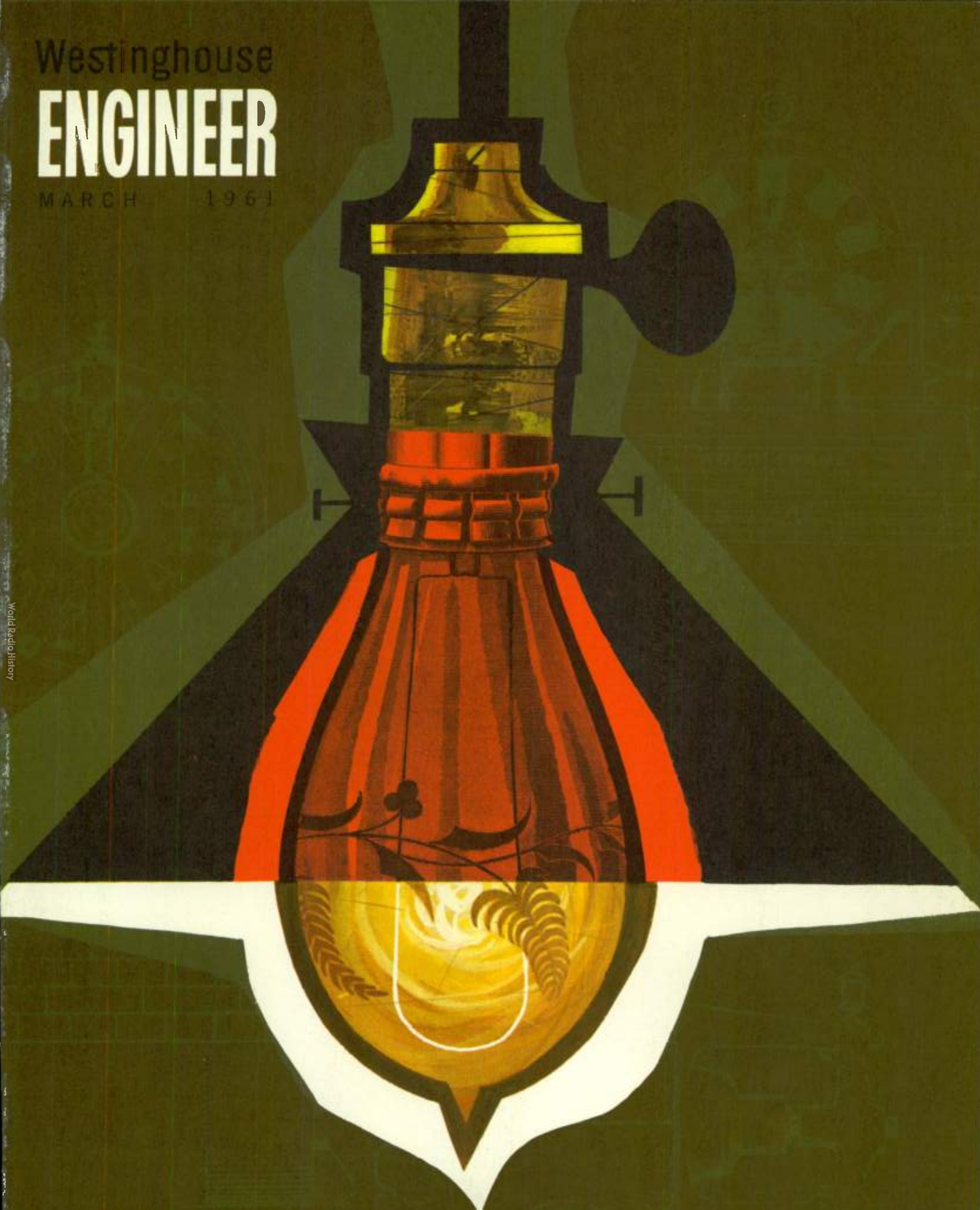
Westinghouse

ENGINEER

MARCH 1961



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WESTINGHOUSE CELEBRATES AN ANNIVERSARY

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MARK W. CRESAP, JR.
President

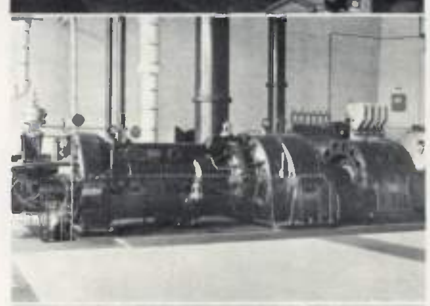
Seventy-five years ago, in 1886, George Westinghouse founded the company now known as the Westinghouse Electric Corporation. By any standards, it was a small company; there were 200 employees in the first plant in Garrison Alley in Pittsburgh, and in 20 000 square feet of floor space they manufactured 13 products, including motors, generators, and switches. Today, Westinghouse employees number over 114 000 in 63 major manufacturing plants, 39 manufacturing and repair plants, and 142 sales offices throughout the nation—and they make 300 000 variations of 8000 basic electric products.

These figures suggest the tremendous growth of Westinghouse during its 75 years of existence. In these 75 years, our country has made more social, economic, and technical progress than in any other period in history, and we are proud to have made contributions to this progress.

A great many specific examples could be cited here as evidence of achieve-

1886 One of the first Westinghouse transformers
1888 The original Shallenberger watthour meter

1887 Typical single-phase alternating-current generator
1900 First central station turbine installation
1920 First commercial radio station, KDKA



ments—technical, economic, and social—made by Westinghouse. But we also recognize that many of these achievements were accomplished by men in other times. And they most certainly were made by men who were looking forward, rather than backward.

Historical patterns can be of little help in predicting the future of a technology. In the electrical industry, a single scientific breakthrough can change our concepts completely, and obsolete past practices. The electrical industry was born of just such a technological breakthrough. For this reason, a review of past accomplishments can, at best, only suggest a *rate* of general technological improvement.

No one could condense the past 75 years of history into a few pages, and do justice to the many people and their many contributions during this period. We do not intend to try. Moreover, we believe that, among the readers of this magazine, most of these accomplishments are already known, particularly in the technical areas. If not, the photographs on these pages show some of the many technical developments in which Westinghouse has played a part.

The life-span of Westinghouse coincides with that of the electric power industry, and our joint efforts have contributed heavily to the progress made in this country. A substantial part of this progress is due to the development of electric power to the point where it is inexpensive, readily available, and reliable. Electric power alone has done much to lighten the burden of people in this country and to enable industry to produce more goods at prices people can afford to pay. The average worker in this country now has about 15 hp at his command, compared to 2 hp in 1900; the housewife has electric "servants" at her command today that she couldn't have dreamed of 75 years ago; and industry is using processes and building products that depend on electric power—or perhaps would not be possible without it.

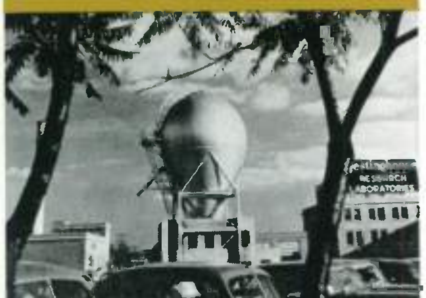
We know that George Westinghouse himself and the Westinghouse Electric Corporation have always recognized that a company is an organization of people, and that the success of the company therefore depends on the capabilities of its employees. Listing even those people who have made outstanding contributions is impractical here, but most technical men will recall names such as Lamme, Hodgkinson, Fortescue, Scott, Rentschler, Skinner, and Conrad. Recognition of the importance of people has been displayed in many ways during the past 75 years. For example, George Westinghouse himself was the first to introduce Saturday half-holidays and vacations with pay; and the company organized in 1907 a sickness benefit plan, and as early as 1910 had an employee suggestion plan.

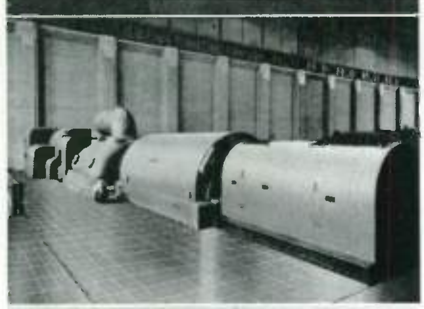
But of most satisfaction to us at Westinghouse is the fact that the recent years of our 75-year history have been just as fruitful as the early ones. In such diverse fields as molecular electronics, arc interruption, power generation, and metallurgy, to name a few, Westinghouse scientists and engineers are continually making new discoveries. Thus, as we at Westinghouse note the 75th anniversary of the company, we are well aware of the Westinghouse traditions—but at the same time we realize that you, our readers, are more interested in what we are doing today, and what we will do in the future. For this reason, we pause but briefly on our 75th anniversary to remind you of technology's progress over this period, and return to today's events—the technical accomplishments of the future.

MARK W. CRESAP, JR.
President

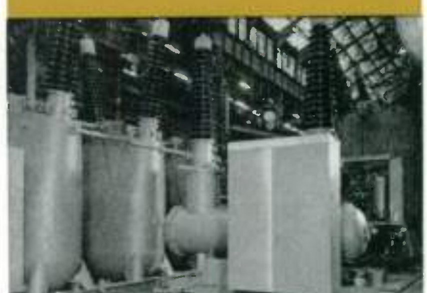
1935 Introduction of Sterilamp bactericidal lamp

1937 The first industrial atom smasher
1948 Development of image amplifier tube
1951 Inner cooling for large turbine generators
1954 Nuclear reactor for the first atomic submarine, the *Nautilus*





1958 Sulfur hexafluoride circuit breaker
1960 Super-pressure turbine



Niagara Project To Have Western World's Most Powerful Generators

EAST PITTSBURGH, Pa., Oct. 7, 1957—Thirteen waterwheel generators which the Westinghouse Electric Corporation will build for the new $600,000,000 Niagara power project will be the largest yet constructed in the western world, according to officials at the Corporation's plant here.

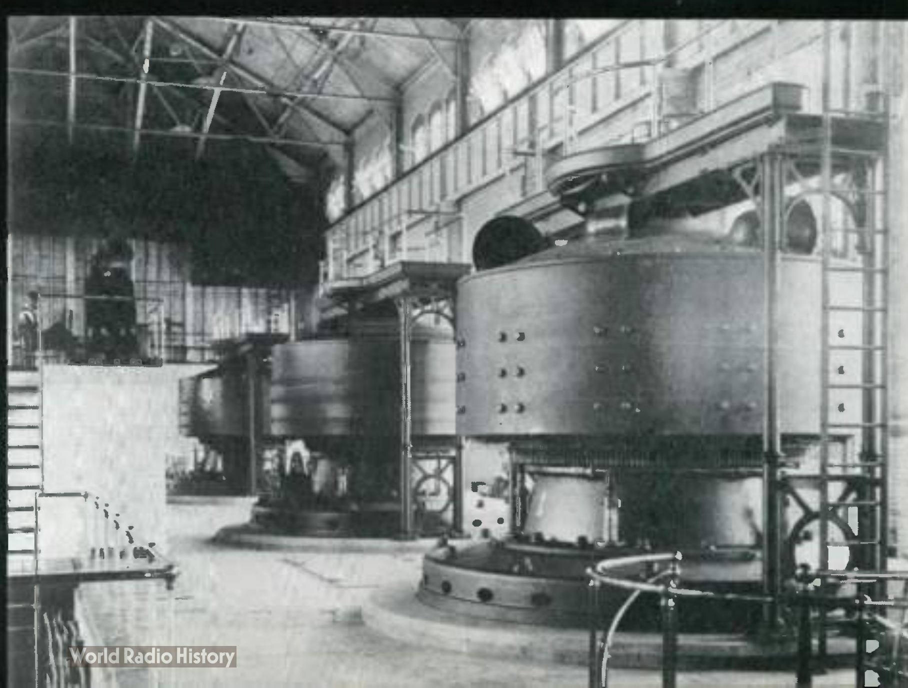
A Westinghouse bid for these generators, each rated at 167,000 kilovolt amperes of electricity, was recently accepted by the New York State Power Authority. The units represent the largest single order of its kind ever placed in the United States.

POWER FROM NIAGARA 1893 AND TODAY

Two different eras are represented in these photographs. At bottom is a scene of the original 5000 hp "dynamos" installed at Niagara Adams Station Number One, which produced power for transmission to Buffalo. By today's terminology, these are 3750 kva generators. At top is a view of the new Niagara Power Project, only five miles from Adams Station. Here Westinghouse is installing 13 waterwheel generators, each rated at 167 000 kva (150 000 kilowatts).

Contract for Niagara Dynamos Awarded

NIAGARA FALLS, N. Y., Oct. 27, 1893—After protracted and exhaustive examinations of many plans submitted by various electrical companies in America and Europe, the Niagara Falls Power Company has awarded to the Westinghouse Company of Pittsburgh, Pennsylvania, a contract covering the constructions and installation of three alternating-current dynamos of 5000 horsepower each.



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Cover design: To symbolize the beginnings of the Westinghouse Electric Corporation 75 years ago, artist Dick Marsh has combined an electric lamp—representing the first large-scale application of electricity—and mechanical drawings of the ac machines that made commercial generation and transmission practical.

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THE ROLLER ROAD A New Concept for a 120-150 MPH Transportation System

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CLARENCE LYNN, Buffalo Division
Westinghouse Electric Corporation

EDITOR'S NOTE: At the moment, the Roller-Road transportation system described in this article is only a concept. But it is a good demonstration of the *functional* approach to a problem; the authors first considered all aspects of the function to be performed, and then searched for a way of fulfilling these requirements. Certainly, our traffic problems of the future need a solution today—the Roller-Road concept is one approach worth consideration.

Approximately 61 million automobiles are in service today. By the 1970's the anticipated ownership is expected to exceed 100 million vehicles. The only answer available today for handling this unprecedented traffic is the construction of more toll and limited-access highways. Unfortunately, new highways will only offset the congestion that would occur if these facilities were not built. There are no real prospects that new road construction can provide a material improvement in driving comfort, safety, or speed.

A study was recently undertaken by Westinghouse engineers to determine whether the electrical industry is in a position to contribute to the solution of 1970's transportation problems. Considering the preponderant use of the automobile for all travel requirements—90 percent of all intercity travel—it appears essential to employ or accommodate the automobile in any new transportation concept. The goal was a system that would be suitable for both long-distance (intercity) and short-distance (commuting) travel at an average speed of 120 miles per hour.

a new form of "highway"—the Roller Road

Any form of 120-mph highway system introduces many problems, but two must influence all other considerations—it must provide adequate capacity with *safety*, and adequate operating *reliability*. In examining various possible solutions—airborne conveyances, monorails, electrified trains, and other concepts—one new concept appeared far superior to all others from the standpoint of safety and reliability. Basically, the system is as follows:

Carriers for automobiles, people and cargo are in the form of sleds or long platforms, devoid of all apparatus whose failure might cause possible traffic shutdown or detention (Fig. 1).

These carriers are propelled on a continuous system of

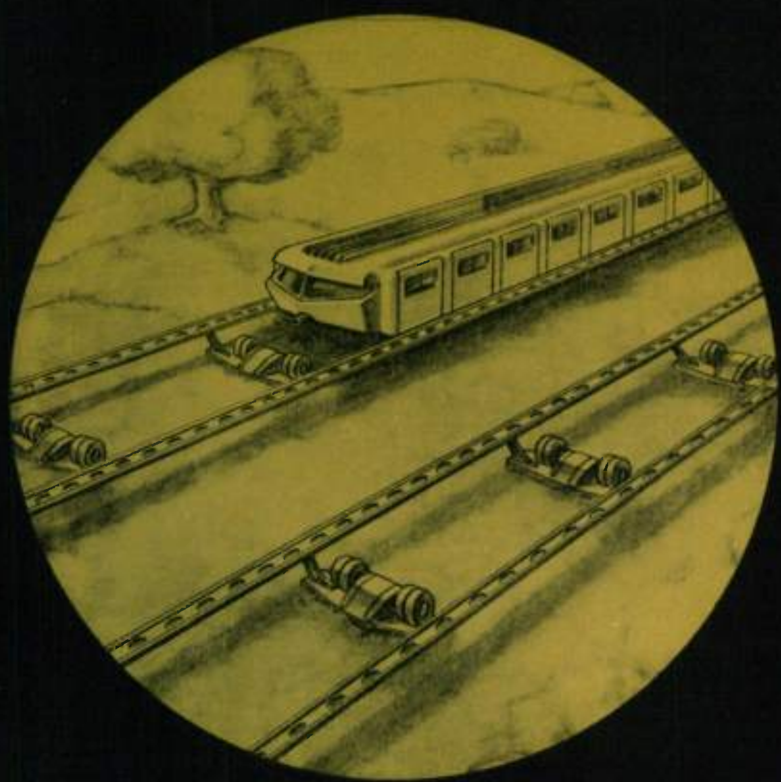

Fig. 1

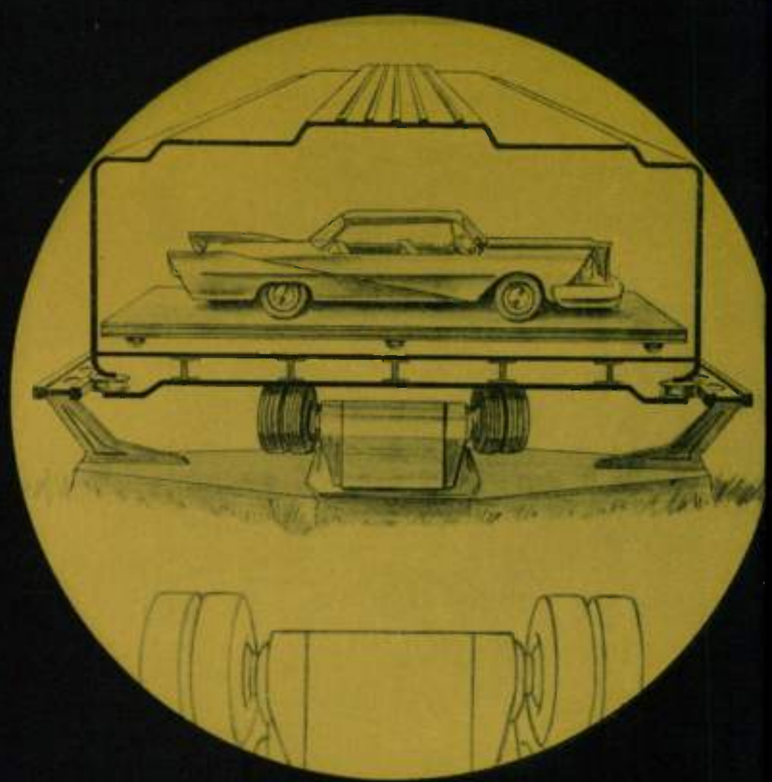

Fig. 2

individually powered rollers, receiving electric energy from neighboring interconnected electric utility systems. This "Roller Road" will provide the highway surface, accelerate the carriers, keep them moving once accelerated, and provide braking power at the proper locations.

The carriers are stopped at fixed stations where automobiles are loaded and unloaded automatically by mechanical means to secure uniform carrier loading in the minimum of time.

The attractive feature of this new propulsion system is the ability to design into it the required degree of reliability.

Several features of the proposed Roller-Road system are worth emphasizing: (1) It can handle conventional toll road traffic at twice the speed; (2) its capacity can be increased with little expense by increasing the number of carriers connected together as an operating unit; (3) it can carry automobiles, passengers, and freight at average air speeds for distances under 500 miles when ground time is included; (4) it has the possible flexibility of any two-track rail system because sidings, turnouts, etc., can be installed wherever needed; (5) it is an all-weather route, invulnerable to delays from fog, ice, sleet or snow; and (6) the same principles can be used to produce either a long-distance route or a rapid transit system for large urban communities.

Fig. 1 The Roller-Road concept consists of carriers propelled on powered rollers.

Fig. 2 Automobiles are carried on movable platforms, which are loaded and unloaded automatically at stations.

Fig. 3 A Roller-Road station.

Fig. 4 Horsepower requirements for Roller Road.

the automobile carriers

Each carrier in the proposed system is envisioned to be about 110 feet long, 20 feet wide, and 7 feet high, exclusive of the under frame. A carrier of this size could handle 10 automobiles and also contain a lounge, with rest room facilities.

Doors are provided on each side to load and unload automobiles. To avoid complicated door mechanisms, which could be a source of major train delays, the entrance and exit doors are automatically opened and closed by external means at the stations. Also, the automobiles are automatically loaded and unloaded by external means at these stations.

The carriers are constructed so that they can be coupled to form strings of carriers of any length, affording flexibility to meet varying traffic conditions. Normally, the carriers probably would be operated in strings of three to ten units. Actually, the only limit to the number of carriers that could be coupled together would be the length of the loading and unloading facilities at stations.

The estimated weight of a single carrier, including ten automobiles, is 50 tons.

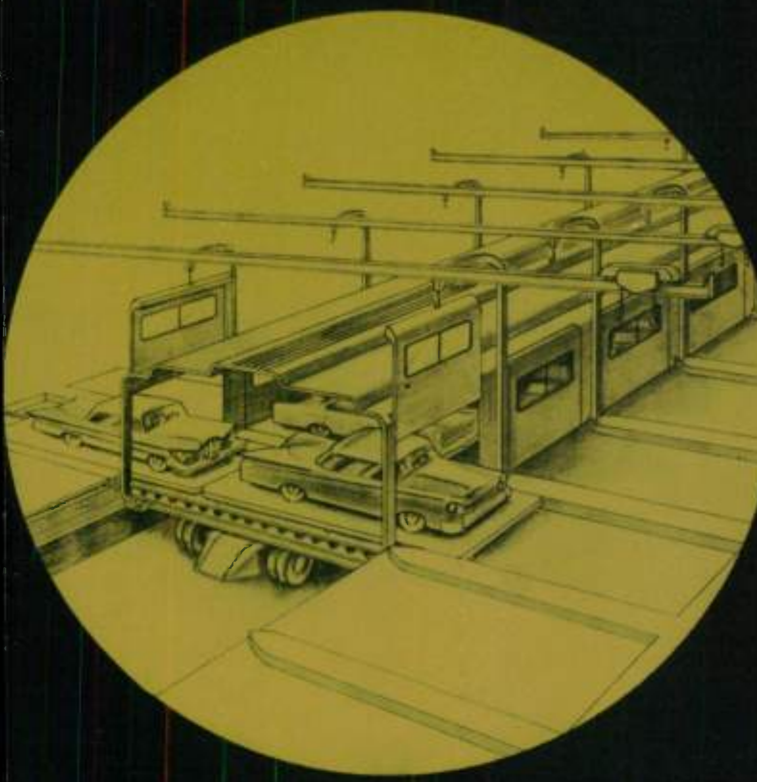

Fig. 3

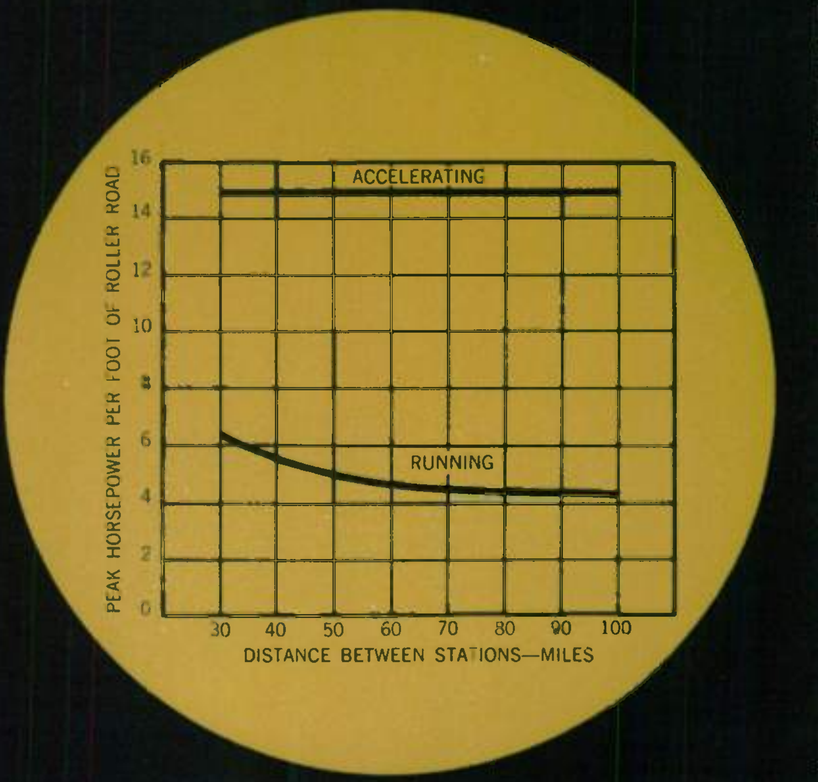

Fig. 4

roller-propulsion system

The source of motive power proposed for the Roller-Road system has already gained wide use in industry. The carriers would be both supported and propelled by a series of rubber-tired rollers. The rollers also must be capable of both starting and stopping the carriers in an emergency any place along the route. The reliability of this system should be exceptionally high since a failure of any roller or any group of rollers will not impair operation. Complicated mobile equipment, which would cause less reliable operation, is eliminated.

A guide rail is provided to steer the carriers along the rollers. The guiding wheels, operating against the guide rails, are the only rotating devices on the carriers. Their primary function is to guide, although they could be partial weight-carrying devices.

The right-of-way for the Roller-Road would be approximately 60 feet, 20 feet each for a roller section in both directions, and 20 feet for a central servicing space.

The exact design of the rollers will depend to a considerable extent upon the spacing selected. The maximum roller spacing is fixed by the length of the carriers, since it is essential for stability that a minimum of three rollers should support a single carrier unit at all times.

From the standpoint of tire and axle designs, a shorter spacing might be desirable for technical or economic reasons. From an electrical standpoint, any choice of spacing can be accommodated.

The drive package for each roller consists of a three-phase induction motor, a torque converter, a brake and a reduction gear. Squirrel-cage induction motors are used because they are simple, reliable, and a relatively inexpensive form of electric motor. The torque converter will permit the rollers to start the carriers at any place without unduly increasing the driving motor capacity.

Also, a mechanical brake is included on each roller so that the carriers can be stopped in an emergency. This brake will be spring applied, electrically released, thus always fail safe.

In the accelerating or braking zones adjacent to each station, motor capacity required per foot of highway is roughly 2½ times that required in the running zones. The motors and brakes on each set of rollers in these zones can be increased in capacity, or the roller spacing can be reduced. When carriers are accelerated or decelerated in these zones, the roller speed will vary from zero to the equivalent of 130–150 mph as the carriers progress from standstill to full speed, or vice-versa during deceleration. To better tailor the rollers to these conditions, the gear ratio between the power package and the axle would be changed on the different rollers in steps from the beginning to the end of the accelerating and decelerating zones.

Light and heat can be provided in the carrier by arranging the guide rollers to drive a small generator, to operate in conjunction with a battery. Thus, a failure of the carrier electrical system would not affect system reliability.

Table 1 OPERATING STATISTICS 1000 MILE HIGHWAY OPERATING AT 100 PERCENT CAPACITY

Carriers Dispatched Per Hour (Each Lane)	200
Carriers Dispatched 24 Hours (Both Lanes)	9 600
Carrier Miles Per Day (Both Lanes)	9 600 000
Transportation Produced (Both Lanes) (24 Hours)	
Automobile Miles	96 000 000
Ton Miles	144 000 000
Power Requirements—String of 10 Carriers	
Average Power to Accelerate	15 000 HP Peak
Average Power to Stop (Absorbed Power)	15 000 HP Peak
Average Power Per Train—Running	5–6 000 HP Peak
Average Electrical Load (1000 Mile Highway)	1 680 000 KW

automatic loading and unloading stations

The problem of loading and unloading is one of keeping the stop time to a minimum. A loading and unloading time of one minute is a logical goal. Should this goal be attained, no difficulty should be experienced in maintaining average speeds over the system of 120 mph, with stations as close as 30 miles apart or dispatching carriers or strings of carriers on three-minute intervals.

A plan for an automatic loading and unloading station is shown in Fig. 3. In this arrangement, the automobile is driven into place on a dolly before carrier arrival. Signal lights can indicate available locations for loading. The signaling function can be provided by an overall computer control. Once the automobile is on the dolly, all further operations are performed automatically.

When the carriers stop, automatic devices that are a component of the station loading apparatus raise the proper doors on each side of the carriers. A mechanical ram or similar device pushes the dolly onto the carrier; the corresponding dolly already on the carrier is pushed off. When this operation is completed, the doors are closed and the carriers proceed. A crane or similar device carries the discharged dolly from which the automobile has been removed back to its original position, ready for loading on the next carrier that stops.

computer control

A Roller-Road system of this kind will require a computer for its control and to program its operation. Basically, this control must perform the following functions:

1. Dispatch strings of carriers at the proper intervals, and maintain the proper intervals throughout the highway.
2. Provide protection against rear-end collisions, should any string of carriers be stopped.
3. Control the automatic loading and unloading at the stations.

Since all propulsion power units are stationary rather than mobile, the control and information circuits are considerably simplified. Furthermore, the induction motors do not require complicated control devices. As used in this scheme, the rollers are either "on" or "off" without any complicated speed-control devices, thereby lending themselves to a digital-type control.

Ample devices are available to initiate information to the computer. One device that might be used extensively would be proximity limit switches. Or another device is radar. In addition, electronic circuits, such as those being considered for automatic automobile control, might form a part of the

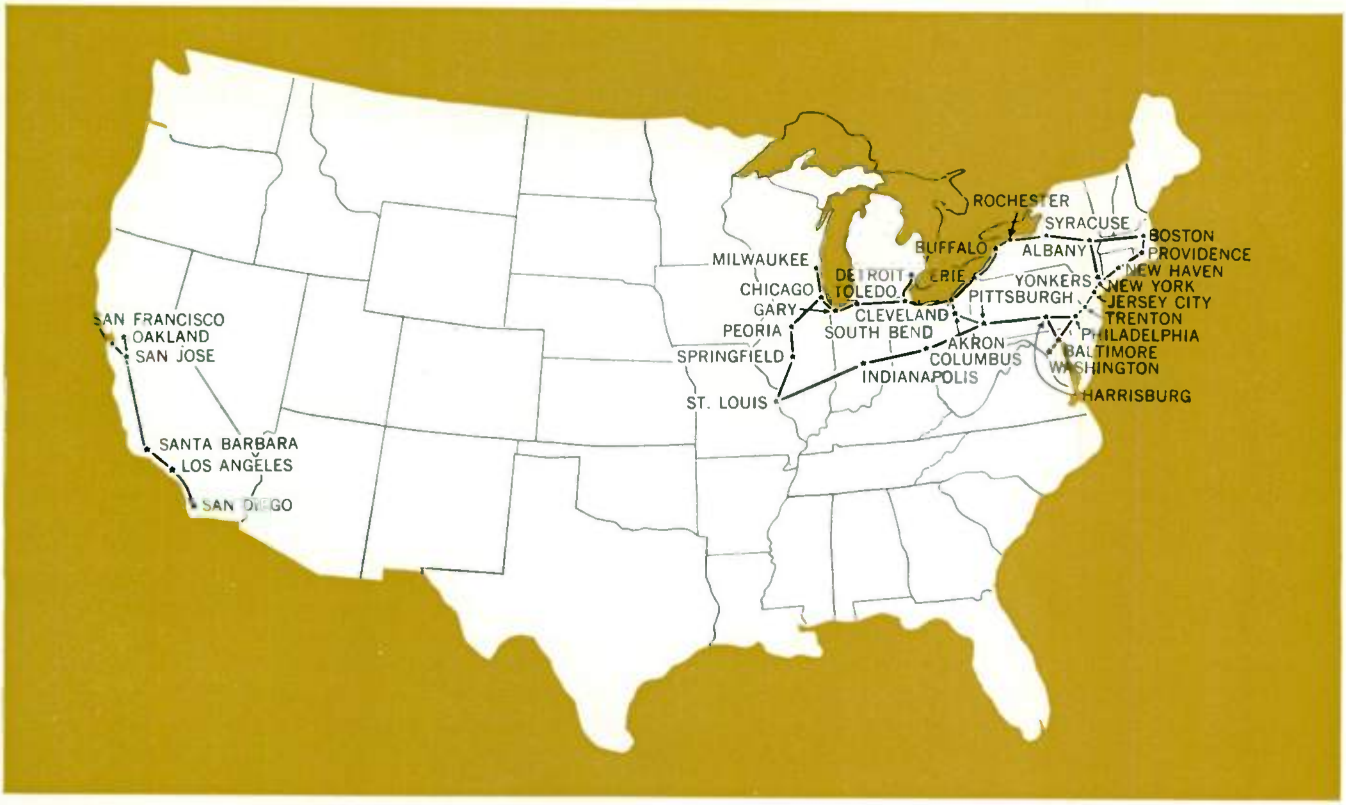

Fig. 5 Proposed routes for Roller-Road systems.

system. These examples are cited to indicate that means of transmitting information to and receiving signals from the computer are available today.

No problems can be foreseen in the control of this highway system that cannot be solved.

power requirements

Due to the large installed horsepower required for the Roller Road, this concept would be applicable only for transportation systems designed to handle very dense traffic.

The peak horsepower requirements are shown in Table I. The peak rating of the motors will be about 50 000 hp per route mile of highway. This would appear to be an exorbitant figure, but upon further analysis, it can be justified.

The roller drive motors need operate at peak load only when a string of carriers pass; at other times, they run at normal speed but at no load. It is estimated that the motors would be operating at peak load only about 3 percent of the time. Therefore, the motors can be designed on a maximum torque basis rather than a continuous-current basis. They could be severely overloaded for short intervals, and therefore could be much smaller physically than normally required for a given horsepower rating.

Furthermore, removing all propulsion power from the carriers reduces their weight by at least 50 percent, thereby greatly reducing the load to be driven.

And finally, induction motors are used for propulsion power rather than commutator motors, the standard for most transportation systems. This also greatly reduces cost. When these factors are evaluated against conventional propulsion systems, the cost and efficiency of the roller system are more in reason.

intercity and commuting service

The map shown in Fig. 5 indicates locations where roller-road systems might be justified. The routes shown total about 3000 miles through territory that contains about 50 percent of our cities over 150 000 in population, and through states where 50 percent of all automobiles are registered. About 12 000 miles of Roller Road could serve all major transcontinental trade routes.

The Roller-Road concept also contains the essential ingredients of a good rapid transit commuting system. High acceleration rates, which are necessary to attain fast schedules where stops are frequent, would appear to be limited only by passenger comfort.

While the riding qualities of the roller system have yet to be proven, cars that do not carry propulsion equipment usually can provide a comfortable ride; this advantage should apply to the carriers used on the Roller-Road system. It would also seem that the Roller-Road system should be well adapted to providing frequent service at low cost because of the lower maintenance costs and lower power consumption brought about by the elimination of driving equipment from the cars.

Although there are many technical problems to be solved in finalizing this new concept, none appear incapable of solution. Both the electrical and mechanical features of this proposed concept should be within the know-how of our present technology.

MOLECULAR ELECTRONICS... Electronic Structures Instead of Circuits Development of functional blocks that can do the work of many individual electronic components is the first step in the new science of molecular electronics.

S. W. HERWALD, S. J. ANGELLO
Research Laboratories
Westinghouse Electric Corporation
Pittsburgh, Pennsylvania

The first great strides in electronics came when scientists learned to control electron flow with a number of fundamental "mechanical" structures. Vacuum tubes, coils, capacitors, and resistors were the original building blocks of electronic circuitry. A circuit was developed by arranging these components in some ordered fashion.

Development of the transistor established a turning point in the design of electronic circuitry. It revolutionized component and circuit design, but, more important, it has now put science on the threshold of an even more significant step—the control of energy flow through arrangements in material.

This new science answers to several names—molecular engineering, molecular electronics, and solid circuits are a few of the terms now in use.

A completely new approach is required for designing molecular "circuitry," if indeed it can even be called circuitry. The primary goal is to arrange functions within solid blocks of material, which will perform a circuit function more complicated than that performed by individual electronic components. This idea is best described by considering some very simple solid structures, and then proceeding to more complicated examples. Most of the work so far has centered upon semiconductors, but this is not a necessary restriction. This condition is a reflection of the fact that semiconductor technology is further advanced than other pertinent solid-state device technologies.

simple RC circuits

The functional block scheme can be illustrated by showing how resistors and capacitors can be integrated into a block of P-type silicon semiconductor of high resistivity ($\backsim$200 ohm-cm). Such a P-type block with a thin skin of N-type, low resistivity silicon obtained by diffusing antimony into the block is shown in Fig. 2. This procedure is a common one for the manufacture of semiconductor devices. The thin slot cut through the skin isolates the region to which leads have been attached, because the substrate-to-skin resistivity ratio is greater than 100. A range of resistors can be fabricated using this principle by varying the thickness, length, and width of the N-type skin. A resistance range from a few tens of ohms to approximately one megohm can be obtained. Ten percent tolerance can be achieved if trial and error resistance trimming is permitted. The temperature coefficient of resistance follows that for the high carrier density diffused skin, which can range from slightly negative, through zero, to slightly positive. Some advantages of this configuration are derived from the intimate connection of the resistor film to the substrate. Silicon is a good heat conductor, and the thermal drop between resistor and substrate is low. Several resistors located on the same substrate will maintain nearly the same temperature as temperature varies over the operating range. Careful designs and appropriate circuits can take advantage of the common temperature to introduce internal compensations for stability. Two disadvantages are that precision resistors have not been made at this stage of development, and very low temperature coefficients have not yet been achieved.

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The attachment of metallic areas on each side of the diffused junction (Fig. 3a) results in a capacitor, with the equivalent circuit shown in the figure. The value of capacitance is not constant, but varies with applied voltage as shown in Fib. 3b; resistance across the capacitance also varies as shown in Fig. 3c. With a few volts positive on the N-region, the resistance is in the megohm range so that a rather good capacitor can be obtained under this operating condition. Capacity values are small, being of the order of 0.005 mfd/cm^2. Larger values in the 1 mfd/cm^2 range are more appropriately obtained by two-dimensional techniques, such as an anodized tantalum film. The variation of capacitance with voltage can be useful or a handicap depending upon the application.

An interesting extension of the capacitance block is obtained by combining the configurations of Fig. 2 and 3a. Such a configuration, (Fig. 4) acts as a phase-shifting network and low-pass filter. In this application, a deviation from discrete components results because the resistances and capacitances are distributed throughout the block.

Another extension is illustrated in Fig. 5. A resistor, consisting of part of the block, is inserted in series with the metallic condenser plate of Fig. 4. The result is a functional block that is frequency selective, similar to a bridged-T circuit. Such a narrow frequency band is passed that the term "notch" filter is given to this block. This functional block replaces an array of at least nine resistors and capacitors. Consequently, a minimum number of required leads emanate from the block.

unipolar transistor blocks

Another type of functional block that can be fabricated from an N-P junction depends upon the properties of the unipolar transistor (Fig. 6). A region of the order of 10^{-4} cm thick around an N-P junction is depleted of current carriers. When N(+) − P(−) bias is applied, the depletion layer widens and becomes a higher resistance, the high reverse resistance of an N-P junction diode. A cut in the

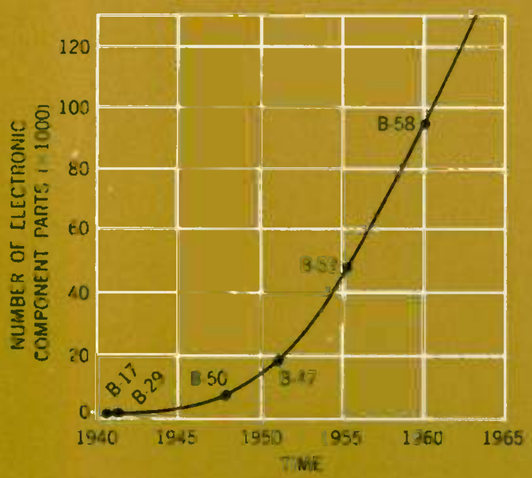

Fig. 1 Trend of complexity of electronics in Air Force weapon systems.

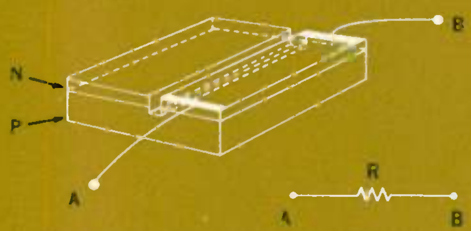

Fig. 2 Silicon block with thin diffused layer.

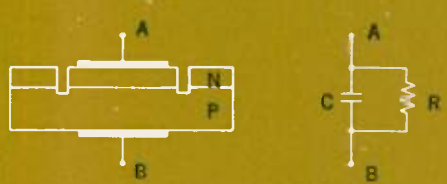

Fig. 3a Diffused silicon block with metallic connections.

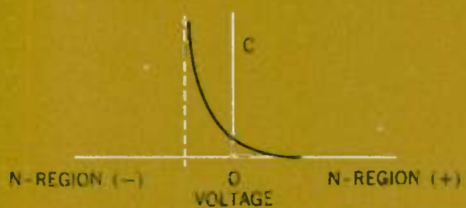

Fig. 3b Capacitance versus voltage for an N-P junction.

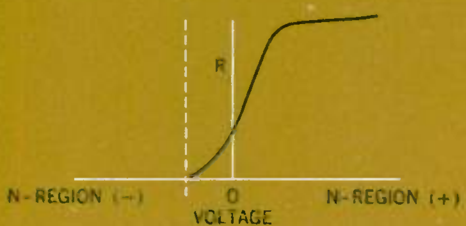

Fig. 3c Leakage resistance versus voltage for an N-P junction.

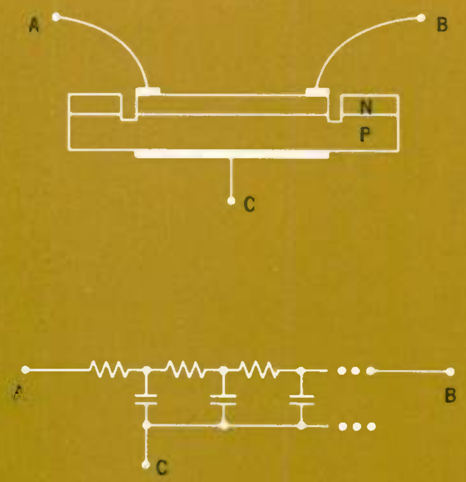

Fig. 4 Phase-shifting network with distributed resistance and capacitance.

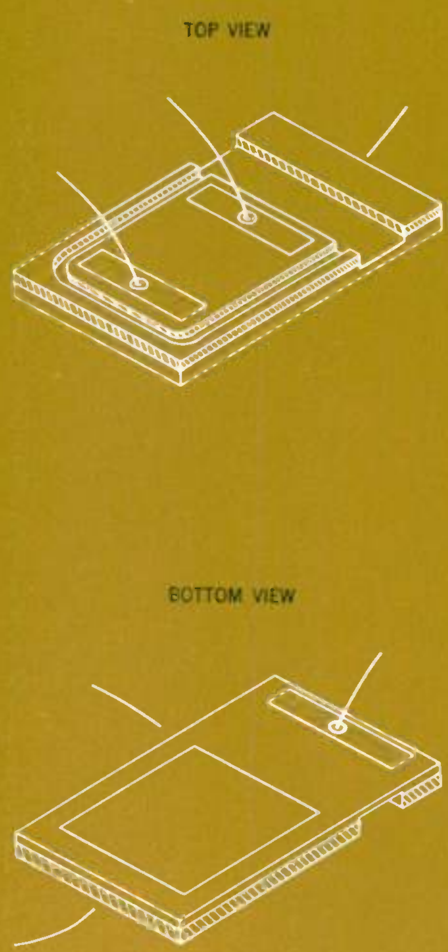

Fig. 5 Notch filter functional block.

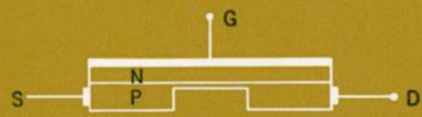

Fig. 6 Basic unipolar transistor configuration.

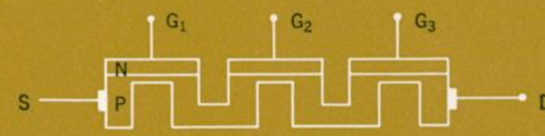

Fig. 7 Example of unipolar transistor logic gate.

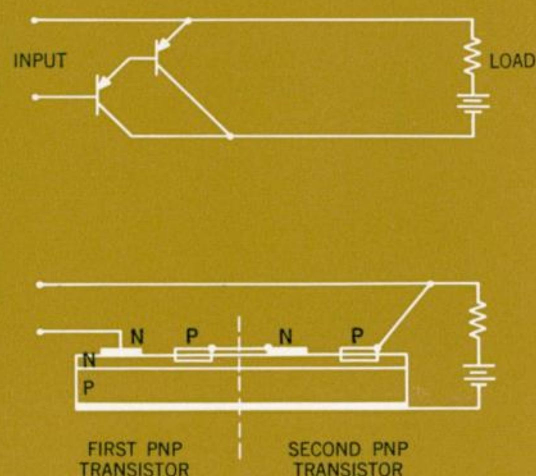

Fig. 8 Darlington connection of transistors in a function block.

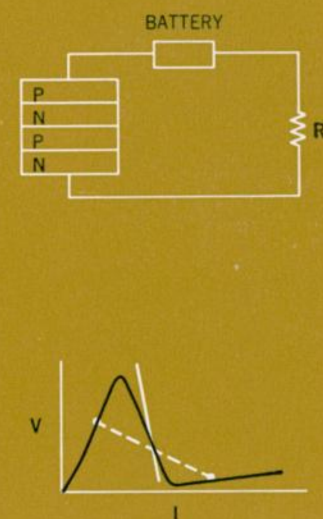

Fig. 9 Four-layer diode oscillator.

P-layer has been made to extend close to the depletion layer region. This cut is just deep enough so that under zero bias, *S-D* resistance is relatively low. Thus, a bias on the N-P junction acts as a gate to open and close the channel between *S* and *D*.

Some very complex and useful block functions can be developed using the principle of the unipolar transistor. A direct-coupled gate is depicted in Fig. 7. The top slots through the N-layer into the P-region form resistors between the unipolar transistors. A circuit exists between *S* and *D* if none of the gates are biased; no circuit exists if G_1, or G_2, or G_3 is biased to close the gate.

This discussion has by no means exhausted the possibilities for functional devices to be constructed in an N-P silicon block. However, real progress in development of functional electronic blocks depends strongly upon invention of new configurations and construction techniques.

It is clear that one may proceed to develop more complicated functions by adding additional layers to the silicon block. Two layers can provide resistors, capacitors, N-P diodes, unipolar transistors, and combinations thereof; three layers will introduce the transistor with many varieties possible according to the construction technique. Of course, all of the functions possible with two layers are also available with three. Adding a fourth layer introduces four-layer switching diodes, Trinistors, trigistors, and other varieties of switches with or without control electrodes.

transistor block

A basic circuit that may be designed to serve either as a low-level audio, a high-level audio, or a video amplifier is the Darlington connection shown in Fig. 8. The function block shown below the circuit can be constructed as follows: The common collector connections are provided by the metal electrode located on the P-region. The input base connection is a metal, which forms an N-connection with the N-region. A P-alloy junction to the N-region completes the first PNP transistor. The second transistor is constructed similarly. Interconnection is effected by allowing the P-emitter of the first transistor to fuse at one point to the N-base of the second transistor. This illustration is over-simplified in that temperature compensation resistors and coupling capacitors are omitted. These elements may be included to result in more stable operation with respect to temperature variations.

four-layer switch block

In the examples, the types of function blocks have had a close analogy with the circuit being replaced. Only a slight deviation from this was noted in the case of distributed RC blocks. It is possible to construct blocks that perform a function, but have no physical resemblance to the circuit being replaced. A four-layer diode in series with a resistor is shown in Fig. 9. Under the sketch is a volt-ampere characteristic for this circuit. If the load resistance is that shown by the dotted line, the switch will have two stable states, one at high resistance and one at low resistance. A higher load resistance, such as R, will permit no stable state and the circuit will oscillate with a saw-tooth output waveform. Because the load line may be shifted on the characteristic by varying the applied voltage, the relaxation time or output frequency is a function of voltage. This behavior has led to the suggestion that this type of block could be used as an analog-to-digital converter.

future development of the functional electronic block concept

The original studies of function blocks were aimed primarily at reducing the number of interconnections to provide electronic circuits of high reliability and stability against shock. The nature of the concept, however, has led directly to the miniaturization of circuits as shown. Future progress in functional blocks is linked to progress in at least three areas. These are: (1) Invention of block configurations, (2) development of solid-state device processing techniques, and (3) development of new materials.

invention

Analog blocks that follow circuit configurations are possible and useful; however, the aim of simplification will not be furthered in this manner. Not only new types of block configurations are needed, but also enhanced usefulness of blocks already known is desirable. Interactions among components on a block can be troublesome, but ingenuity can turn some of these interactions to advantage.

Perhaps one of the most serious limitations of miniaturization is the problem of heat dissipation. Better designs of blocks to perform a given function with lower power dissipation is one approach. Better schemes to remove heat is another. Many facets of design enter into the power dissipation problem—the tolerance of resistors, for example. The looser the tolerance prescribed for in a given circuit, the higher one can expect the power dissipation to be. The ideal solution is to design circuits that can tolerate reasonable spreads in component characteristics and at the same time operate at low power.

More circuit investigation in the general area of RC active networks is needed if the full potential for two-dimensional miniaturization is to be realized. Circuits containing inductances are usually large and must be eliminated insofar as possible.

Another aspect of invention is the extension of functional blocks to other types than semiconductor substrates. Magnetic films, titanate substrates, ferroelectric materials, electroluminescent cells, and Hall generators are fruitful possibilities for the construction of function blocks.

techniques

The realization of a function block, once designed, depends upon the ability to fabricate junctions, slots, holes, and the like needed to perform the function. Another important aspect is that one should aim not only to make one good block, but to make a number with acceptable economical yield. The present state of the art does not enable the required tolerances to be maintained with an economical yield. More development work is needed in the techniques of masking, etching, electron beam cutting, and other block-shaping techniques.

materials

The materials problem centers on at least two aspects: New semiconductor materials with new properties are needed to make new functions possible; and improved techniques for handling present materials are required.

Two recent advances in materials modification show the way to major future advances in function block development: One is the growth of germanium and silicon crystals in dendrite form. In semiconductor manufacturing practice it is necessary to cut thin wafers from large silicon boules. The process is wasteful of material because the saw is usually nearly the same thickness as the slice. In addition, the surface layers of the wafer must be removed by etching to eliminate defects introduced by the cutting. Dendrites are grown from the melt with optically flat surfaces. Proper control will result in ribbons of the width and thickness required for device fabrication. Since the surface of the dendrite as it is pulled is clean and undamaged, further processing can begin without intermediate surface preparations.

The second advance is the growth of epitaxial layers of silicon on a silicon substrate. By this means, the multiple junction layers required by function block design can be provided. The functional blocks described had two, three, and four layers of various conductivity types. These layers were provided by crystal growing and impurity diffusion techniques.

conclusion

These developments in molecular electronics are the beginnings of profound changes taking place in electronics. The trend will be away from individual component circuits and toward the integration of circuit functions into functional blocks. The ever-increasing need for reliability will force the development of more reliable assemblies. Functional electronic blocks and two-dimensional techniques in combination will fill this need.

Size and weight are becoming more important in a wider and wider range of applications. Again, integration of components into functional blocks must be carried out to achieve this reduction.

The boundaries between materials and devices and between devices and circuits are being removed, and we shall see an integration of disciplines in the future development of molecular electronics.

FEEDWATER HEATER CONTRIBUTION TO EFFICIENCY OF CENTRAL STATIONS The feedwater heater, used in the regenerative steam cycle, contributes significantly to central station efficiency.

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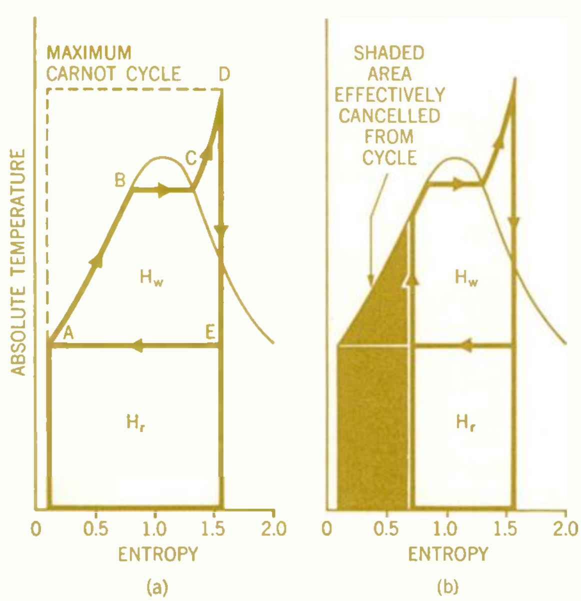
The overall heat rate of the large central station has improved during the past thirty years from about 15 000 Btu/kwhr to less than 8100 Btu/kwhr for the newest, most efficient station. Many people have contributed to this improvement—metallurgists, scientists, engineers, businessmen, and bankers have all had a role. Today, only about four times as much fuel is used to produce an eightfold increase in electrical energy.

Two fundamental advances in the steam power station have been responsible for the reduction in the heat energy required to produce a unit of electrical energy: First, research and metallurgical improvements have permitted an increase in steam pressure and temperature, including the use of reheat, at which the steam cycle can be operated; the second fundamental advance has been the universal use of the regenerative cycle. In its simplest conception, the regenerative cycle heats boiler feedwater by extracting steam from the turbine at increasing pressure levels to heat the feedwater flowing from the condenser to the boiler. Broadly, the regenerative steam power system converts heat into electrical energy and rejects as little heat out the stack or in the circulating water as the laws of nature permit, within the economic limitations of such items as fuel, equipment, maintenance, and building costs.

feedwater heater and the regenerative cycle

The regenerative steam cycle is largely dependent upon the feedwater heater, which as auxiliary apparatus, contributes significantly to the improvement in overall station heat rate.

A comparison of heat rates for a simple cycle with no feedwater heaters, a single-heater cycle, and a two-stage feed-heating cycle is shown in Fig. 1. The cycles shown have initial steam conditions of 2400 psia and 1000 degrees F, and an exhaust pressure of 2 inches hg absolute. The calculations are over-simplified since boiler efficiency, turbine efficiency, and generator efficiency are all considered to be unity. The heater also is assumed to heat feedwater to the saturation temperature of the extraction steam, and the drains from the heater are returned to the



REGENERATIVE CYCLE EFFICIENCY

The significance of the regenerative cycle can be shown graphically on the temperature-entropy chart. The chart is a particularly effective method of demonstrating turbine cycles because the area traced on the chart by an ideal cycle (no flow losses or throttling losses) is proportional to work done by the cycle. The cycle with no feedwater heater is shown in (a). Tracing the cycle; from *A* to *B*, pressurized fluid is heated at constant pressure to its boiling point at *B*; *B* to *C*, constant-temperature-pressure phase change from water to steam; *C* to *D*, superheating of saturated steam; *D* to *E*, expansion of steam through turbine; *E* to *A*, steam condenses to water through condenser. If perfect processes are assumed with no losses, the area *Hw* within the cycle represents the work done by the cycle. The area below the cycle, *Hr*, represents energy in the working fluid that cannot be used. The efficiency of the cycle is represented by the ratio of energy developed (*Hw*) to total energy supplied (*Hw* + *Hr*).

The regenerative cycle is shown graphically in (b). Here, the most inefficient water-heating portion of the cycle is effectively canceled out by extracting steam from the turbine for this purpose. Although the total work available from the cycle is reduced, the amount of wasted heat is also reduced, with a net improvement in cycle efficiency. (It will be noted in Fig. 1 that for comparative purposes, the pounds of fluid flow (*w*) has been adjusted to maintain the same total work *Hw*.)

cycle at the feedwater outlet from the heater. Despite these simplifications, the example points out the improvement in efficiency possible with the regenerative cycle (See Box).

The examples also indicate (for the ideal cycle) the change in the amount of steam flowing to the condenser, and therefore, the effect on the condenser size. The change in fuel requirements is also shown. These figures reveal that feedwater flow to the boiler increases with cycle efficiency (larger boiler feed pumps are required) and that the total steam flow to the turbine increases. The figures also show the relative amount of heat converted to electrical energy by steam passing to the condenser and from steam extracted to heat feedwater.

The generalized improvement in cycle efficiency as a function of the number of feedwater heaters and final feedwater temperature is shown in Fig. 2. As would be expected, an eventual diminishing return is clearly apparent.

A large central station unit requires six or seven stages of feedwater heating. For 300 mw and larger, eight and nine stages of feedwater heating have been justified.

feedwater heater operation

The shell-and-tube heat exchanger is most often used for feedwater heaters. Feedwater always passes through the tubes, and the extracted steam is always in the shell. This arrangement is used because feedwater is always at a higher pressure than the extracted steam. Therefore, feedwater can be contained within the tubes and the channel; this design arrangement is economical of material and hence the cost of the heater is minimized.

In most central stations, feedwater is pumped to the steam generator by two pumps operating in series. Condensate is first pumped from the condenser by a condensate pump through heat exchangers and feedwater heaters; in the second step, the boiler feed pump moves the feedwater through additional heaters and heat exchangers to the steam generator.

feedwater heater types

Feedwater heaters can be classified in a number of ways.

Pressure—Under this category, a feedwater heater can be classified as a low-pressure, intermediate pressure, or high-pressure heater.

A *low-pressure* heater is located on the discharge side of the condensate pump. Channel and tube design pressure is dictated by the shutoff head of the condensate pump, i.e., pressure developed by the pump at zero flow. Since condensate pump discharge pressure is only a fraction of boiler feed pump discharge pressure, economical use of material and hence minimum cost can be achieved with low-pressure heaters.

Intermediate-pressure heaters are located on the discharge side of a booster pump. The booster pump is the first of two boiler feed pumps often used in series when steam is generated at extremely high pressure. The discharge pressure developed by this pump is between that produced by the condensate and boiler feed pump. Heaters designed for the booster pump discharge pressure are more economical of materials than those designed for discharge pressure of the final feed pump. An economic study will determine whether costs of the booster pump and system complication can be justified by savings in heater cost.

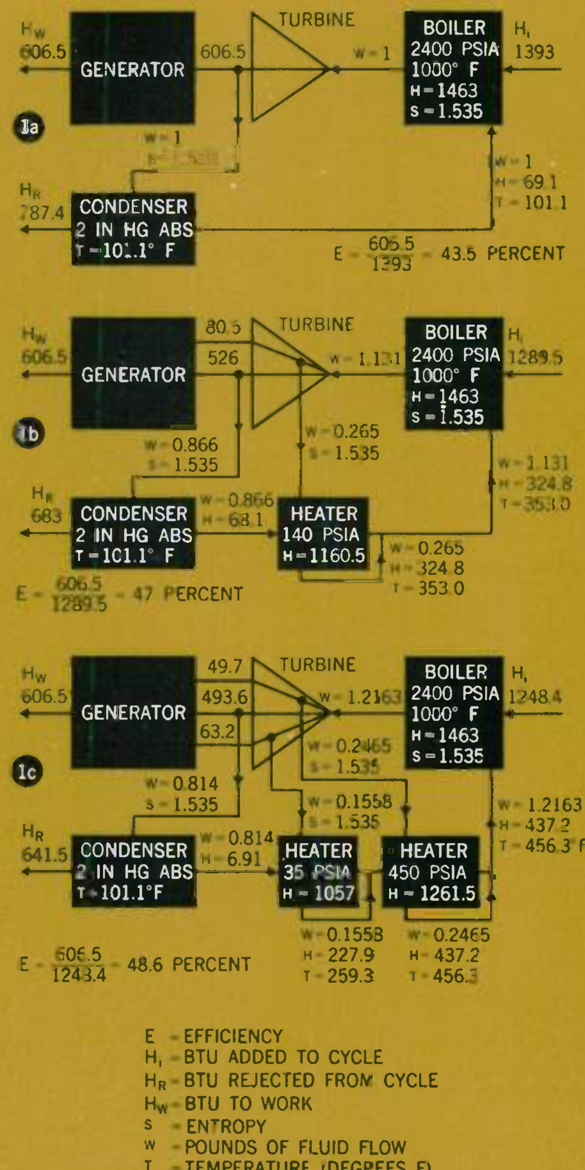


Fig. 1 The improvement in efficiency to be gained through feedwater heating is illustrated in these simplified cycle diagrams: (a) no feedwater heating; (b) one feedwater heater; and (c) two feedwater heaters.

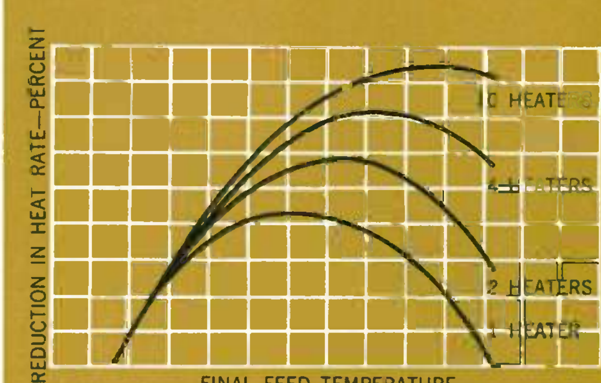


Fig. 2 Typical gains in heat rate through feedwater heating are illustrated.

The *high-pressure* heater is located on the discharge side of the boiler feed pump. The tubes and channel in these heaters are subjected to the highest pressure in the cycle. The temperature of feedwater leaving the last heater is often in excess of 500 degrees F.

Position—Another method of classifying feedwater heaters is by the position of the heater as installed. This position is usually dictated by plant arrangement and piping requirements. Each position has advantages and disadvantages.

A *horizontal* heater has the axis of the tube bundle horizontal. In this arrangement, the flow of steam and condensate accumulated in the shell can be arranged for parallel flow, which is a stable flow pattern. When the heater shell also contains a drain cooler, the static pressure required to maintain flow (the pressure difference between heaters) is at a minimum. Arrangementwise, space is required for tube bundle or shell withdrawal. This requirement limits to some extent the freedom of equipment location. However, with the trend to all-welded heater designs, withdrawal space can be questioned.

The heater is classed as *vertical* when the axis of the tube bundle is vertical. This category can be further divided by the placement of the channel

The heater is *channel-up* when the channel is at the top of the heater. Floor space is not required for removal of tube bundles, but vertical height is needed for removal of the tube bundle or, with the trend to all-welded design, for removal of the complete heater. Internally, the flow of steam and the condensate produced in the shell must to some extent flow counter current. This is an extremely critical flow pattern, which frequently controls shell size, baffle porting, etc. When drain coolers are incorporated, they must be full length of the shell and in many cases only include part of the tubes in the first pass; hence the static pressure required to maintain flow through the drain cooler is equal to the length of the shell plus the pressure drop through the drain cooler. The effectiveness of the drain cooler and heater at partial load may be impaired with a resulting loss in station economy. (The drain cooler in many cases has been bypassed at partial load, further reducing station economy.)

The heater is *channel-down* when the channel is at the bottom of the heater. As with the vertical heater channel-up, floor space is not required for removal of shell, but vertical height is required for the removal of the shell or the complete heater. This arrangement usually decreases the amount of feedwater piping required. Internally, the flow of steam and condensate produced within the shell is to a large extent counterflow. Again, this critical flow pattern usually dictates shell size and baffle porting. When drain coolers are incorporated in the shell, they frequently become two pass on the drains side to achieve the desired approach temperature and to prevent flashing of the drains inside the drain cooler. (The drain temperature must at all times be below the saturation temperature, which of course, decreases due to friction loss and static elevation as the drains flow upward in the drain cooler.) Again, it may be necessary under some load conditions to bypass the drains cooler with a loss in station economy.

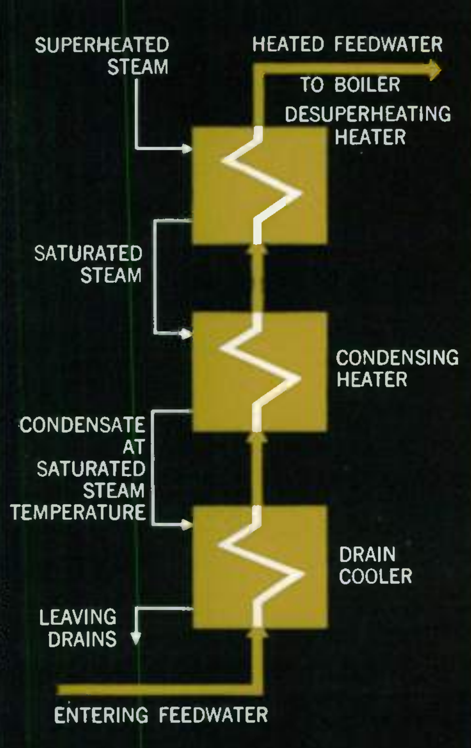


Fig. 3

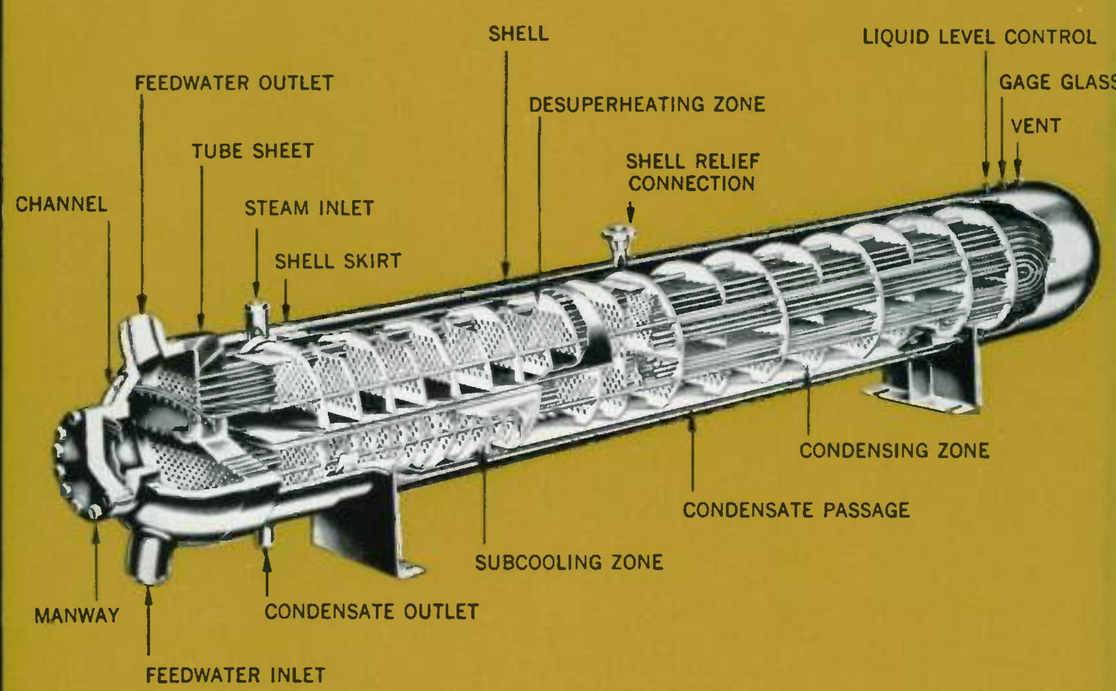


Fig. 4

Operation—Finally, feedwater heaters can be classified by the nature of the heat exchange being performed. Usual classifications are:

Condensing—Extraction steam condenses on the outside of the tubes and leaves the heater as a liquid at the saturation temperature corresponding to the pressure in the heater shell.

Drain Cooler—The heater takes condensate from a condensing heater and cools these drains by heating the feedwater before it enters the condensing heater.

Desuperheating—When extraction steam contains considerable superheat, this heater removes the heat of superheat by heating the feedwater leaving the condensing heater before the steam enters the condensing heater. The functional relationship between the three types of heat exchange is shown in Fig. 3. Feedwater heaters can be different combinations of these three in a single shell, such as: desuperheating—condensing; desuperheating—condensing—drain cooling; or condensing—drain cooling.

design standards

Over the years, design standards have been established for temperature differences between the heating fluid and the feedwater. Like most standards, they are violated when an economic gain can be realized. The conventional standards are approximately as follows:

Drain Cooler Approach—For integral drain coolers, the temperature difference between the leaving drains and the entering feedwater (Fig. 3) is never closer than 10 degrees F; in many cases, 15 or 20 degrees is all that can be economically justified. Two factors dictate the 10-degree minimum drain cooler approach in integral coolers: First, closer approaches require an increase in cooler surface, which cannot be justified economically; and second, the heat transfer into the drain cooler through the enveloping baffle limits the degree of drains cooling.

Terminal Temperature Difference—Condensing heaters are generally designed for a terminal temperature difference—temperature difference between condensate, which is at saturated steam temperature, and leaving feedwater—of 5 degrees F. A lower TTD (feedwater heated closer to the saturated steam temperature in the shell) may sometimes be justified economically. However, a condensing heater is never designed for a TTD of less than 2 degrees F.

Feedwater Temperature from Desuperheating Heaters—Desuperheating heaters are designed to heat the feedwater to a higher temperature than is possible in a condensing heater. Desuperheating heaters, or more often desuperheating sections in heaters, usually heat the feedwater to the shell-side saturated steam temperature or above it by 2 or 3 degrees F. There are cases where the feedwater has been heated 7 degrees above the temperature of the extraction pressure by utilizing the superheat in the extraction steam. The maximum temperature to which the feedwater is heated depends on two factors; thermally, by the amount of heat of superheat in the steam and the relation between the quantity of extracted steam and the amount of feedwater, and by the economics of the station.

The various designs discussed are used when they can economically be justified to approach the theoretical ex-

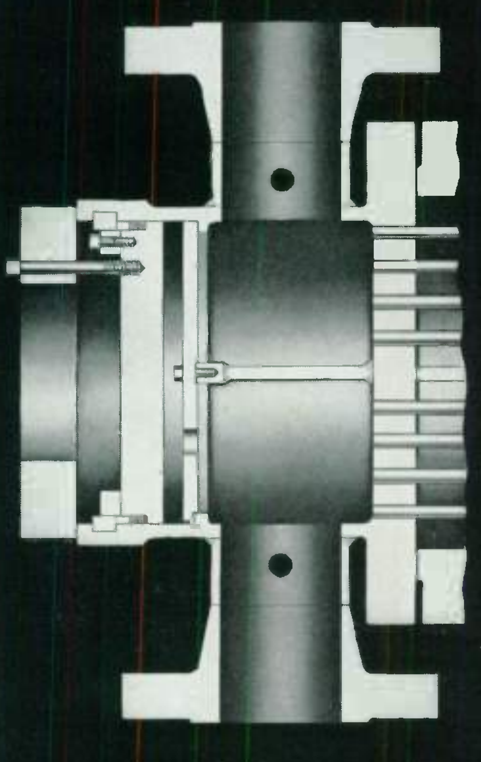


Fig. 5

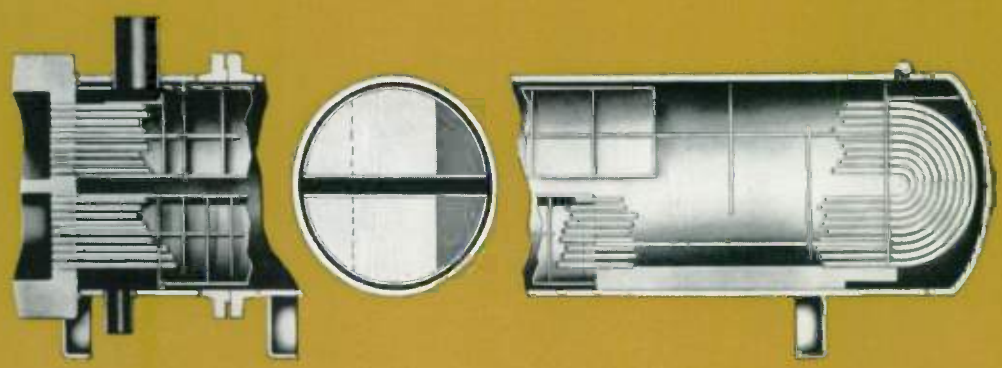


Fig. 6

Fig. 3 Functional diagram of three types of heat exchange. All of these methods can be incorporated into a single feedwater heater shell.

Fig. 4 Cutaway drawing of a high-pressure desuperheating, condensing, and drain-cooling horizontal heater.

Fig. 5 Cutaway drawing of a pressure-sealed cover.

Fig. 6 In this horizontal desuperheating, condensing, and drain-cooling heater, the desuperheating section is built as a "shell within a shell" to confine the high-temperature steam to this section.

amples given in Figs. 1b and 1c. For example (Fig. 1c), the first heater (35 psia shell pressure) assumes 0 degrees TTD and either pumping the drains forward or zero degrees approach temperature in drain cooler. In a practical application with a drain cooler approach of 10 degrees F, the drains would be cascaded to the condenser at 111.1 degrees F and an additional 10 Btu per pound of drains would be rejected by the condenser to the circulating water. Furthermore, the temperature of the feedwater leaving this heater assuming a 5 degree TTD would be 254.3 degrees F and therefore less steam would be extracted to the heater shell. (Note: steam entering the shell is wet for the conditions assumed.)

Also (still referring to Fig. 1c), the second heater (450 psia shell pressure) assumes a 0 degrees TTD, and either pumping forward or drain cooler with 0 degrees approach. The steam entering this heater is somewhat superheated, so that the assumption of 0 degrees TTD may be justified. However, the feedwater would be entering this heater 5 degrees colder than assumed on the diagram. The drains from this heater would normally be flashed to the 35 psia heater after passing through a 10 degrees F approach drain cooler. Both of these factors would require more steam to be extracted for the heater than the diagram indicates.

The overall effect on cycle efficiency would be a degradation due to incomplete transfer of heat caused by requirement of TTD and approach TD to satisfy the law of heat transfer, which requires a finite difference in temperature before there can be an exchange of heat between the hot and cold body.

horizontal feedwater heater design

The mechanical design of a high-pressure, horizontal, desuperheating, condensing and drain-cooling feedwater heater is shown in Fig. 4. In this advanced design, the extraction steam line and the drain line are welded to the shell; the shell, channel, and the tubes are welded to the tube sheet; and the feedwater lines are welded to the channel.

The trend has been toward this all-welded design for several years. First, the channel was welded to the tube sheet or forged integrally with it. However, a pressure-sealed cover (various designs) was used and access (through the cover opening) to all the tube ends was provided. One of these pressure-sealed covers is shown in Fig. 5. Until the welding of tubes to tube sheets was perfected, tubes were roller expanded into the tube sheet. When it was necessary to reroll tubes, access for the rolling equipment directly in front of the tube end made a design of this type desirable. The pressure sealing design was attractive since it eliminated gasketed flanges and pressure-carrying bolts.

Prior to the 1940's, the shell joint to the tube sheet was flanged and bolted. However, at this time, the extension of the steam cycle to higher pressures and temperatures and further extension of the cycle to turbine inter-stage reheat was accelerated. Pressures and temperatures in the extraction lines and heater desuperheating sections were extended far beyond previous experience. These shell joints in some cases leaked, especially during changes in load, i.e., under transient conditions.

Many types of joint facings, gaskets, etc., were explored in an attempt to retain the flanged joint. One successful solution, as shown on Fig. 6, was to build the desuperheating section of the heater as a shell within a shell and confine the high-temperature steam to this desuperheating section. A shell skirt section welded to the tube sheet was added and the shell flange removed from the tube sheet. The steam inlet was made an integral part of the shell skirt section. Heating and cooling of the shell flange occurred only by conduction from the steam inlet through the shell material. Thus, the effect on the flange of rapid transients in the steam temperature was drastically reduced.

However, flanged joints require maintenance and since a large portion of the tubes are enclosed by the desuperheating and drain cooling enveloping baffles, the need for the shell flanged joint was reconsidered and, in most cases, has been eliminated, by welding the shell to the shell skirt, as shown in Fig. 4.

Apart from the conditions described above, both the desuperheating and subcooling sections must have the tubes passing through these sections segregated from the tubes in the condensing sections if these tube surfaces are to perform the intended function. The feedwater inside the tubes flows, first through the drain cooler, then through the condensing section, and finally through the desuperheating section.

A desuperheating section must be designed so that the heat transfer is from the superheated steam to a dry tube, and through the tube wall to the feedwater. Although the heat transfer rate from a dry gas to a tube is much lower than from a condensing fluid to a tube, the mean temperature difference is normally larger so that the resulting heat flux is greater. A transition point exists at which the heat flux from the gas to the dry tube is equal to the condensing rate times the condensing difference. By keeping the surface dry down to this transition temperature, the enveloping baffle provides the environment in which feedwater temperature can be raised above the steam saturation temperature for the pressure in the shell.

The segregation of tubes under an enveloping baffle with suitable transverse baffles to direct the flow of the drains over the tube surface increases the effectiveness of surface heat transfer in the drain cooler section.

The materials used in the tubes of feedwater heaters have historically been chosen for high conductivity, consistent with strength at operating temperature and cost.

Low-pressure heaters generally are furnished with admiralty metal tubes. High pressure heaters progress through several alloys as pressure and temperature increase, namely, 90-10 cupro-nickel, 80-20 cupro-nickel, 70-30 cupro-nickel, monel, and very recently inconel.

conclusions

The feedwater heater has played a basic role in the improved efficiency of the steam cycle. Heaters can be made for a variety of services or installation arrangements, for fitting economically into the overall plant design. The heater shown in Fig. 4 illustrates the continuing improvements in feedwater heater design to match the evolution of the steam cycle. For example, the hemispherical head on the channel is most economical for containing high pressure, and all-welded construction eliminates the possibility of leakage during temperature or pressure transients.

Westinghouse ENGINEER Mar. 1961

APPARATUS FOR UNDERGROUND RESIDENTIAL SERVICE

Underground distribution systems have not enjoyed widespread use as yet, a major drawback being economics. However, the search for better equipment goes on because of the inherent advantages of underground systems.

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Conventional distribution system practice in residential areas, using pole-mounted distribution transformers, and low-voltage secondary mains and services, has not changed fundamentally in many years. Economics of installation and operation have favored this practice, and the overall performance of such systems has, until recent years, been quite satisfactory. Recently, however, certain shortcomings have become evident, and this has led some utility companies to investigate underground systems as a possible solution.

underground residential distribution systems

Perhaps the most apparent advantage of an underground system is the removal from view of conductors, equipment, and supporting structures. The underground system is free from service outages and accompanying expense due to damage caused by lightning, ice, sleet, snow, rain, and windstorms. The probability of trouble caused by motor vehicles, building fires, and foreign objects coming in contact with the system elements is far less than on overhead systems.

Stated briefly, the advantages of the underground system are: greatly reduced secondary voltage drop, improved appearance, greater safety, fewer service interruptions, lower operating and maintenance costs, and longer life.

A major deterrent to the widespread use of underground systems for residential distribution has been the economics of the situation. The cost of vaults or housings for transformers and of ducts for cables have made these systems uneconomical except in regions of great load density, or where premium rates could be charged. Other disadvantages are the increase in installed transformer capacity resulting from the reduction in load diversity, the increase in cost per kva of transformers due to the small rating of each unit, and a generally more costly process involved in adding new services.

Many types of transformers and transformer housings have been tried with underground systems to find the most economical solution for a given system. Some electric utility companies have used standard pole-type distribution transformers installed in vaults or prefabricated housings, while others have approached the transformer manufacturers for some standardized solution to this portion of the equipment problem.

earth buried distribution transformers

Because the distribution transformer formed an important element in many of the proposed underground residential distribution systems, requests for recommendations were received as early as 1939. In the interest of holding the cost down, engineers tried to determine experimentally what would happen if a standard distribution transformer were completely buried in the earth. These tests indicated a reasonable chance that the heat from the transformer losses would keep the surrounding earth sufficiently dry to prevent severe corrosion of the transformer case.

Trial installations were made in 1939, and after load tests covering several months, this scheme was abandoned. Corrosion was quite severe in some cases, depending upon the character of the soil at the installation site. Also, heat

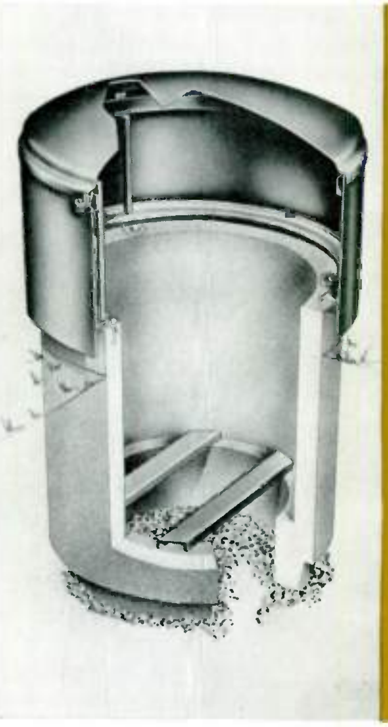


Fig. 1 This is the "semiburied" transformer installation, a concrete pipe topped with a steel housing and cover.
Fig. 2 Utilization transformers such as this can be applied at each residence, with either an underground or overhead system.

transfer properties of the soil varied over such an extreme range, depending upon location, soil character, and rainfall, that the transformers had to be severely derated. Such derating might have to be experimentally determined for each location, or made so large that the increase in installed kva would make the scheme unattractive.

An alternate arrangement was then proposed—provide the transformer with an outer steel shell, with this shell to be only partly buried and the upper portion of the shell to be above ground. This arrangement would lessen the problems of maintenance and derating, and would still be less conspicuous than a surface-mounted transformer. As a result of a joint study between Westinghouse and a large eastern utility, the judgment of their engineers was accepted that it would be questionable practice to bury the steel housing in the ground because of the risk of corrosion.

"semiburied" distribution transformers

In 1946, a new type of transformer enclosure overcame the serious limitations attendant upon the direct earth-burial method of transformer installation. This enclosure consisted of a cylindrical concrete pipe for the buried portion, with the superstructure in the form of a steel housing and cover that could be fabricated at the transformer factory. This design came to be known as a "semiburied" transformer installation. Two housing sizes, 36-inch diameter and 48-inch diameter, were designed to accommodate the CSP and conventional transformers.

Standard concrete pipe dimensions were used in the design of the base, shown in Fig. 1. The steel housing is larger in diameter than the concrete base, to permit cooling air to be drawn into the enclosure. A section of grillwork near the top allows heated air to escape to the outside. The domed cover is flanged to fit snugly over the steel housing and can be padlocked to the housing.

An important aspect of any transformer housing mounted where it is readily accessible to the public is the degree to which it can be made completely safe and completely tamperproof. Special safety measures must be designed into any such installation.

The housing case for the semiburied transformer installation is fitted with a baffle ring welded to the inside, behind the open grillwork, to prevent the entry of wires, rods, or sticks, which might otherwise come in contact with live parts. The housing support ring at the bottom of the housing serves a similar purpose, preventing entry of objects between the case and concrete base. When the enclosed transformer is properly installed and grounded to the steel housing, there is no external danger.

Since the introduction of the semiburied transformer installation, a considerable number have been installed throughout the United States, the Virgin Islands, and Puerto Rico. The operating experience has been entirely satisfactory.

the utilization transformer

As residential loads increase, overhead secondaries are becoming shorter and transformers are becoming larger and more numerous. By projecting this trend into the future, a possible conclusion is that eventually most new

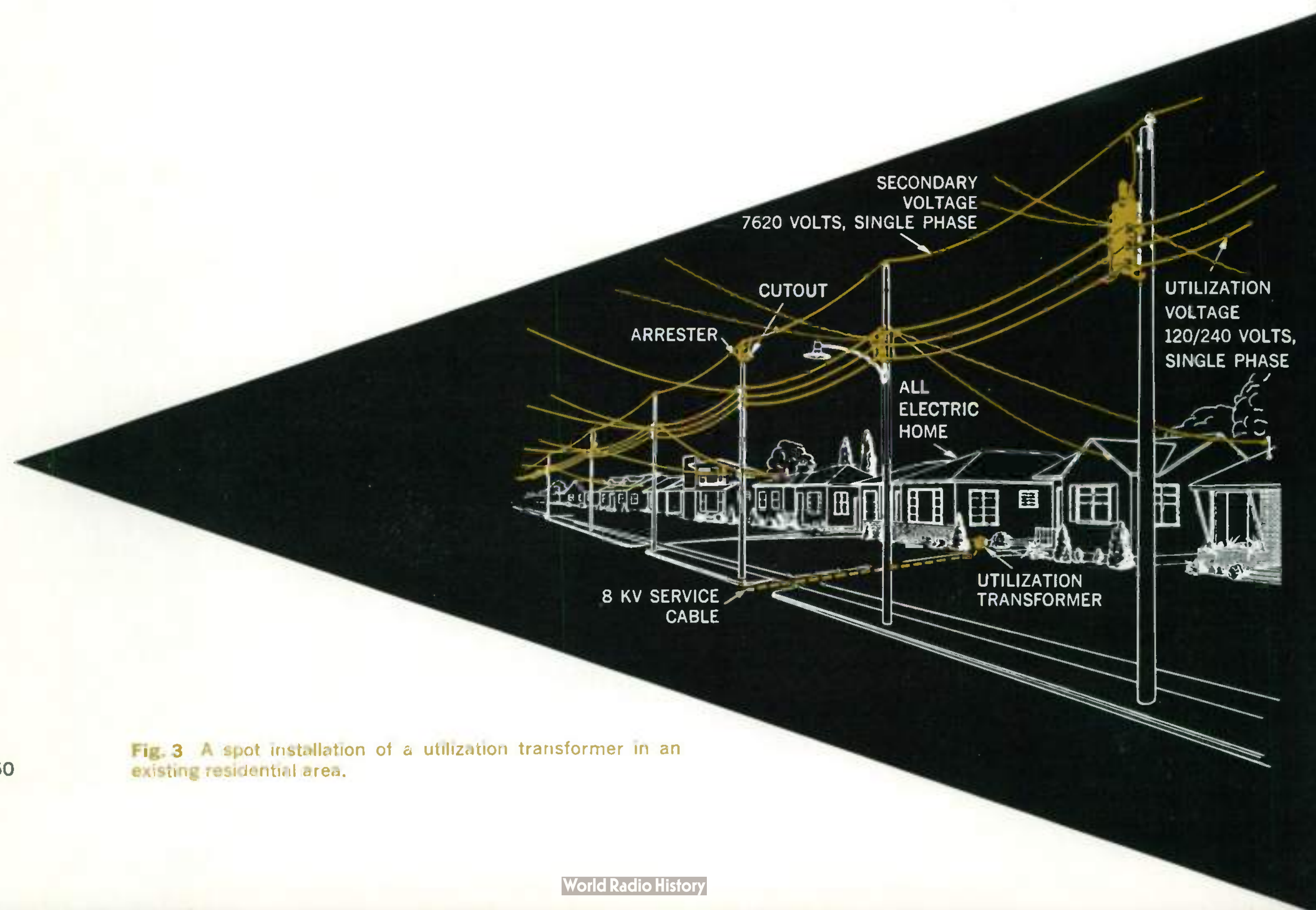


Fig. 3 A spot installation of a utilization transformer in an existing residential area.

homes may be served from individual transformers mounted adjacent to those homes.

This concept can be applied to new construction with little change in the existing distribution system, by employing underground radial feeders, and surface-mounted distribution transformers at each residence. Applicable to either an existing underground or overhead system, for practical purposes this scheme presents a service supply of unlimited capacity as viewed from the "utilization transformer" at the residence.

The utilization transformer is quite simple in construction, differing from a pole-mounted transformer only in shape and in the fact that all live parts are enclosed in a grounded structure, Fig. 2. A locked, metal housing covers the high- and low-voltage bushings, and is designed to be completely tamperproof from the outside. This is accomplished by suitable baffles inside the housing. Rather than the conventional round tank, the transformer core-and-coil assembly is enclosed in a rectangular tank designed for low silhouette, to make it inconspicuous as possible. A surface mounting of this type precludes the necessity for an expensive underground vault and aids in the transfer of heat from the transformer.

The high-voltage protection for this type of distribution system is generally provided by having overcurrent and lightning-protective devices mounted at the point where the high-voltage service cable is tapped to the high-voltage feeder. Low-voltage protection may depend upon a secondary breaker within the utilization transformer, or upon the user's entrance fuse or breaker alone.

The utilization transformer can be used to supply an occasional "all electric" home located in an established area served by an overhead radial system. The use of hollow plastic poles would permit the high-voltage service cable to be tapped to the aerial cable, run down the inside of the pole, and underground to the transformer, Fig. 3. In the same manner, overhead systems can be greatly "cleaned up" in new housing areas by the use of utilization transformers as shown in Fig. 4.

the primary service unit

Since underground high-voltage services can solve some of the electric utility company's problems, and since connecting underground services to overhead primaries presents some new problems, the use of a buried primary system has been proposed for some areas.

This type of system has generally developed using a three-phase feeder with a grounded neutral, with single-phase, looped laterals. A grounded neutral system is generally desirable to provide safety and simplicity in metering and switching, and to permit maximum grading of the insulation of the distribution transformers.

A schematic diagram of such a system is shown in Fig. 5. Note that sectionalizing of the looped lateral is provided by a switch in each transformer enclosure. The fact that the enclosure includes not only a distribution transformer but also high-voltage disconnects, possible lightning arresters, and other switching or protective devices, gives rise to the term *primary service unit.*

With the high-voltage disconnect, any service and the

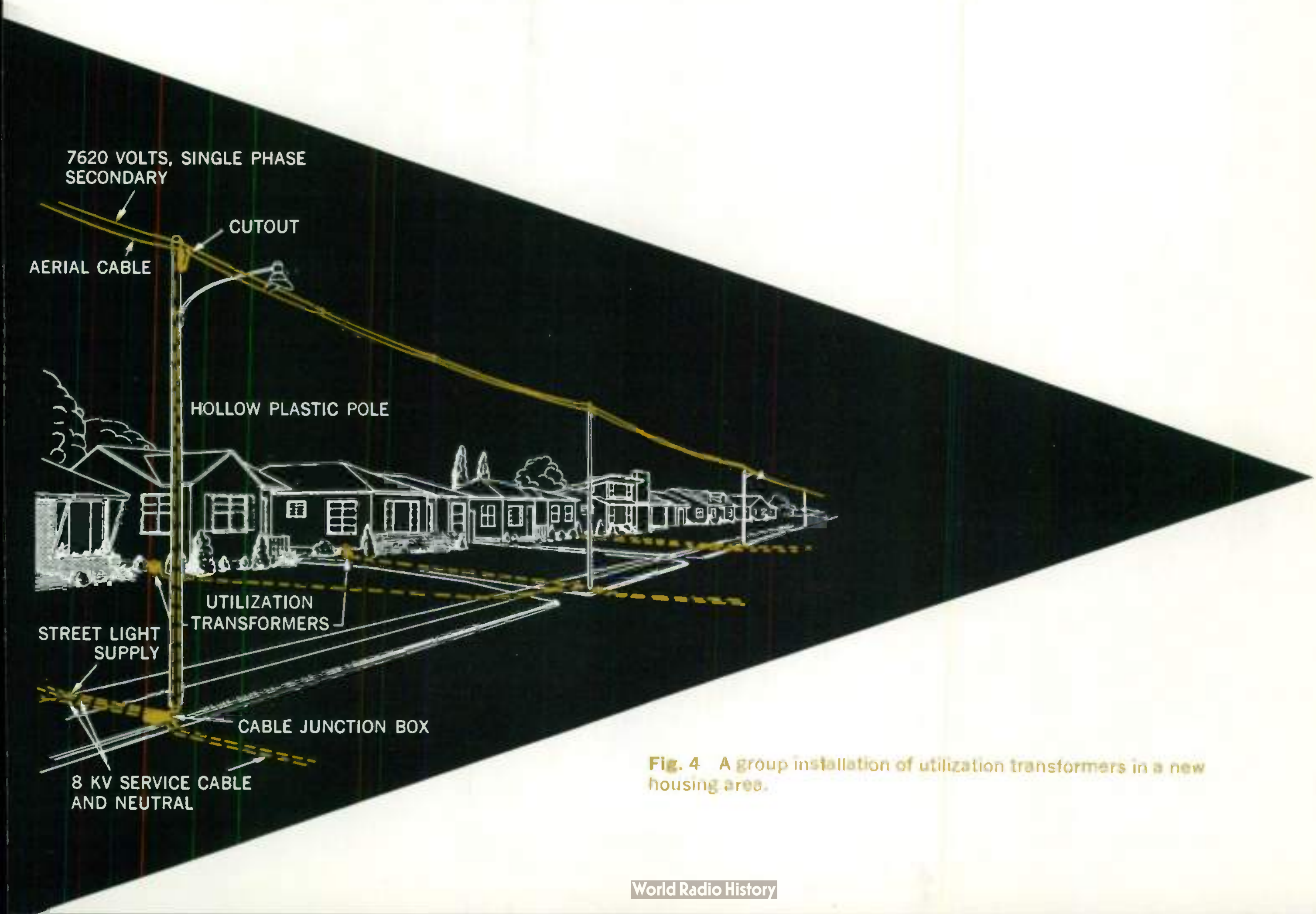


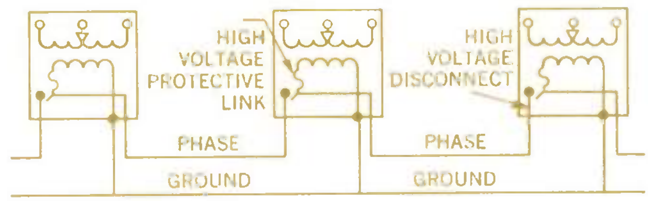
Fig. 4 A group installation of utilization transformers in a new housing area.

associated section of lateral can be de-energized for maintenance, repair, or test, without interruption to other services. Further, in the event of failure of a lateral, the fault can be located quickly, since test points are available at each service unit, and the faulty section isolated by means of the adjacent switches. Service may then be restored to all homes except the one associated with the faulty section, which may also be re-energized as soon as the faulty cable is disconnected within the service unit. This is a particularly important feature in this type of system, since corresponding faults in radial underground systems tend to cause extensive outages, are difficult to locate, and must be repaired or bypassed before all service can be restored.

Laterals can be protected from faults in distribution transformers or on the user's premises by a fuse in each service unit. An additional fuse may be desirable in the two units adjacent to the three-phase feeder, limiting the outage resulting from a lateral cable fault to the services on the faulty loop.

A looped lateral distribution system using primary service units with two disconnect switches is shown in Fig. 6. With this scheme, in the event of a lateral failure, service can be restored to all residences once the faulty section is isolated by adjacent switches, and no transformer capacity is lost to the system.

One type of primary service unit is shown in Fig. 7. This is a 50-kva CSP unit with two internal isolating switches and a dummy high-voltage bushing position to provide a visible open circuit. Since these isolating switches will not break load currents at full line-to-ground voltage, primary load-break disconnects at the points where the loop is tapped to the high-voltage feeder should be used to de-



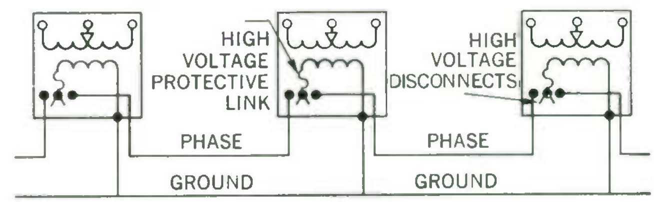


Fig. 5 A three-phase grounded neutral system with single phase looped laterals, with a single high-voltage disconnect.
Fig. 6 This is the same type of three-phase system shown in Fig. 5, except that two disconnect switches are used here.

energize the loop, and faulted sections then isolated by means of the unit switches.

a new concept

Custom-designed transformers and transformer housings for underground distribution in the past have proven to be quite expensive, both for the utility and for the transformer manufacturers. To achieve competitive costs, standardized construction is necessary. This has not generally been the case, since there are such widely varying solutions to the problem of transformer equipment.

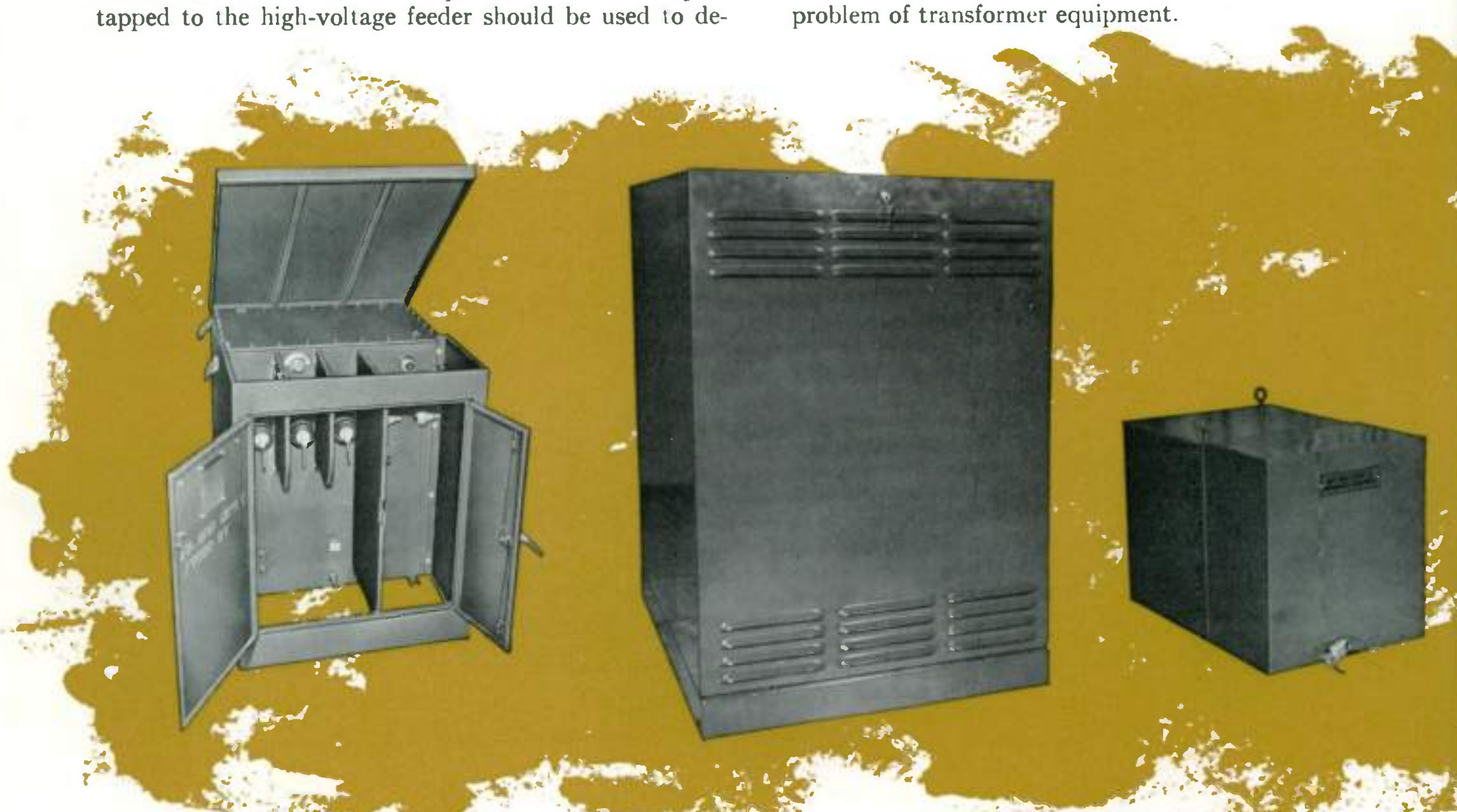


Fig. 7 This is a 50-kva CSP primary service unit, with two internal isolating switches.

Figs. 8 and 9 This "universal" housing (larger of two enclosures) will accommodate standard pole-type transformers rated through 25 kva. For simple

A new concept in equipment for underground distribution is incorporated in a new transformer housing. This housing can be described as "universal," since by adding standard pole-type distribution transformers and the desired accessories, it can be used with any underground distribution scheme proposed or in use today.

This housing, shown from the outside in Fig. 8, will accommodate standard pole-type distribution transformers rated through 25 kva. With a 7-inch extension that is easily attached to the bottom of the housing, this range can be extended to 50 kva, thus providing considerable margin for load growth. Other housing sizes are available to accommodate distribution transformers as large as 250 kva. The housing is provided with a draw-out type door at either end, to provide selected access to either the high- or low-voltage side of the transformer. Both doors contain screened and baffled louvers, giving sufficient air circulation to make unnecessary any derating of the transformers. Edges of the doors are also baffled, as is the remainder of the housing, for "completely tamperproof" construction.

Both high- and low-voltage transformer connections can be made in the open, without hindrance from any part of the housing. The housing can easily be lifted by two men, and lowered into place over the connected transformer.

Overall plan dimensions would be 32 inches by 44 inches, with a height of 46 inches through 25 kva, and a height of 53 inches above 25 kva.

For the simple radial or utilization transformer system, only the housing and a suitable pole-mounted distribution transformer would be needed. This is shown in Fig. 9. Housing surface temperatures would be considerably lessened, safety hazards reduced, and change-out problems simplified compared to the utilization transformer.

For the looped lateral system utilizing a single disconnect, this transformer housing has provision for mounting a single-pole, oil switch within the high-voltage compartment. This switch, shown in position in Fig. 10, has a full load-break rating of 200 amperes at system voltages up to 14 400 volts, thereby eliminating the need for additional load-break devices at the high-voltage feeder tie. This switch is completely self-contained, and therefore easy to install or remove as the character of the application changes. The switch is practically maintenance-free, performing up to 10 000 switching operations before inspection is required. For this application, a knife-blade attachment for the oil switch gives visual indication of an open disconnect.

For the looped lateral requiring two separate disconnect points at the transformer location, provision is made within the high-voltage side of the housing to mount a two-position blade disconnect with "Loadbuster" attachments. The center position of this multiple disconnect can be supplied with a high-voltage fuse, readily accessible through the door of the high-voltage compartment.

The success of the several methods of underground residential power distribution depends to a great extent upon the cost of the specialized equipment. Of this equipment, the most costly items are the distribution transformer and the transformer enclosure. The present state of development indicates that it is much too early for transformer manufacturers to standardize on any one type of transformer or enclosure for this application. Therefore, a standardized housing, using standard pole-type distribution transformers and having provision for the addition of switchgear and protective devices to suit all proposed systems, should prove useful.

Westinghouse ENGINEER Mar. 1961

radial systems, only the universal housing and a pole-type transformer are needed. Utilization transformer is shown for comparison.

Fig. 10 For looped lateral systems, a single-pole oil switch can be mounted in the high-voltage compartment.

AUTOMATION OF GAS TRANSMISSION The trend away from manual operation in gas transmission is culminating in plans for completely automatic pipeline operation.

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Natural gas can be used only if it can be made available economically to consumers. The problem of making it available was faced by the ancient Chinese and it still faces gas producers today.

There is evidence that the Chinese built gas pipelines from bamboo pipe as early as A.D. 900, but not until the 1800's was natural gas used in the Western world. In 1827, natural gas was piped into a small town in New York and there used for street lighting. The first large-diameter line was installed by the Equitable Gas Company in Pittsburgh. It was 21½ miles long, 36 inches in diameter, and made of ¼-inch steel plate riveted into pipe and caulked to prevent leakage.

The first long-distance transmission lines were constructed in the 1920's and 1930's. Pipe diameters ranged from 22 to 24 inches, and operating pressures of 400 to 600 pounds per square inch (psi) were common. The great expansion began after 1945, when improved steelmaking and fabrication techniques and better compressing equipment made it possible to design and build lines up to 36 inches in diameter operating at pressures up to 1000 psi.

The first stations were entirely manually operated. Men did everything from opening valves to reading instruments and logging data. But as new lines were designed and as older lines were modified to increase their capacity, higher operating costs and advances in control technology initiated changes in operating procedures away from manual operation. These changes are now culminating in plans for completely automatic lines.

transmission systems

A natural-gas transmission system is a complex organization of pipe, valves, compressors, instruments, and communications equipment whose function is to deliver gas from the producing fields to local distributors. These lines are long, generally 300 to 2000 miles, and have many compressor stations. Distance between compressor stations is usually uniform and about 30 to 60 miles. The exact spacing depends mainly on the size of pipe and the flow rates the lines are designed to handle. A 24-inch line may carry as much as 700 mmscfd* with a station spacing of about 30 miles, while a 30-inch line may carry as much as 1000 mmscfd with a station spacing of about 60 miles.

The operation of a gas transmission line varies in complexity from system to system depending on the availability of terminal storage. Terminal storage has a smoothing effect on the normal demand variations. This smoothing of flow permits the operation of some lines under constant load at all times. Where no storage is available, lines must "swing" in accordance with load demands. For the swinging or peaking line, automatic operation poses the most difficult engineering and economic problems but also promises the greatest benefits.

Basically, the operation of a gas transmission system consists of coordinating a number of subsystems. This coordination is presently carried out by a dispatcher. The various subsystems that he supervises may include sequencing systems at each station for compressor startup and shutdown, feedback control systems in each station for pressure and flow regulation, telemetering and communications systems for information generation and transmission, and supervisory control systems for remote operation of the stations. These subsystems now have varying degrees of automation. For example, it is common practice to regulate prime-mover and compressor speed by a feedback controller and then adjust speed manually to achieve a desired flow or discharge pressure. Automatic control of flow or pressure is less common. Similarly, information may be transmitted "manually" by voice or it may be transmitted automatically by modern telemetering equipment.

automated transmission

Automation of a gas transmission system is undertaken to improve system performance. The improvement in performance is both economic and operational. To realize economic improvements, gas must be transmitted at a lower unit cost. This lower cost may result from reduction in capital investment and improved operating efficiency. The improvement in performance must be realized through better control and regulation of the entire system and of the various subsystems. Increased safety and reliability are additional goals of automation, but, basically, control equipment should be justified on the basis of economics.

A study of natural gas transmission has developed the concept of a completely automated line represented in Fig. 1. There are 10 stations in this example and 10 sale and purchase points. Control is exercised at two levels. The first level, local station control, is functionally required to operate each compressor station. Included in this control are the station protective devices, local regulating loops, annunciation equipment, sequencing equipment, and telemeter transmitting equipment. At the second level, centralized dispatching control is functionally required to coordinate the operation of the line. A control computer there receives and scans 200 pieces of telemetered data, including pressures, flows, and temperatures, from each remote location. The computer controls all data logging and display, determines station operating points, and determines which compressors should run.

*Flow is in millions of cubic feet per day measured at standard conditions—60 degrees F and approximately 15 psia.

The study of gas transmission line automation has two objectives. The first is to develop and establish the mathematical and logical patterns of coordination; that is, to derive the rules that must be followed in operating a gas line to achieve the desired performance. The second is to analyze the rules thus found with the purpose of specifying the functional requirements of system equipment that would implement the rules automatically. A number of specific problems have been studied, all of them aimed ultimately at automatic control.

The study was conducted by a team of mathematicians, thermodynamicists, computer programmers, and industry specialists. This team's basic mathematical tools were the partial differential equations relating pressure, density, velocity, and temperature for flowing fluids. Also fundamental to the study was an investigation of the characteristics of several types of compressor/prime-mover combinations—gas-turbine-driven centrifugal compressors, gas-engine-driven reciprocating compressors, and electric-motor-driven centrifugal compressors. The characteristics of greatest interest were efficiency and head-flow relationships and the limitations imposed by speed boundaries, power ratings, and surge characteristics.

It was evident that mathematical models suitable for machine computation and simulation had to be developed to study the economic factors affecting line operation as a means of determining how operating economy might be improved within the limits of operation imposed by equipment characteristics and load. System dynamic performance also had to be predicted.

economic performance

First, costs of operation were examined for gas lines operating in the steady state to determine what line conditions or pressures would minimize operating cost for transmission at a fixed rate. Experience indicated that maximum economy was to be achieved only when the operating pressures along the line were kept as high as equipment limitations allowed. However, some questions existed concerning the quantitative effect of machine efficiencies, which vary with load. That is, line conditions permitting, would any increase in total line efficiency be realized by shifting load from one station to another? A similar question existed when different stations along the line had different energy cost schedules.

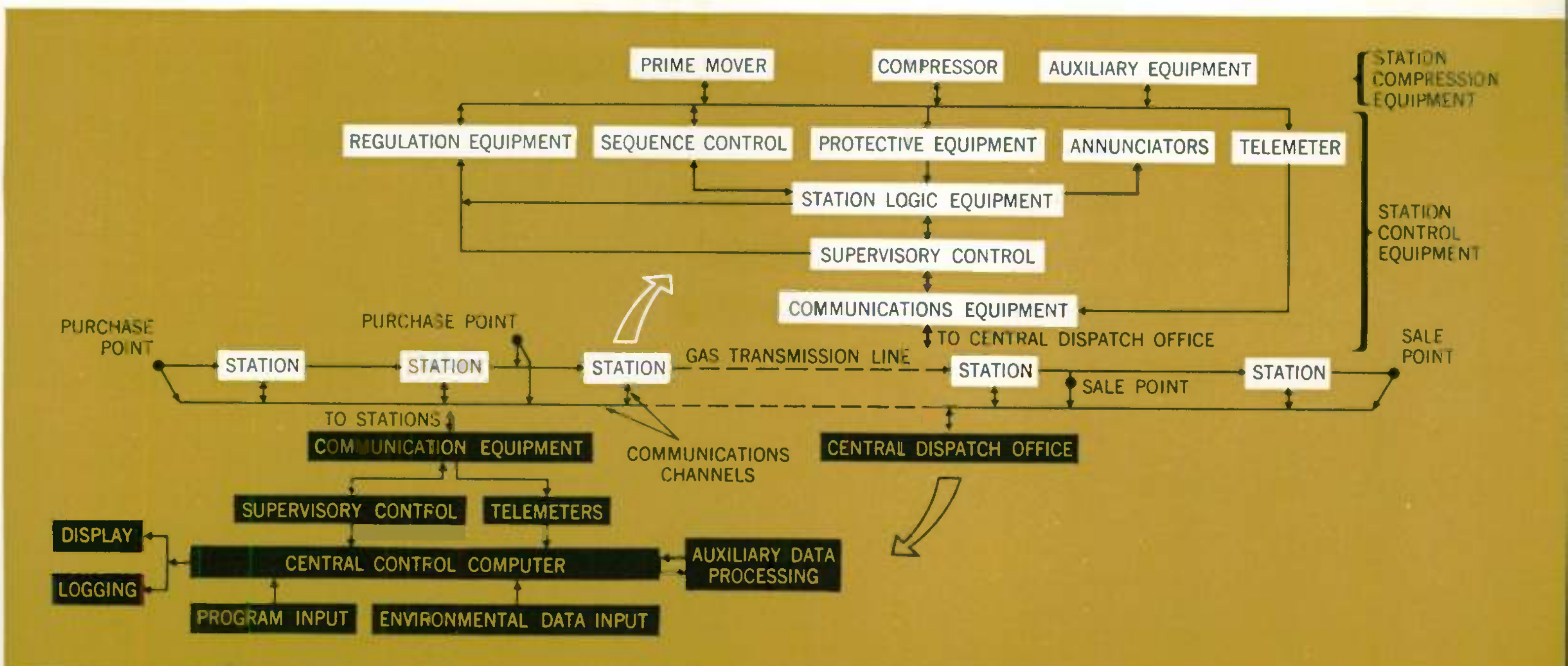
To analyze these problems of economic operation, a simple mathematical model was developed to describe the economics of steady-state operation of a transmission system. (See *Mathematical Model*, p. 56.) Using the model permits calculation of the operating conditions for maximum economy if the various machine and line parameters and limits are given.[1]

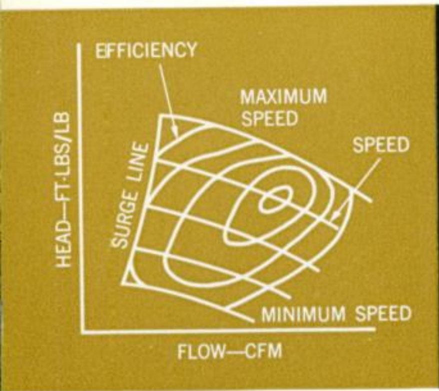
Briefly, this phase of the study revealed that operating pressures should be as high as possible except where large amounts of gas are being withdrawn from the system. In this special case, operating pressure at the upstream station should be controlled to minimize throttling losses at the delivery point. Although all the cases studied thus far have led to these conclusions, they may not be universally true. However, a tool is now available—a mathematical model and an associated computer program—that can be used in economic investigations of any system for determining the proper line conditions to achieve maximum economy in the steady state.

transient operation

Since the steady-state economic studies indicate that line losses far outweigh station or machine losses, it appears

Fig. 1 Diagrammatic representation of an automated natural-gas transmission line.





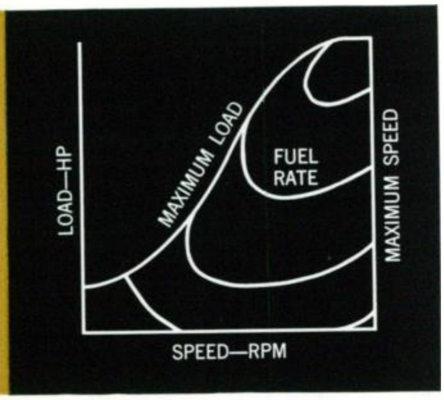


Fig. 2 (Left) Compressor characteristics. Maximum and minimum speed lines and surge line bound the permissible operating range, and contours indicate efficiency variations. Head is expressed as work required to move a pound of gas through the compressor.
Fig. 3 (Right) Gas-turbine characteristics, showing fuel rates and operating limits imposed by maximum load and speed.

that in the unsteady or transient cases it is not necessary to consider machine efficiencies in attempting to minimize transmission costs. A simpler and sufficient objective is the minimization of work done on the gas.

The conclusions drawn from the economic studies indicate two possible avenues for improved economy in operation. On the one hand, high pressures must be maintained in purely transmission zones; on the other, control must be such as to reduce throttling losses at delivery points.

Maintaining Pressure—Consider the problem of maintaining high pressure in the line. The characteristics of the compressors and prime movers limit their ranges of operation. (See Figs. 2 and 3.) Consequently, if maximum discharge pressure were maintained as line flow was reduced, the rising suction pressures resulting from the lower line losses would eventually force the machines into a limit. Only by reducing discharge pressures, which causes a somewhat greater reduction in suction pressures, could all machines continue to operate. By shutting down alternate stations, however, maximum discharge pressures can be maintained. In either case, average line pressures are reduced and losses increased.

The question of when to switch from running all stations at reduced pressure to running alternate stations at higher pressures has been answered by using another model. Initially, the model used only two stations and their downstream line sections. By calculating the line losses under different conditions of flow and pressure and number of stations operating, the optimum-economy switchpoint for changing from all stations running to alternate stations running can be determined.

The determination of best operating pressures along the line requires computing capability at the central dispatch point. Maintaining these pressures requires good feedback control at the stations.

Reducing Throttling Losses—Before considering the reduction of throttling losses at delivery points, some explanation of why such losses occur should be given. Gas is delivered to distributors from the transmission system under contracts that specify such factors as peak load, average load, and minimum acceptable delivery pressure. Control is exercised over delivery by throttling, so that the distributor, under varying load conditions, can maintain suitable input conditions to his system. It is customary for transmission systems to meet peak demands by "packing" the line at light loads. While this is economic in purely transmission zones, it does result in high throttling losses at delivery points.

It is desirable, then, to devise a regulating system that operates the line in the vicinity of a delivery point in such a way as to reduce throttling losses, and still does not impair the capability of the system to meet rapid changes in load. Extensive model analysis and testing show that such a system is feasible. A number of models for compressing equipment and lines were used in this work. Analog simulation was used in early exploratory parts of the problem, and more comprehensive digital simulation was relied on as basic ideas for a control structure took shape. Both linear and nonlinear models have been used. The linear models serve to suggest control requirements and to verify certain characteristics of the nonlinear models. The nonlinear models are used to refine control parameters and to predict accurately the behavior of the nonlinear system.

This new remote pressure-control scheme for reducing throttling losses involves regulation of an upstream machine to control pressure into the throttling valve. Its ability to achieve its function is somewhat better than was originally thought possible, and the estimated savings justify the cost of control in all cases examined to date.

MATHEMATICAL MODEL

A mathematical model of a system is a set of mathematical equations or logical relations, or both, that describes some particular features of the system. For example, the partial differential equations below describe the relation between the pressures, densities, and velocities of flowing gas. Thus, they constitute one mathematical model for the study of transient gas flow in a pipeline.

Continuity equation:

$$\frac{\partial(\rho v)}{\partial x} = -\frac{\partial \rho}{\partial t}$$

Momentum equation:

$$v\frac{\partial v}{\partial x} + \frac{\partial v}{\partial t} + \frac{1}{\rho}\frac{\partial P}{\partial x} + \frac{2f}{D}v^2 = 0$$

Equation of state:

$$P = RTZ\rho,$$

where:

ρ = density	f = friction factor
v = velocity	D = line diameter
P = pressure	R = gas constant
x = distance	T = temperature
t = time	Z = supercompressibility factor

These equations in this form do not necessarily provide a convenient basis either for analysis or for computer simulation. Consequently, a number of distinctly different models describing flow in pipes have been developed for studying various aspects of the automation problem. For the same reason, various compressor-station models based on characteristics of compressors and prime movers and on descriptions of control equipment have been developed.

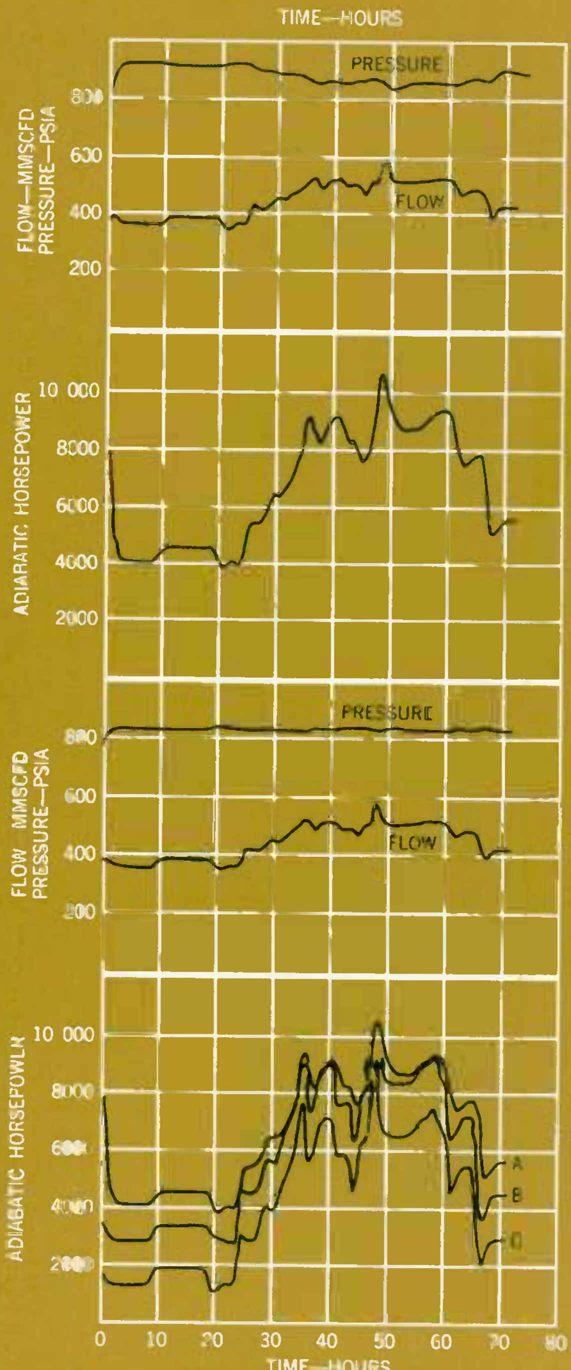


Fig. 4 Pressure and flow at throttling valve with upstream-compressor discharge pressure fixed at 990 psia.
Fig. 5 Adiabatic horsepower required at upstream compressor when discharge pressure there is fixed at 990 psia.
Fig. 6 Pressure and flow at throttling valve with upstream-compressor discharge pressure regulated for 850 psia at throttling valve.
Fig. 7 Comparison of adiabatic horsepower requirements at upstream compressor for (A) fixed discharge pressure (990 psia), (B) throttling pressure regulated to 850 psia, (C) throttling pressure regulated to 765 psia.

The effects of applying the control in a typical situation are shown in a series of graphs. A three-day load cycle and the pressure in the throttling valve when the discharge pressure immediately upstream is fixed are shown in Fig. 4. This fixed discharge pressure is typical of current operation. Adiabatic horsepower required at the upstream compressor for this operation is shown in Fig. 5. Fig. 6 shows the valve inlet pressure under control, regulated for 850 psia at the valve. Adiabatic horsepower requirements at the upstream station for current (fixed-discharge-pressure) operation, control at 850 psia at the valve, and control at 765 psia at the valve are compared in Fig. 7. The areas between the curves represent three-day energy savings, still on an adiabatic horsepower basis. The discontinuities in the lower curves occur where the adiabatic horsepower is off the chart range, but still well within station capability.

Ultimately, of course, the system can perform no better than internal station controls permit. These controls include sequencing for startup and shutdown, feedback systems for pressure or flow regulation, protective devices, and instrumentation and telemetering equipment. Even with the existing advanced state of station automatic controls there are some problems that deserve attention, especially in feedback control systems. Central control involves the determination of set points for station feedback control, and over-all system objectives are ultimately met in terms of feedback follow-up at the stations. Feedback control design in the station requires consideration of both upstream and downstream line sections as well as compressors and prime movers. Here, as throughout the study, mathematical model analysis, combined with computer simulation, permits functional design and performance evaluation.

summary

A thorough understanding of the factors affecting the economics of gas-line operation and gas-line dynamic performance has been acquired. Studies indicate that two distinct possibilities for operational savings exist, and that the mode of operation required to realize these savings is consistent with the necessity for a swinging line to meet its contractual obligations.

A set of tools (the general mathematical models) has been developed. These tools permit general investigations of gas pipeline automation and also constitute an essential aid in the automation of any specific line.

A clear concept of the functions to be performed through local control and those to be performed at the central dispatch point has been developed. By working out over-all system objectives and knowing how they are to be implemented, a progression can be worked out that allows an automatic system to be acquired a step at a time. Each step can be justified in itself and will be consistent with long-term over-all automation plans.

Thus, the automation of natural gas transmission systems is now within reach. Both the technology and the equipment required are available, and under most circumstances the application of control equipment is economically justified.

Westinghouse ENGINEER Mar. 1961

REFERENCE:
[1]AIEE Transactions Paper 60-1180. "Derivation of Economic Dispatch Equations—A Step in the Automation of Gas Transmission," by R. G. Abraham, R. T. Byerly, and D. C. Washburn.

AIR IONS: A New Role for the Sterilamp

Various research men have uncovered evidence of effects of air ions on physical well-being. Herewith some facts about the generation and measurement of ions, and some of their possible uses.

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Nearly a quarter of a century ago, the first of a series of ultraviolet lamps designed to destroy bacteria, viruses and molds was developed at Westinghouse. These were appropriately named Sterilamp tubes. Since that time these ultraviolet germ-killing lamps have found wide use in a variety of applications, ranging from hospital operating rooms to air conditioning systems in offices and homes. Now a new use looms on the horizon—as an element in a generator for producing negative ions, which medical research indicates may have profound physiological effects.

background of Sterilamp tubes

During the first ten years after the development of Sterilamp tubes, many evidences of their effectiveness were discovered. For example, when used in operating rooms they reduced the rate of infection of clean wounds from about 10 percent to about ¼ of 1 percent, and the number of deaths to zero. Experience showed that the rate of respiratory diseases in hospital infant and children's wards, and in school rooms were materially reduced. During this period antibiotics were discovered and large volumes of sterile air were needed for the environment where these compounds were fermented and packaged; Sterilamp tubes proved effective and today every pharmaceutical manufacturer uses some form of bactericidal radiation. They are also used in the Tenderay Process* for beef.

Within recent years, research on the Sterilamp has continued. Higher intensity tubes having a longer life have been engineered for disinfection of air in large air conditioning systems as well as for home air ducts. Various small home units were developed for deodorizing as well as disinfecting air. The invisible odors in the air are oxidized by the equally invisible ozone molecules produced by special ultraviolet lamps. The 23 years of research with the application of the Sterilamp at Duke University, which have just been summarized in the Journal of the American Medical Association by Dr. Deryl Hart, has supplied the answer to the elusive antibiotic-resistant Staphylococcus aureas bacterium, which has plagued nearly every hospital in the world. A proper intensity of radiation in the operating room will practically eliminate this killer.

Research has also demonstrated that under certain conditions the radiation from the Sterilamp tubes will generate large quantities of negatively charged molecules, sometimes called negative air ions. This fact by itself is unimportant. Hertz in 1887 showed that electrons can be removed from metals by radiation in the ultraviolet portion of the spectrum. The electrons then attach themselves to oxygen to form negative ions.

medical background

The importance of negative air ions is that for the past sixty years investigators have reported that both negative and positive ions have a physiological effect. Negative air ions seem to produce a beneficial effect while positive ions generally have been considered harmful.

Since ultraviolet lamps under certain conditions produce negative ions, some of the beneficial effects attributed to the radiation could have been caused by the ions. Dr. I. H. Kornblueh of the University of Pennsylvania has compiled a table on the reported physiological effects of ultraviolet radiation and negative ions. Many of the reported effects are the same. As an example, ultraviolet radiation has been reported by some investigators to relieve asthma, stimulate certain endocrine glands, have an analgesic or sedating effect, and to speed the healing of wounds and burns. Surprisingly, all of these effects have also been reported for ionized air. This indicates that many of the early tests made with the Sterilamp tubes in school rooms, poultry houses, and hospitals, and which were so promising at that time, could probably have given even better results if more had been known about negative air ions. This is not just speculation but is based on analysis of the early tests.

Most published information on ions has been in medical literature; ions have been applied for therapeutic purposes, such as for the relief of asthma, hay fever, and other respiratory diseases. Some German hospitals have been successful in the treatment of silicosis and have even reported relief in cases of "colds." Recent reports indicate that over

*See "Fighting Bacteria with Ultraviolet," Westinghouse ENGINEER, February, 1942, p. 3.

one hundred hospitals and health centers in the U.S.S.R. are using ion therapy.

Research in the United States has shown that negative ions will relieve "hay fever" and are very beneficial in "burn" therapy. However, most of the research has been directed toward determining the mechanism by which the ions work in the body. As an example, Dr. A. P. Krueger and his associates at the University of California have shown that negative ions stimulate the movement of cilia, hairlike projections lining the bronchial tubes that help to remove dirt, while positive ions retard or stop this wave-like motion. Negative ions also stimulate the flow of mucus in the bronchial tubes, which helps to remove dirt, while positive ions decrease mucus flow. This provides for the first time a mechanical picture to explain how negative ions could be helpful in such cases as "hay fever" or silicosis. The action of the ions on the cilia and mucus generation occurs through certain enzymes in the body.

measurement of ions

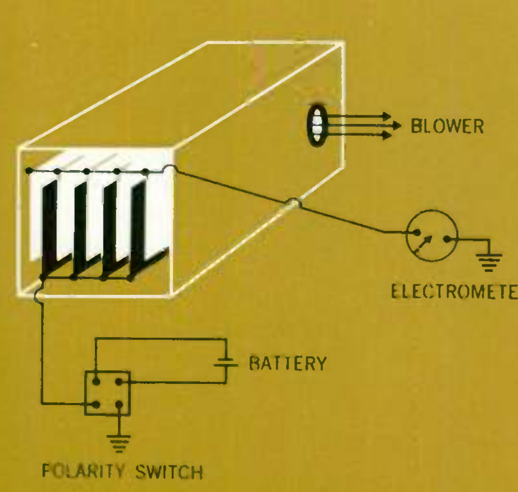
Outdoor air contains both positive and negative ions ranging in size from one molecule with a single charge to a large particle with multiple charges. The removal of an electron from a molecule or particle yields a positive ion, while the addition of an electron forms a negative ion. The size of the ions is expressed in terms of their velocity in an electrostatic field of known force. The slow-moving heavy ionized dirt particles have a mobility of about 0.0005 cm/sec/v/cm, the medium size ions have a speed of 0.02 to 0.01 cm/sec/v/cm, while the small ions have a mobility of 1 to 2 cm/sec/v/cm (mobility of ions in centimeters per second as measured in an electrical field expressed in volts per centimeter). Most investigators believe that only the small and medium sized ions produce a physiological effect.

A collecting unit such as shown in Fig. 1 can be designed to measure only the physiologically active ions. The mobility of the ions can be expressed as follows:

$$M = d^2 v / l\,V$$

where

M = mobility of the slowest ions collected,
d = distance between plates in cm,
v = air velocity in cm/sec,
l = length of collector plates in cm,
V = voltage applied to plates.



Thus, to collect all ions having mobilities below 0.1 cm/sec/volt/cm with plates that are 0.7 cm apart and 30 cm long and with an air velocity of 180 cm/sec, a voltage of 30 volts would be required. A higher collecting voltage would be needed for the large slower ions, while a lower voltage would collect only the smallest ions.

One method of determining the number of ions (charges) in a unit volume of air is to draw the air with a suction fan through the collecting plates and measure the current with an appropriate microammeter. The number of ions, N, is:

$$N = I/qA$$

where

I = ion current in amperes,
$q = 1.6 \times 10^{-19}$ coulombs,
A = volume of air flow in cubic centimeters/second.

generation of ions

Ions in nature are generated by cosmic rays, radioactive elements in the soil, precipitation, ultraviolet radiation and winds. Indoors, ions may be generated by x-rays, very hot surfaces, certain ultraviolet lamps, radioactive materials, and high-voltage devices. All of these devices, except the ultraviolet lamp, produce an excess of positive ions in a room.

Radioactive materials such as polonium and tritium have been used to generate negative ions in a room, but there is some danger that radioactive material may be introduced into the air. Such ion generators also require a high-voltage supply to remove the positive ions that are produced along with the negative ions.

Corona discharge has been used for many years to generate either negative or positive ions. A high voltage is placed on a very small diameter wire; electrons are liberated from the wire if a negative voltage is used. A large number of ions can be produced with a minimum of ozone and nitrogen oxides depending upon the design of the electrodes and the voltage used. Very high voltages produce an excess of these noxious gases.

Ultraviolet lamps have been reported to ionize the air and patents have been issued on the use of various types of mercury lamps to produce ions for discharging static electricity from celluloid and paper. It is now known that even the shortest radiation emitted from mercury lamps (1849 Angstroms) does not have a sufficient amount of energy to ionize oxygen or nitrogen. Thus any ions produced by an ultraviolet lamp are created by attachment of an electron to oxygen or dirt particles. The electrons are liberated from a metal or material near the lamp by the radiation, a process similar to that observed in phototubes.

The number of ions generated by an ultraviolet unit depends upon many factors. Since electrons are liberated from a metal photoelectrically, their number is determined by the intensity and wavelength of radiation. Thus fewer ions would be expected from a 4-watt Odorout bulb than from a 16-watt Sterilamp tube.

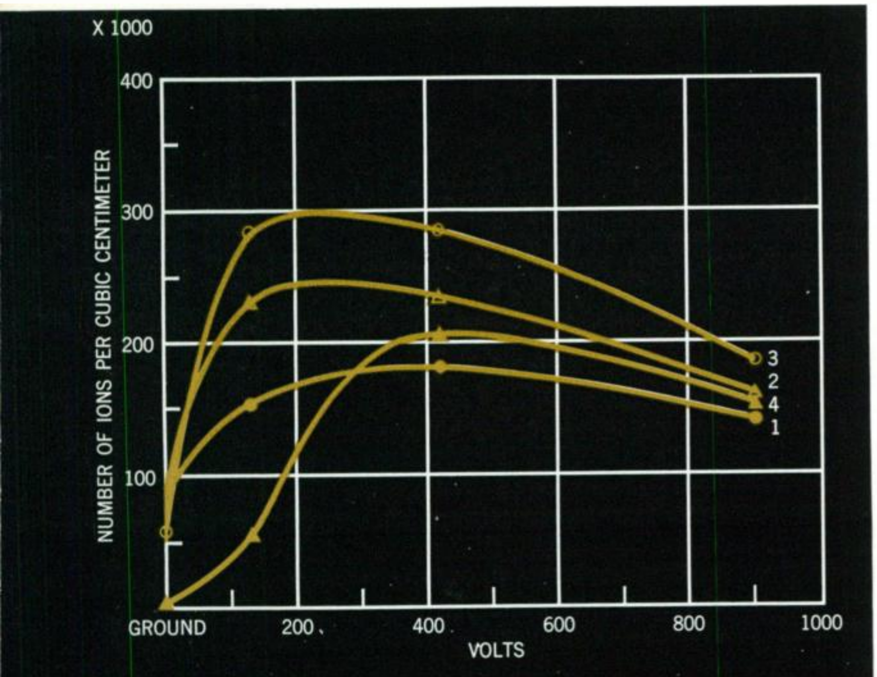
Photo The author with experimental ion generator. Generator is in box to author's left, and ion collecting and counting devices are shown in foreground.

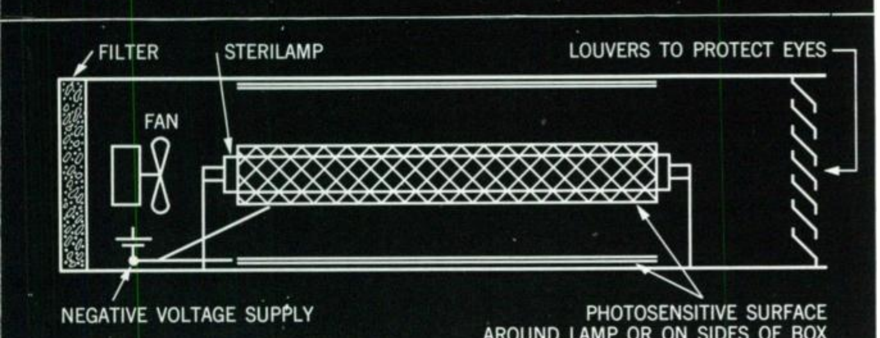
Fig. 1 Schematic diagram of plate collector for the measurement of air ion concentrations.

Over 90 percent of the radiation emitted from Sterilamp tubes has a wavelength of 2537 A. Radiation of this wavelength is not as efficient in ejecting electrons as 1849A, which is also emitted by some lamps. However, increasing the amount of shorter radiation would result in too much ozone; therefore most of the ions in Westinghouse units are formed by electrons released from the photoelectric surface by 2537A.

Metals such as sodium, potassium, and barium that have a low work function are very unstable in air and cannot be used for the photogeneration of ions. Even such metals as aluminum and zinc are readily oxidized, especially if ozone is present. However, the high photoelectric work function of some of the more stable metals can be decreased by a proper combination of other metals. As an example, if silver, which is more electropositive than copper, is plated on copper, a dipole is produced, which aids in the ejection of electrons. The layer of electropositive ions on the surface acts like a grid of a thermionic tube. Gold could be placed on top of the silver to protect the surface. However, the thickness of the layers should be about 100 atomic diameters. Beyond this thickness the surface work function becomes more nearly that of pure gold.

Fig. 2 (Top) Effect of voltage on the output of negative air ions from differently prepared emissive surfaces: (1) Copper wire plated with thin layers of silver and gold; (2) Copper wire plated with a heavier layer of silver and gold; (3) Copper wire plated with a heavy layer of silver and gold; (4) Copper oxide on copper wire.
Fig. 3 (Bottom) Schematic of an ion generating unit.





The number of electrons emitted from a photoemitting surface is greatly influenced by an electric field. A negative voltage applied to the metal surface increases the concentration of ions, as shown in Fig. 2. The ejected electrons are repelled from the metal by the negative voltage thus preventing recombination.

The number of negative ions generated by an ultraviolet unit is also dependent upon the air flow and construction of the unit. Rapid nonturbulent air flow removes the air ions from the unit, while turbulent air discharges the ions on the inside walls. An example of an efficient ultraviolet ion generator is shown in Fig. 3.

concentration of ions

The concentration of negative ions in the air is reported to be between 10 and 1000 per cubic centimeter, sometimes reaching as high as 2500. The concentration and polarity varies with the locality, air pollution, and weather conditions. Indoors, the number of small negative ions varies with the number of individuals in the room, diminishing rapidly when several people are in the room. The discomfort some people feel in air conditioned rooms reportedly is caused by the lack of negative ions. A concentration of ions of 500 to 1000 per cubic centimeter, as found in nature under certain conditions, might relieve this discomfort.

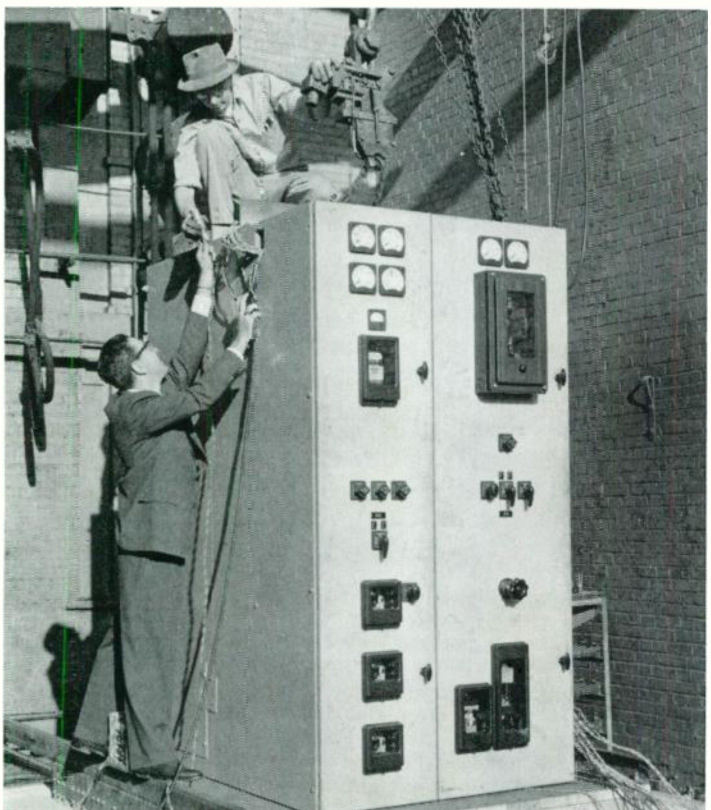
The concentration of negative ions used for therapeutic purposes has generally been of the order of 10^7 ions per cubic centimeter. This is usually administered for 5 to 30 minutes. This number of negative ions inhaled by healthy individuals over a period of time has been shown to be harmless. However, positive ions in concentrations of this magnitude do produce definite changes in the ratio of many of the blood constituents. Tests with 32 000 positive ions per cubic centimeter applied directly at the patient's face produce headache, nasal obstruction, and difficulty in breathing. The concentration of negative ions used in this country for the relief of "hay fever" has been of the order of 700 to 4000 with an average of 1500. All patients were not relieved at this low concentration. A longer time of exposure might have given better results.

The concentration of ions cannot build up to a high level in a room. Small ions condense onto large dirt particles. Both large and small ions are also rapidly discharged by the walls and furniture. The half-life of small ions in a vacant room has been reported to be about one-half hour. Probably the half-life is much less in an occupied room.

The 60 years of sporadic research on air ions leads but to one conclusion and that is that negative ions produce a beneficial environment while positive ions are generally harmful. More tests are necessary to evaluate these effects as well as to determine the mechanisms through which the ions react with the body. However, sufficient information is available to indicate that ion generators emitting a quantity of ions comparable to that found in favorable natural environment should be beneficial.

U.S. Army Corps of Engineers Photograph

WHAT'S NEW IN ENGINEERING



Electric Drive for Longest Lift Bridge

The longest vertical-lift bridge span ever constructed—a 558-foot structure weighing some 2000 tons—is raised and lowered by a coordinated electrical control system designed for extremely reliable operation. The span (see photo at left) is a section of the new bridge carrying the track of the Staten Island Rapid Transit Railway Company (a wholly owned subsidiary of the Baltimore and Ohio Railroad Company) over the Arthur Kill between Staten Island, New York, and Elizabeth, New Jersey. The bridge replaces an old swing bridge whose center pier had become a navigation hazard.

The lift span is suspended between two towers and raised and lowered by giant cable sheaves driven through reduction gearing by dc mill motors. The adjustable-voltage drives use magnetic amplifier exciter regulators for precise speed and skew control, smooth acceleration and deceleration, and low maintenance. The drives in each tower are synchronized by a skew-detecting system that automatically keeps the span level during operation by reducing the speed of the leading motor and increasing the speed of the trailing motor. The span can be raised 104 feet in about two minutes.

A complete duplicate drive system is provided to operate the bridge if trouble develops in the normal system. In addition, a standby diesel-generator set supplies power if the regular power supply fails. ■ ■ ■

Low-Cost Mechanical Shock Testing

Will electrical equipment continue to function when subjected to unusual mechanical shocks? If not, what must be done to protect or strengthen it? To answer these questions, Westinghouse engineers devised a program that uses two ingeniously simple test devices to give information quickly and at moderate cost.

Left Engineers install a magnetic actuator in the "cellar-door" shock tester's dropping device. The platform will be raised and then dropped into the sandbox to test the mechanical shock resistance of the high-voltage switchgear shown on the platform.

The program was initiated specifically to test standard and modified commercial apparatus for suitability for service in hardened missile bases. These bases, though well protected, would be subjected to mechanical shock and vibration of various intensities during a nuclear attack, so military specifications for equipment used in them include minimum acceptable shock resistance.

Interestingly, Westinghouse commercial apparatus supplied for the bases proved to be inherently stronger than had been realized. Most of it withstood a shock of 5 g and some withstood as much as 100 g. Electrical and/or structural modifications were made as required to enable all of the equipment to withstand the specified shock levels of 20 to 50 g.

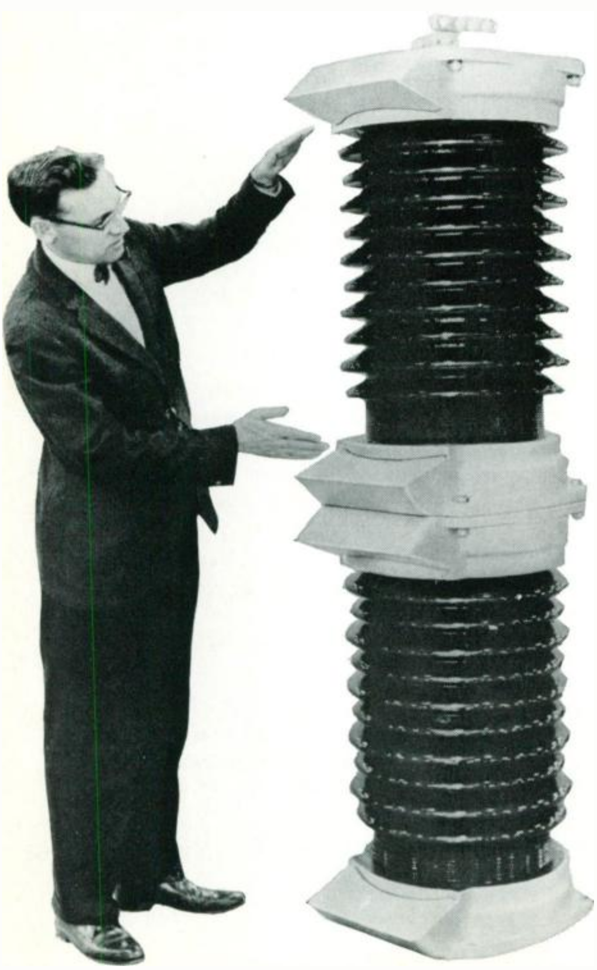
The program was designed in such a way as to produce shock spectra instead of shock pulses, eliminating the need for an elaborate shock machine. By using a shock spectrum, which is a plot of peak shock response versus resonant frequency, any pulse can be analyzed and valid conclusions regarding apparatus acceptability can be made.

One of the test devices used consists essentially of a platform hinged to a support at one edge. Equipment to be tested is placed on this "cellar-door" tester and the platform's free edge is raised. It is then dropped, and arresting blocks fastened to the underside of the platform punch into sand contained in a box under the platform. The amount of deceleration as the blocks enter the sand determines the amount of shock imposed; consequently, the shock level can be controlled by varying the height of the drop and the number of arresting blocks.

The "trapeze" tester is a suspended platform free to swing laterally. Equipment to be tested is placed on the platform, which then is pulled away from a vertical assembly of spring-loaded blocks and released to swing against the blocks. The amount of shock is controlled by varying the spring tension of the arresting blocks and by varying the distance of swing. Both devices were used to produce accelerations from 3 g to 100 g.

Equipment such as motors, switchgear, meters, and lamps was placed on the testers, connected to monitoring instruments, and energized with its normal operating voltage. The equipment then was subjected to the shock specified by the acceptance standard. The monitoring instruments recorded the equipment's performance during the shock, and post-shock tests determined if it had been damaged. If the equipment failed to function properly during or after the shock, it was redesigned.

The test method has broad applications because it can be used to evaluate almost any equipment at any desired shock level. For example, shipment shocks can be simulated economically and measures taken to protect against them, and airborne equipment can be engineered to resist the shocks that are peculiar to its environment. ■ ■ ■



Left Type SVS station-class arrester with pressure-relief ports sealed by breakable metal diaphragms. The man is showing how, if the arrester fails, the ports direct gases in intersecting streams that provide an outside path for the arc and thereby prevent explosion of the housing.

Improved Arresters Resist Explosion

An improved pressure-relief system for station-class lightning arresters prevents explosion of the porcelain housing in the unlikely event that the arrester is damaged by fault currents and loses its ability to interrupt power-follow current. Metal diaphragms at the top and bottom of the type SVS arrester are designed to rupture before pressure generated by the arc inside the arrester exceeds a safe limit.

To make sure the diaphragms rupture soon enough, a small hammer placed near each one is propelled by gas pressure and cracks the diaphragm. Hot ionized gases are then expelled through the exhaust ports, which direct the gas streams toward each other so that they intersect and form an external path for the arc. This transfers the arc from the inside to the outside of the housing in less than 1/4 cycle. The arrester is made in all SVS ratings. ■ ■ ■

High-Energy Arc Heater Sparks Aerospace Research

A high-energy arc heater will be built by Westinghouse for the National Aeronautics and Space Administration (NASA). It will supply a stream of hot high-pressure air for 10 minutes at a time in a NASA wind tunnel at Moffett Field, California, to simulate the extreme conditions met by missiles and other spacecraft on re-entry into the earth's atmosphere. Aerodynamic and mass-transfer tests will be conducted in the new facility.

For aerodynamic tests, the heater will be guaranteed to exhaust gas at a pressure of 1500 psia and an enthalpy of 2000 Btu per pound at a flow rate of 1.16 pounds per second. However, the unit is designed for a pressure of 3000 psia. The temperature of the air inside the heater will be approximately 6500 degrees R. This air will pass through a nozzle on its way to a test chamber so that the energy of pressure and temperature will be translated into velocity, enabling engineers to conduct tests at air speeds of 9 to 12 times the speed of sound and at simulated altitudes above 200 000 feet.

Air for mass-transfer tests will be supplied at a rate of one-half pound per second, a pressure of 100 psia, and an enthalpy of 10 000 Btu per pound. Passing this air through a nozzle will reduce its temperature from approximately 13 500 degrees R to selected levels. Mass-transfer tests are used for determining the temperature capabilities of various materials in re-entry environments.

Power input to the heater will be approximately 10 000 kilowatts. In this installation the arc heater will operate from direct current supplied by motor-generator sets. However, it is capable of operating from single-phase alternating current.

Two water-cooled doughnut-shaped electrodes are the heart of the heater. An arc is struck between them and rotated by a magnetic field. Arc rotation and water cooling virtually eliminate erosion of the electrodes. This keeps gas contamination at a low figure (guaranteed not to exceed 0.2 percent in the NASA unit) to duplicate actual reentry conditions closely. The unit is so designed that every molecule of air entering the machine will pass through the rotating arc at least twice, thus insuring a uniformly high gas temperature. ■ ■ ■

One side of this Mark I demand register scale reads 0 to 96 kilowatts; the other side reads 0 to 48 kilowatts. The tab at the right depresses a pin that shifts the register's gears to the high range when the scale is installed in this position.

Demand Register Converts in Field

A new dual-range demand register can be converted from its nominal (100-percent) operating range to an alternative 200-percent range by simply reversing its double-faced scale plate. This feature permits installing the Mark I register for prevailing service requirements and later converting it in the field to handle an increased load. The scale and the instrument's internal gearing cannot be mismatched because reversing the scale plate depresses a pin that changes gear ratios to double the range.

The demand register is combined with a watt-hour meter and is made in standard capacities with a combination of Class 2 and Class 6 or Class 3 and Class 5 scales. Standard demand intervals are 15, 30, and 60 minutes, but provision is made for intervals as great as four hours.

Another design improvement in the Mark I register increases accuracy by reducing the time required to reset the mechanism at the end of a demand period to a fraction of a second instead of the six or seven seconds ordinarily required. This is accomplished by using two indicator drive pushers, one of which is held in readiness during each demand interval while the other is moving the pointer. At the end of the interval the reserve pusher is instantly brought into operation by a magnetic clutch. ■ ■ ■

Parametric Amplifiers Airborne

Designers of airborne radar equipment have developed several versions of the parametric amplifier for use on the front end of radar receivers.

Most significant is a 10 000-megacycle nondegenerate parametric amplifier with a single sideband noise figure of only 2.8 db. Gains of 20 to 24 db have been achieved with excellent stability, and a bandwidth of approximately 20 to 25 megacycles. Amplification is achieved with a varactor diode.

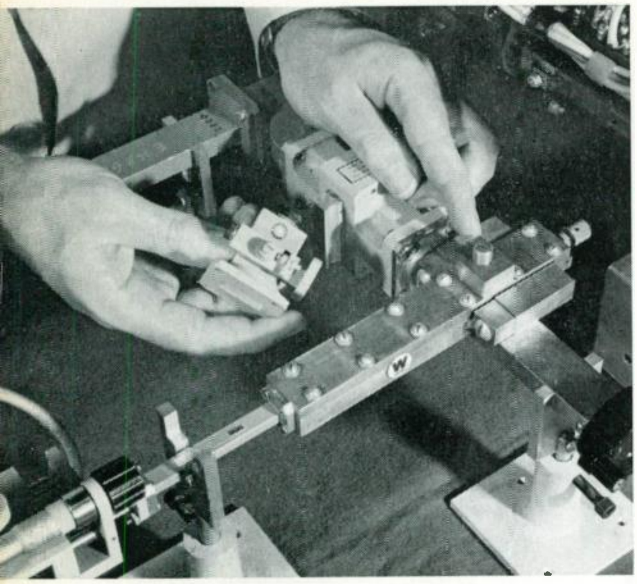
Another 5000-mc parametric amplifier for airborne use has been developed with an improvement in noise factor of at least 6 decibels.

Engineers are presently working on a wide-band parametric amplifier with which they plan to obtain a bandwidth of 10 percent. An inherently narrow-band device, most parametric amplifiers developed to date have bandwidths of about one percent. The device achieves its wide-band characteristics with a single parametric diode, tuned to a number of filters in the incoming waveguide. ■ ■ ■

Pipeline Control and Power

Automatic and economic dispatch of bulk materials is the ultimate goal in pipeline design. The following paragraphs describe pipeline control and power developments that indicate some of the directions of engineering effort in this industry.

A compressor station control system being installed at a Longview, Texas, gas pipeline station provides either manual or automatic control. The control point can be either local, at Longview, or remote, from Shreveport, Louisiana. "Manual" control in this case is actually single pushbutton control that energizes relays to initiate the sequence of operations required to put the station's gas engines and auxiliary equipment in operation. "Automatic" control places the entire station under a control system that selects the units to operate, regulates engine speeds, and controls compressor cylinder valves to maintain the desired hydraulic conditions. The only



The 10 000-mc parametric amplifier is shown in a test setup. The hand-held amplifier is the production model.

operator control required when the station is operating automatically is establishing the pressure and flow set points. This can be done locally or at Shreveport. Data are automatically logged and displayed in digital form at the Shreveport control center.

In petroleum transmission, an automatic central control has been designed for a pipeline of the Iraq Petroleum Company, Ltd. This line is being equipped to transport about a million barrels of crude oil a day from Iraq to the Mediterranean Sea. Two main pumping stations about 140 miles apart in Syria will be controlled from a station approximately midway between them. Each pumping station will serve two parallel 30-inch pipelines, and each will have five 6000-horsepower gas turbines for main pump drives. Two turbine-pump units with bypass check valves will be in series on each line, and the fifth unit in each station will be valved to serve either line as a spare. Each station will be equipped for local operation of the main pump units and auxiliaries through automatic sequence control, which includes an automatic pressure-control system to govern the turbine speeds in accordance with line requirements. In addition, the stations can be remotely operated from the central control station by a supervisory control and telemetering system of the digital type. The two pumping stations will be the largest remotely operated gas-turbine installations in the petroleum industry.

Power equipment is progressing hand-in-hand with control equipment toward the common goal of reduced transmission costs. A significant trend is the increased use of outdoor equipment made possible by new motor insulating materials that are impervious to moisture. Using outdoor motors eliminates the cost of pump buildings. In addition, the change from indoor to outdoor location usually changes the National Electric Code classification of the hazardous atmosphere from Division 1 to Division 2. This permits the use of less expensive electrical equipment and can be an important economic factor, especially in large installations.

Since 1956, Texas Eastern Transmission Corporation has installed five large centrifugal compressor units driven by 4160-volt, 17 250-horsepower motors. The stations have attracted wide interest because of their low installed cost and high operating efficiency. Now the company has taken the next step in economical station design by installing two similar units with motors, speed-increasing gear, and compressors mounted outdoors. The main 5-kv switchgear is the Shelterfor-M type and is located adjacent to the 12/16-mva transformer in the outdoor substation, which receives power at 161 kv. The motor field controls, instrumentation cubicles, 480-volt auxiliary controls, and control console are housed in a control room overlooking the outdoor main drive. The control system employs automatic sequence operation from the unit console and is designed for future use of remote supervisory control.

Outdoor motors and pumps are used at all 13 mainline pumping stations of Mid-America Pipeline Company's new line that delivers butane, propane, and natural gas from the West Texas-New Mexico production area to Minnesota and Wisconsin. The 26 main pump motors are FA (fully accessible) NEMA Type I outdoor weather-protected units equipped with air filters and screens; 22 auxiliary pumps are driven by vertical outdoor explosion-proof motors.

PERSONALITY PROFILES

The names C. LYNN and CHARLES KERR, JR. may have a familiar ring to many readers. For one thing both have written for the ENGINEER in the past. But more important, each is well-known in his respective technical field.

Lynn's association with Westinghouse began shortly after World War I. A graduate of the University of Kansas, he had spent a summer working at Westinghouse, where he became fascinated by the large rotating machines. When he joined the company, he was selected for engineering design school, then went to work on the design of large dc machinery, beginning a long career in this field punctuated with many notable technical developments. By 1938 he was manager of the department that produced these machines and several other major products. Since 1952 he has been executive assistant to the vice president at the Buffalo Division.

Kerr's career covers almost the same span of time, but in a different field. He graduated from the University of Virginia and M.I.T., and then came directly to Westinghouse on the graduate student course. Like Lynn, Kerr was fascinated by a heavy equipment field, but in this case it was railroads. Thus it was natural that he joined the Transportation Engineering Department. In the years since, Kerr has had a hand in nearly every electrical vehicle on rails, and has been prominently connected with most of the major railroad electrifications in this country and several abroad. Since 1954 Kerr has served as Automotive Consultant in the Industry Engineering Department.

S. W. HERWALD and S. J. ANGELLO team up to describe the operating principles of several elementary molecular function blocks. In effect, this article begins where Dr. Herwald's previous molecular electronic article (Westinghouse ENGINEER, May 1960) ended. Dr. Herwald, Vice President of Research, directs the activities of the Westinghouse Central Laboratories. Dr. Angello is now Consulting Engineer for molecular electronics research at the Research Laboratories.

M. A. NELSON joined Westinghouse in 1929 after graduating from Johns Hopkins University with a bachelor's degree in engineering. After attending the Westinghouse design school, he was assigned to the condenser engineering department of the Steam Division. Nelson was manager of the condenser and heat exchanger section from 1940 until 1956, when he became engineering manager for the newly organized heat transfer department of the Steam Division. Since 1959, he has been on the engineering manager's staff as a Consulting Engineer.

R. B. PHERSON is a graduate of Purdue University, where he earned his BSEE in 1949. After graduation, he joined Westinghouse on the Graduate Student Course, and then went to work in the Transformer Division. His first assignment was in the development section of the distribution transformer department, where he was responsible for circuit breaker design and application. In 1955 he transferred to the distribution transformer commercial design section; in 1957 he was appointed section supervisor, and in 1958 the section manager of the group.

Many people have been talking about the automatically dispatched gas pipeline, but D. C. WASHBURN, JR., and R. T. BYERLY are two engineers who have done something about it. The problem was largely undefined before this team attacked it; their joint effort has produced mathematical models with which the performance and economic return of pipeline automation systems can be demonstrated.

Washburn received his BS degree in electrical engineering from the University of Colorado in 1949. He worked as a field engineer with a consulting engineer and contractor and then entered the Army, where he served in an aviation engineer battalion. On his discharge in 1953 he joined Westinghouse as a field service engineer in El Paso, Texas. Since 1956 he has worked on pipeline electrification and automation in the mining, petroleum, and chemical section of the Industrial Engineering Department.

Byerly was graduated from Texas A and M in 1948 with a BS degree in electrical engineering and immediately joined the Westinghouse graduate student course. He was appointed to the staff of the University of Pittsburgh electrical engineering department in June 1948 and served there until 1954, receiving his MS degree in electrical engineering in 1951. Byerly returned to Westinghouse in 1954 as an engineer in what is now the Advanced Systems Engineering and Analytical Department. He became supervisor of special investigations in 1957 and Advisory Engineer of advanced system automation technology in 1960.

RUDOLPH NAGY, a biochemist, has worked with ultraviolet lamps almost exclusively since he first joined Westinghouse in 1937.

After earning his BS in 1932, and his PhD in 1937 from the University of Wisconsin, Nagy worked with Dr. H. C. Rentschler on the Sterilamp activity in the Lamp Research Department. Here he helped with some of the initial applications of these ultraviolet lamps.

When the war came along, he was one of those that helped prepare the uranium that went into the first atomic pile. For about 10 years, he has been active in searching for phosphors for fluorescent lamps, for television tubes, and for electroluminescent lamps.

With the recent upsurge of interest in the subject, Nagy is again spending time on ultraviolet applications, and particularly those involving negative ions.

FOR EXPLORING DEPTHS OF SPACE

This new electronic "seeing eye," the Uvicon, promises to give man a new and different look at the stars and interstellar space. Operating upon ultraviolet light that is screened from view by the atmosphere and never reaches the earth's surface, the new electronic tube is the heart of an electronic telescope that will be fired by rocket into space and, eventually, placed into orbit aboard a satellite observatory. The telescope, known as Project Celescope, is a Smithsonian Astrophysical Observatory experiment planned for the National Aeronautics and Space Administration's orbiting astronomical observatory program.