase and 1500-kVA three-phase, types DS-3 and DT-3 respectively. They are for use in general-purpose indoor applications at 5000 volts and below, 60 hertz, 150 degrees C rise. Small and light in weight, the transformers are insulated and cooled by air. A built-in vibration damping system makes extra vibration mounts unnecessary, and operating sound levels are lower than established ANSI-NEMA standards. Insulation is Class H. *Westinghouse Sharon Transformer Division, 469 Sharpsville Avenue, Sharon, Pennsylvania 16146.*

COBOL "tool kit" combines six time-saving cost-cutting programmer's aids. They are a shorthand translator to overcome COBOL's inherent wordiness, a TABTRAN decision table processor that translates specially formatted decision tables into COBOL source language, a flow chart generator that produces a diagram showing the logic flow of a program and the sequence in which operations are performed, a COBUREF processor that processes the output of the COBOL compiler and adds cross-reference and index information to the output source listing, a library facility that lets the programmer request prewritten coding to be inserted automatically into his program and thus reduces redundant coding, and a source language debug facility that enables the programmer to specify which paragraphs and/or data names he wants to monitor. *Westinghouse Telecomputer Systems Corporation, 2040 Ardmore Boulevard, Pittsburgh, Pennsylvania 15221.*

ACKNOWLEDGEMENT
We would like to acknowledge the contributions of M. W. Goodman, MD, N. E. Smith, J. W. Colston, and E. L. Rich at the Westinghouse Ocean Research and Engineering Center to the article "Respiratory Heat Loss Determined in Deep Diving Tests," J. E. Hudgens, Westinghouse ENGINEER, *May 1972. This acknowledgement was inadvertently omitted when the article was published.*

About the Authors

R. C. Hoyler has contributed to the development of a number of subsystems relating to automatic control of trains, including the ones for signaling, fail-safe multiplexing, and train identification described in his article. He has been awarded seven patents.

Hoyler graduated from Cornell University with a BEE degree in 1963, and he earned an MS degree in electrical engineering at New York University. He has since done additional graduate work at New York University and at Carnegie-Mellon University.

Hoyler worked first at Bell Telephone Laboratories, Inc., and then joined Westinghouse in 1966 at the Research Laboratories. His work there involved transportation systems, so he transferred in 1967 to the Transportation Division. His major responsibilities have been in design and application engineering of systems and subsystems for automated transit. He is now Manager of Negotiations Support in the Transportation Products Department, responsible for technical liaison and application engineering for potential customers.

Ed Izzi is Manager of the Industrial Design Department, Westinghouse Corporate Design Center. Since joining Westinghouse from Pratt Institute, Izzi has held various industrial design positions at the East Pittsburgh plant and at the Lighting Division in Cleveland. His involvement in many industrial design projects has resulted in 49 disclosures and 28 patent awards, one a special patent award in 1965 for a luminaire design.

Ralph Caplan is a writer and editorial consultant. For several years Editor-in-Chief of *Industrial Design* magazine, he has also written for such magazines as *Design*, *Graphis*, *Canadian Art*, *The New Yorker*, *The Nation*, *Consumer Reports*, *Think*, *Communication Arts*, and *Progressive Architecture*, and for *Encyclopedia Americana*. He is the author of special design publications for the United States Information Agency and UNESCO, and he wrote the text of *Design in America*, published in 1969 by McGraw-Hill.

Caplan has also written *Say Yes!*, a comic novel, and he was Editorial Director of *Rights in Conflict*—the Walker report on violence in Chicago during the Democratic National Convention of 1968. He is currently co-authoring a book on the uses of police. As a consultant, Caplan works with design offices, industrial corporations, foundations, and educational institutions in preparing publications, films, and exhibits.

Rex S. Garrett is President of Urban Systems Development Corporation, a wholly owned subsidiary of Westinghouse. He was responsible for the creation of the subsidiary and has served as President since its inception in 1968.

Garrett graduated from Purdue University in 1947. He came to Westinghouse in the Indianapolis Sales Office and has worked his way through a variety of marketing, product management, and corporate administrative assignments. Prior to forming USDC, Garrett was Executive Assistant to the Group Vice President of the Westinghouse Construction Products Group. In that position, he was responsible for the Construction Group's long-range planning, investigation of acquisitions and new businesses, international activities, and development of management personnel.

Garrett has been active in The Producers' Council, Building Industry Manufacturers Research Council, National Association of Homebuilders, Urban Coalition, and American Society of Planning Officials. He has held executive positions with such trade associations as NEMA and the Association of Electrical Inspectors.

George A. Kappenhagen graduated from Cleveland State University in 1959 with a BEE degree and a BES in physics, and he has done graduate work at John Carroll University toward an MS degree in physics. He worked first at Park Ohio Industries in design of r-f generators and control circuits for induction heating.

Kappenhagen joined Westinghouse in 1966 in the Lighting Division, where his assignment was design of a 25-kW square-wave converter for operating fluorescent lamps. He then served in the ballast engineering section of the Outdoor Lighting Department, responsible for design of solid-state photo-controls, solid-state dc ballasts for high-pressure lamps, and both hybrid and full solid-state ac ballasts for high-pressure lamps.

Kappenhagen was transferred last year to Hub Electric Company, Inc., a Westinghouse subsidiary. He is a Senior Engineer in the Design and Development Department.

Westinghouse Electric Corporation
Westinghouse Building
Gateway Center
Pittsburgh, Pennsylvania 15222

A small training reactor at the Zion Nuclear Training Center enables students to experiment safely while learning how to control a nuclear plant. **(***See page 125.***)**