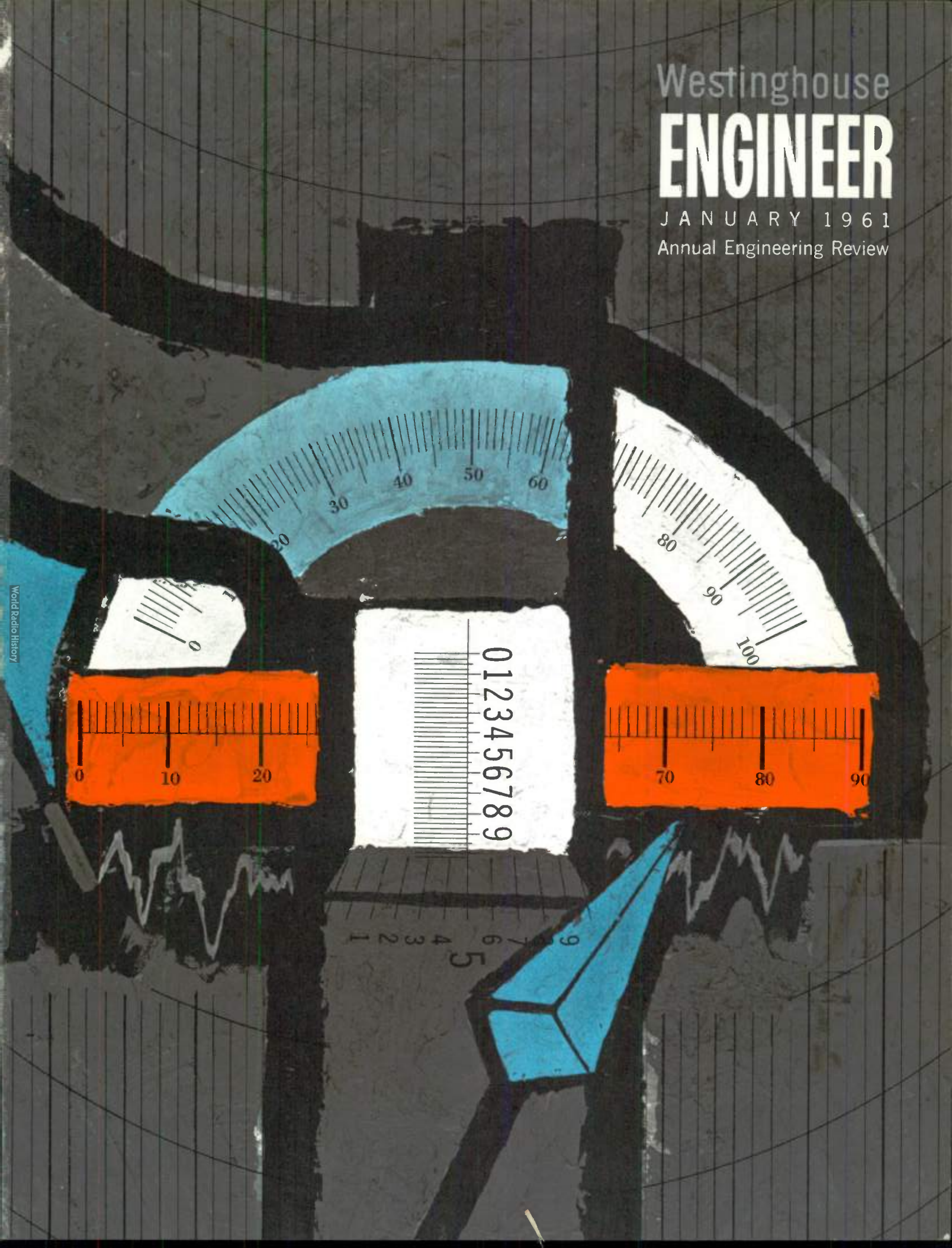

THE HIDDEN INGREDIENTS

While this annual review issue is intended primarily to describe some of the technical progress made during the past year, for those who care to delve a little deeper there are hidden ingredients. A little reflection and "reading between the lines" will reveal a number of interesting aspects about our changing technology.

For example, the inherent—and necessary—discontent of the scientist and engineer with the way things have been done in the past shows up in many places. The most dramatic examples, perhaps, are those that deal with completely new approaches to a basic problem—the development of thermoelectric and magnetohydrodynamic devices to provide new energy sources are two such advances. But engineers can be equally persistent in trying to wring greater performance out of existing devices and processes. Few machines have undergone more extensive development and continuous refinement than the steam turbine, yet engineers are still struggling to improve this already capable device. And they are succeeding. Witness the super-pressure turbines mentioned in these pages.

The knowledgeable reader can also peer behind the scenes and note many changes occurring in technology itself, in the basic approaches to technical problems. For one thing, the classic distinctions between the scientist and the engineer, between research and development, are becoming hazier, and may ultimately disappear. In many advanced technology projects today, the dividing line is difficult to determine, and frequently the same scientist or engineer may be required to carry the project through all stages. This points squarely toward the need for versatility in tomorrow's scientist-engineer, if he is to cope with the technology of his day.

Many other facets of technology are illustrated in these pages, for the reader who cares to reflect. But whether you read this issue for its technical news value, or as a means of gaining a better perspective of technology, we hope you find information of benefit and interest.

J. A. HUTCHESON, *Vice President, Engineering*

Westinghouse
ENGINEER
JANUARY 1961

Volume 21 • Number 1

Cover Design: The measurement of magnitude and form is a basic requirement of engineering. The increasing degree of accuracy and convenience of modern measurement techniques is a major factor in our advancing technology. Cover artist Dick Marsh formed this month's cover design from elements of a variety of well-known measuring devices.

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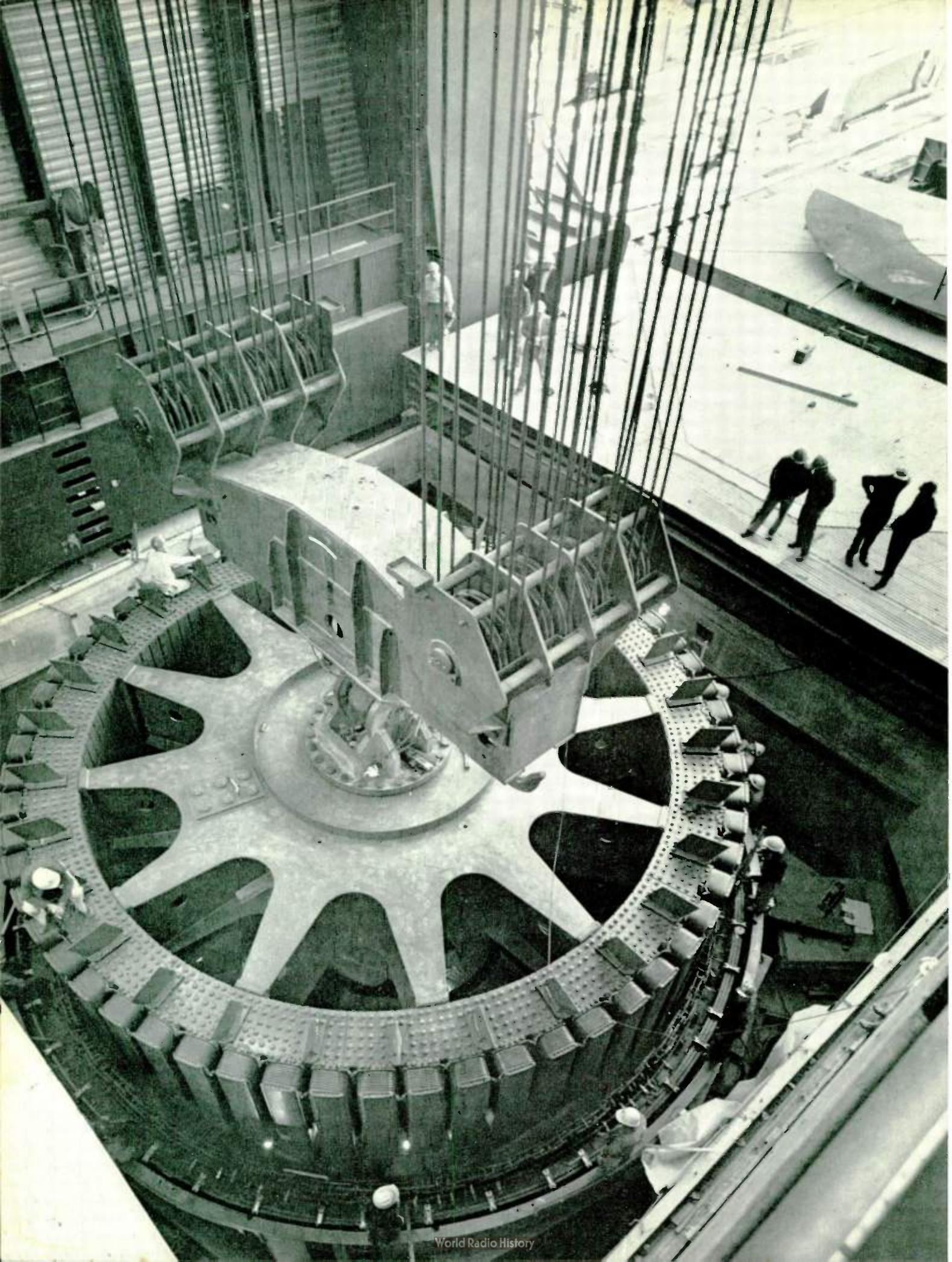
Annual Engineering Review

for the year 1960



ATOMIC POWER

Larger Core for PWR

The advanced state of development of large scale water-cooled atomic reactors in the United States is largely attributable to design and operating experience obtained from the Shippingport Atomic Power Station. In furtherance of Shippingport's purpose to advance the technology of pressurized water reactors, the decision was made in the Spring of 1959 to design Core 2 at two-and-one-half times the power rating and design lifetime of Core 1. This objective of a six-fold increase in energy release is both a stimulus to technological development and a positive step towards a reduction of the fuel cycle cost by more than a factor of three. The design of Core 2 is now being finalized and manufacture has begun. Duquesne Light Company operates Shippingport for the AEC.

Core 2, like Core 1, utilizes the seed-and-blanket concept, in which the seed, a small region fueled with highly enriched uranium, is surrounded by a natural uranium blanket. This concept provides a smaller inventory of enriched uranium and less down time for refueling than would be necessary for a uniformly enriched core of equal performance. In Core 2, the seed lifetime will be 10 000 effective full power hours. The blanket will be operated for at least two seed lives, or 20 000 hours. The increased power—the thermal equivalent of 150 000 electrical kilowatts—will be generated within the existing pressure vessel. This will result in a seed power density of 160 thermal kilowatts per liter.

The decision was reached early in 1960 to construct a heat sink to dissipate power generated by Core 2 in excess of the 100 000 kilowatt rating of the turbine-generator portion of the plant. This arrangement will meet all requirements for proving the developmental objectives of Core 2.

Left This 500-ton rotor is shown being lowered into place at the Niagara Power Project. The 150 000 kilowatt waterwheel generators are the largest ever made by an American manufacturer. The project will be the largest in the western world and is being built by the New York State Power Authority. This rotor is the first of 13 units which will be installed at the Niagara generating plant.

Contributing to the achievement of the Core 2 performance objectives are a number of significant new developments in reactor technology. For example, the fuel elements in both the seed and the blanket of PWR Core 2 will be compartmented Zircaloy-4 plates, containing rectangular shaped wafers of ceramic fuel. The ceramic fuel materials, natural uranium dioxide (UO_2) in the blanket and a mixture of highly enriched uranium dioxide and zirconia in the seed, have been demonstrated by comprehensive in-pile testing to have the greatest potential for long term irradiation of any of the presently known fuel materials. By using the ceramic fuel in plate shapes, instead of in rods as in the Core 1 blanket, increased heat transfer surface needed for high power density will be obtained. Another advantage of plates is their greater ability to contain fission gases. This apparent paradox results from the lower temperature at the center of the fuel because the release of fission gases from the fuel material is strongly affected by temperature. The central temperature of the blanket fuel will be 1200 degrees F in the plate design; it would be 3000 degrees F in rods of equivalent thermal performance.

Section I
Power
Generation,
Transmission,
and Distribution

A second significant advancement in Core 2 will be the use of self-shielded boron as a burnable poison. Because of its high neutron absorption cross-section, boron tends to deplete more rapidly than uranium-235. However, if boron is concentrated in discrete lumps, the self-shielding effect makes it possible to match the depletion of boron to the depletion of the fuel, so that at any time in life, the excess reactivity of the core will be small. As a result of using self-shielded boron, Core 2 with five times the energy output of Core 1 can be controlled with two-thirds the number of control rods. Another important advantage to be derived from the use of self-shielded boron is a flatter power distribution. This is achieved by placing lumps of boron in locations where peaks in power distribution would normally occur.

A third advance over Core 1 will be to permit nucleate boiling of the coolant during steady-state operation. This could lead ultimately to improved secondary side steam conditions and increased cycle efficiency.

Until Core 2 becomes available early in 1962, Core 1 will continue to operate. Of major interest now is information on the long-term irradiation characteristics of the blanket. The first seed, with which the reactor went critical in December, 1957, lasted the equivalent of 5800 full power hours. Refueling of the seed region was completed in March 1960 and full power operation was again achieved in May 1960. Seed 2 is expected to last about 7000 full power hours. A third seed of about 7000 hours lifetime is also scheduled.

The nuclear portion of the Shippingport Atomic Power Station was developed and designed at the Bettis Atomic Power Laboratory under the direction of and in technical cooperation with the Naval Reactors Branch of the AEC; Westinghouse operates the Laboratory for the AEC. ■ ■ ■

Progress in Nuclear Projects

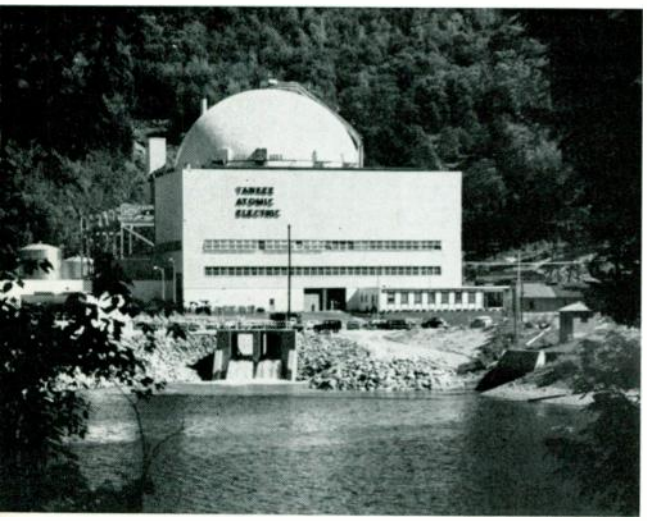
In Rowe, Massachusetts, on November 10, the reactor for the nation's newest atomic power plant produced electric power, and began the series of operations that would bring it to full power. With its first core the Yankee reactor is rated at 110-mw net electrical, from a heat output of 392 mw; the plant itself, however, is rated at 136-mw net electrical.

While the Yankee plant was going into operation, the 11.5-mw BR-3 reactor plant was in final stages of completion. This plant, erected near Mol, Belgium, is the first commercial reactor to be exported from the U.S.

During 1960, two other nuclear plants moved into the construction

phase. Near Bedford, Pennsylvania, ground was broken in February for the nuclear reactor for the Saxton Nuclear Experimental Corporation. This 20-mw reactor will provide steam to operate a turbine in the existing Saxton Generating Station. This reactor is designed for the primary purpose of providing information needed for the construction of future water reactor plants. In the experimental program, the reactor will be studied under advanced operating conditions. Fuel temperatures will be pushed upward, the reactor coolant will be allowed to run hotter, or even boil, and dissolved poisons will be used for control purposes.

In October, ground was broken for another small experimental plant—this one a 17-mw pressure-tube reactor for Carolinas-Virginia Nuclear Power Associates. This unit, scheduled to go critical in 1962, will serve as a prototype for a 200-megawatt reactor of the pressure-tube design.



Yankee Atomic Electric Company's atomic powered generating station is the first such facility in New England.

Meanwhile, two huge atomic plants loomed in the future. In July, Westinghouse and two European associates received a letter of intent for a 242-mw atomic plant to be built at Chooz, France, near the Belgian border. The plant will be designed by Westinghouse and equipment will be built by Westinghouse, Ateliers de Constructions Electriques de Charleroi of Belgium, and Framatome of France. The award was made by Societe d'Energie Nucleaire Franco-Belge des Ardennes (SENA). The plant is scheduled to operate in 1965.

In April the Southern California Edison Company issued a letter of intent to Westinghouse and the Bechtel Corporation for a 360-mw atomic power station. The contemplated plant would be the largest yet undertaken in this country, and would employ the world's largest atomic reactor. Studies reveal that the plant would be economically competitive with conventional plants over its lifetime. ■ ■ ■

TURBINES AND GENERATORS

Automatic Steam Plant Computer

Plans for an extensively automated turbine-generator unit were announced in September 1960 by the Public Service Electric and Gas Company of New Jersey and Westinghouse. The automated unit, rated at 342 megawatts, will be installed as the No. 5 Unit at Public Service's Sewaren Generating Station. The unit will be completely controlled by a digital computer system, called Prodac, which is designed for power plant automation.

The purpose of the new computer system is threefold:

First, plant reliability can be improved. The ever-increasing size and complexity of turbines, generators, and quick-responding boilers are demanding far more instrumentation than ever before required. The hundreds of operating variables can be quickly analyzed, and required changes in controlled quantities can be made according to preplanned procedures established by plant operators and equipment designers. This will insure that all equipment is operated within design limits at all times.

Secondly, safety to personnel and expensive plant equipment is insured through high-speed monitoring and pre-planned precise control in the event of an emergency. This eliminates hurried operating decisions and possible errors during periods of extreme operator stress.

And finally, plant efficiency can be improved by the computer's ability to rapidly scan the instrumentation system and furnish up-to-the-minute records, such as unit heat rate and efficiency. During normal operations and load variations, peak efficiencies will be maintained by precise control through continuous computer adjustment of sub-loop control set points.

The Prodac computer will be programmed to start, operate, and shut down the entire No. 5 Unit—boiler, turbine-generator, and unit auxiliaries—following pre-established programs for both normal and abnormal operating conditions. Programming instructions are fed into the computer in the form of punched paper tape: The computer is told what readings to take, and when; sequencing instructions outline control operations.

During normal operation, the computer will scan more than a thousand sensing points throughout the plant—temperature, pressures, flows, voltages, and currents—and convert these analog indications to digital quantities for computer use. The computer periodically compares these quantities with upper and lower limits, and takes appropriate corrective action if any are out of range. The computer will also process these data and other unit data in storage to compute heat rates, boiler and system efficiencies, and other indexes necessary to optimize the unit operations.

To control the unit under normal running conditions the computer supervises the conventional automatic analog subloops in the plant. For example, the voltage regulator subloop acts in itself to hold voltage at a particular value; if the computer then decides that voltage should be raised, it raises the set point on the voltage regulator. By retaining the conventional automatic controls, operators can take control of the plant at any time by taking over these automatic controls and other manual controls that underlie the computer system.

The computer controls the subloops and other controls through more than 500 contact-closure inputs and an equal number of outputs. The inputs keep the computer informed of the operating positions or condition of breakers, valves, motors, etc., and the contact-closure outputs operate these same devices per computer decisions.

The Prodac computer calculates and continuously displays the status of all key unit functions, and periodically, or upon the plant operator's command, prints out these data.

Among the unique features of the

1

Photo 1 This 325-mw super-pressure steam turbine, now in operation at Philadelphia Electric's Eddystone station, has the highest steam conditions of any machine in service. The unit went into commercial operation in February 1960. It is nearing the end of a starting program during which pressures and temperatures were increased in steps.

Presently the turbine is operating with initial steam conditions of 5000 psig at 1150, and two stages of reheat at 1050 degrees F. After a final inspection in the early part of 1961, the turbine will begin operation at its final design steam conditions of 5000 psig, 1200 degrees F, and 1050/1050 degrees F reheat.

The machine is serving as a base-load unit, operating at full load 24 hours a day.

2

Photo 2 This super-pressure turbine generator unit was placed in service by the Cleveland Electric Illuminating Company in December 1959. The machine is a tandem-compound, triple-flow reheat unit on a single shaft, and is rated at 215 megawatts, with a maximum capability of 250 megawatts. Steam inlet conditions are 3500 psig and 1100 degrees F, with single reheat to 1050 degrees F.

Except for the additional super-pressure element, the turbine is similar to a conventional three-cylinder single-shaft machine. A flexible coupling is used between the super-pressure element and the vhp-hp element to allow for differential expansion in the four-cylinder line up.

3a

3b

Photo 3 These photographs, taken in mid 1960, show construction progress of the Rocky Reach Hydroelectric Project of Public Utility District No. 1 of Chelan County, Washington. (a) This aerial view looking upstream shows final-stage construction of the dam and powerhouse. (b) Unit 4 generator, shown during installation, is the fourth of seven 107 000-kva waterwheel generators being installed. The machines will operate at 90 rpm with a head of less than 100 feet.

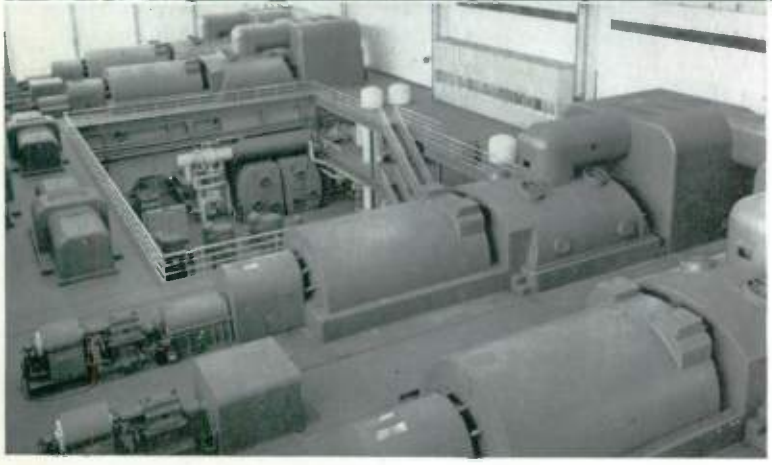


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Photo 4 These two "cross-quad" 3600/3600 turbine generator units, each rated at 290 megawatts, are now operating at the Bergen Generating Station of the Public Service Electric and Gas Company. Throttle steam conditions are 2350 psig and 1100 degrees F, with reheat to 1050 degrees F. These turbine generators are the prototype of a new concept in the design of cross-compound machines. An outstanding feature of the design is the high degree of component duplication on each shaft.

5

computer is a priority director, which enables the computer to switch automatically from one program to another, depending upon the urgency of any of the thousands of decisions that must be made by the computer.

Turbine designers are developing special turbine-generator sensing elements and operating mechanisms for automatic computer operation. Particular care has been taken to provide sensing elements that will be completely reliable, to prevent any possible false indications to the computer. Considerable engineering effort has gone into developing detailed logic diagrams, utilizing sensing elements and operators, to define turbine and other plant equipment operation under any possible combination of circumstances so that appropriate computing procedures could be developed.

The automated unit is scheduled to go into operation early in 1962. ■ ■ ■

Record-Breaking 3600-rpm Generators

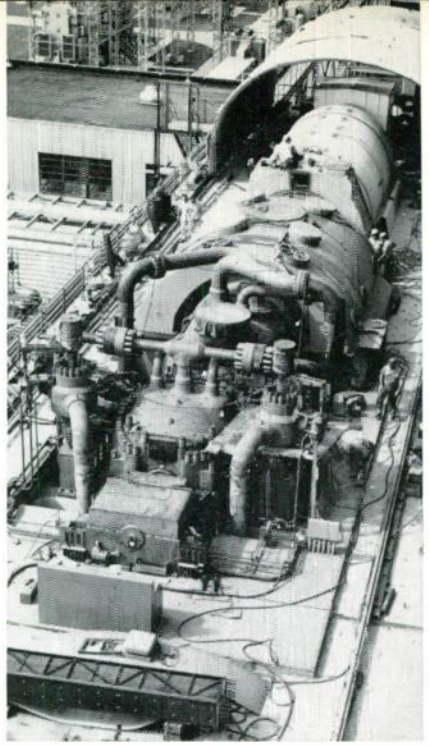
Two 3600-rpm generators will each be the nation's "largest" of this type at the time they go into service, probably in the first quarter of 1961. The first titleholder will be a 352-mva generator nearing completion on the Houston Lighting & Power Company's system. About two months after the Houston machine goes on the line, a 384-mva generator will go into service at the Helena, Arkansas station of the Arkansas Power and Light Company.

Steam conditions for the tandem turbines for these generators are 2000 psig, 1000 degrees F, with reheat to 1000 degrees F. The Arkansas Turbine will be the first tandem-compound machine with four exhausts; previous four-exhaust units have been of the cross-compound type.

Both generators will be inner cooled, with their design ratings corresponding to 45-psig hydrogen gas pressure. The generators are capable of operation at a maximum hydrogen pressure of 60 psig, which will permit an additional 10 percent kva output. ■ ■ ■

Turbine Improvements

The initial or control stage of a steam turbine has perhaps the most severe mechanical duty of any stage in the machine. At this point, steam is at maximum temperature, pressure, and density. Furthermore, to obtain maximum operating efficiency at part-load points, steam is admitted only on a portion of the rotor circumference. This partial admission creates high vibratory forces on the blades and a large transverse load on the rotor. The transverse load causes large rotor deflections and high bearing reactions.



352-mva turbine generator shown during construction at the Houston Lighting & Power Company's W. A. Parish plant.

For large-capacity machines, an innovation in turbine construction serves to alleviate one of these problems and practically eliminates the other. In this construction, the high-pressure turbine is built as a double-flow element. For a given load, steam flow is reduced and the resulting applied force on the first-stage blading is reduced to half that in a single-flow machine. More important, the height of the first row of blades is reduced to about one half of that which would be required in a single-flow machine. Reduction in height considerably raises the vibration frequency of the blades and reduces the bending stress on them. Both of these features greatly improves the ability of the blades to withstand vibration forces.

A second feature of the new construction is the arrangement of admission nozzles in the two parts of the control stage in such a manner that the two active arcs of admission are diametrically balanced. By this arrangement, the effect of the steam forces on the rotor deflection and bearing reactions is practically eliminated. This, in turn, allows the turbine to be built with smaller blade and gland seal clearances, smaller glands and smaller bearings. All these features result in a more efficient and a more reliable machine. ■ ■ ■

Trinistat Joins Mag-a-Stat

The Trinistor, a solid-state controlled rectifier, has won a place in the building-block program for regulator and excitation systems. Called the Trinistat regulator, the new regulator approaches the ultimate in speed of response, and furthermore, is more versatile in application. In building-block form, the Trinistat can be applied to regulate the voltage, current, power factor and kilovars of engine-driven, turbo and waterwheel generators—the position control of arc-furnace electrodes in response to impedance, voltage and current—the torque of synchronous motors, and other related equipments.

The Trinistat regulator consists of two new elements—a transistorized pre-amplifier circuit, and a power element to provide controlled power for regulating purposes.

The Trinistor, used in the power element, is a controlled solid-state rectifier, which performs like a thyratron; once the device is triggered, it loses control until the current is again reduced to zero. The Trinistor is controlled to fire at some point on the ac voltage wave, thereby providing controlled power.

The new unit is considerably reduced in size and weight, and is also more versatile in application than the Mag-a-Stat system. For example, the magnetic-amplifier system must use two control fields; the Trinistat system gets push-pull control into a single field circuit, and therefore does away with one control field.

Silicon components are employed throughout so that the unit is able to operate at high temperatures. Trinistors can presently provide outputs of 50 amperes up to 400 volts; 100 and 200 ampere Trinistors are expected in the near future. ■ ■ ■

TRANSFORMERS

New Insulation Made Still Better

Three years ago a new insulation system, called Insuldur, gave a big lift to transformer life. At that time,

the weakest link in the traditional oil-paper-varnish insulation used in transformers was the paper that provided layer and high-low insulation. Cellulose is sensitive to elevated temperatures, which eventually embrittle and weaken it. The new system used an organic stabilizing compound to react chemically with the cellulose fibers to make the paper stronger and longer lasting.

This year, engineers doubled the effectiveness of the Insuldur system, which allows temperatures as much as 30 degrees C higher than can be permitted with untreated insulation, with the same life expectancy. This means that one of two approaches can be used with transformers incorporating the new insulation system: utilities can either load the transformer more heavily for the same life expectancy, or at rated load the transformer will have much longer life.

The new Insuldur system is now being used on all oil-immersed 55 degrees C distribution and power transformers. With distribution transformers, the advantages of transformer overloading must be balanced against the cost of increased operating losses and voltage drop; therefore, the overload capacity of the pole-type transformer remains at 180 per cent of nameplate rating, but with the added safety factor supplied by the improved insulation system. For power transformers, the nameplate of all oil-immersed units will indicate a supplementary rating of 12 percent higher than the 55 degrees C rating.

As one example of the improvement brought about by this new insulation, engineers cite some impressive figures; after 100 hours at 170 degrees C, untreated insulation has only 15 percent of its initial bursting strength; the original Insuldur system is twice as good, with 30 percent of its strength remaining; the improved Insuldur system, however, still retains 66 percent of its original strength.

Hi-Load 65—One outgrowth of the new Insuldur system is a new distribution transformer designed to operate at 65 degrees C. This is a 25-kva unit, available in all voltage classes. The advantages of this new unit are not solely due to the higher capabilities of Insuldur insulation, even though this is a large factor. The copper-to-iron loss ratio has been reduced from 3 to 1 to 2 to 1; this means a lower impedance, which decreases the voltage drop in the transformer. This relieves the voltage limitation on loading. Another contributing factor is a new high-temperature insulating oil, with a higher flash and boiling temperature, which is compatible with existing transformer oils.

Despite its higher operating temperature, the new transformer, known as the Hi-Load 65, has the same thermal overload capacity—180 percent of nameplate—as the 55 degree C transformer. ■ ■ ■

This new distribution transformer is designed to operate at 65 degrees C, but has the same thermal overload capacity as the 55 degree C transformer.

A Giant to Test Giants

The ratings of power transformers continue to grow by leaps and bounds, and consequently they require even larger and more complex test facilities to check their capabilities after manufacture. A specific example is two huge new test transformers now under construction for the power transformer plant being built at Muncie, Indiana.

These test transformers have three windings. One is a 13.8-kv delta winding rated at 20 mva; the second is a 24-kv wye or reverse delta winding, rated at 125 mva; and the third is a 249-kv delta, wye or reverse delta winding rated at 125 mva.

The 13.8-kv winding is supplied by the generator. It can be varied from 34 to 68 turns in one-turn steps, thus giving a 2 to 1 variation in the voltages on the other windings. The 24-kv winding is connected to a capacitor bank which supplies the reactive power to the transformer under test. The winding has a wye-reverse delta switch so that single-phase voltages from 6490 to 42 210 volts can be obtained. On the wye position, three-phase voltages from 5620 to 36 560 volts can be obtained. These voltages are obtained by using the 13.8-kv winding, a 33-position URT load tap changer, and a five-position no-load tap changer. A total of 5775 different positions for three-phase voltages are available, and an equal number for single-phase voltages. The 249-kv winding will be connected to the load; i.e., the transformer under test.

The combination of switches and tap changers, all motor operated, make this one of the largest units ever built in physical size. The size is such that the lower portion, containing the core and coils, will be shipped by Schnabel car, while the upper portion containing the high-voltage switches, will be shipped on a depressed-center car. The assembled unit is about 16-feet wide, 34-feet long, 42-feet high, and weighs nearly 440 tons. It takes a lot of test transformer to check a power transformer! ■ ■ ■

New Load Tap Changer

In this country, the conventional method of limiting current when

switching between points of a high-voltage tap changer is to use a preventive autotransformer. A new tap changer uses resistors for this purpose, with some significant advantages. One advantage is increased contact life; but other important results are reduced losses, lighter weight, and smaller shipping dimensions.

This new tap changer is being incorporated on a 200-mva forced-air cooled autotransformer, to be used to step down voltage from 230 kv to 120 kv. In this case, the unit is 10 percent lighter and its shipping length is 25 percent less than the transformer with conventional tap changers using series transformers and preventive autotransformers.

The load tap-changing equipment is designed so that its electrical components are mounted with sufficient clearance to ground to allow the tap changer to be used for voltages as high as 138 kv. This is accomplished by mounting the transfer switches and switching resistors at the top of a porcelain bushing on the outside of the transformer. The selector switches are mounted at the bottom of the bushing in a separate oil-filled compartment on the side of the main unit. All connections, both mechanical and electrical, between the transfer switch and selector switch are made inside the porcelain bushing.

This new tap changer (type URH) not only provides reduced losses and subsequent saving to utility companies, but also makes possible shipment of some units that could not be shipped with the conventional arrangement of series transformers and preventive autotransformers. ■ ■ ■

Coils by the Half Dozen

Mechanization of any process is often thought of as merely a means of getting higher production and lower cost. Actually, the improvement frequently ranges far beyond this. A good example is a new multiple-winding machine for winding coils for dry-type distribution transformers.

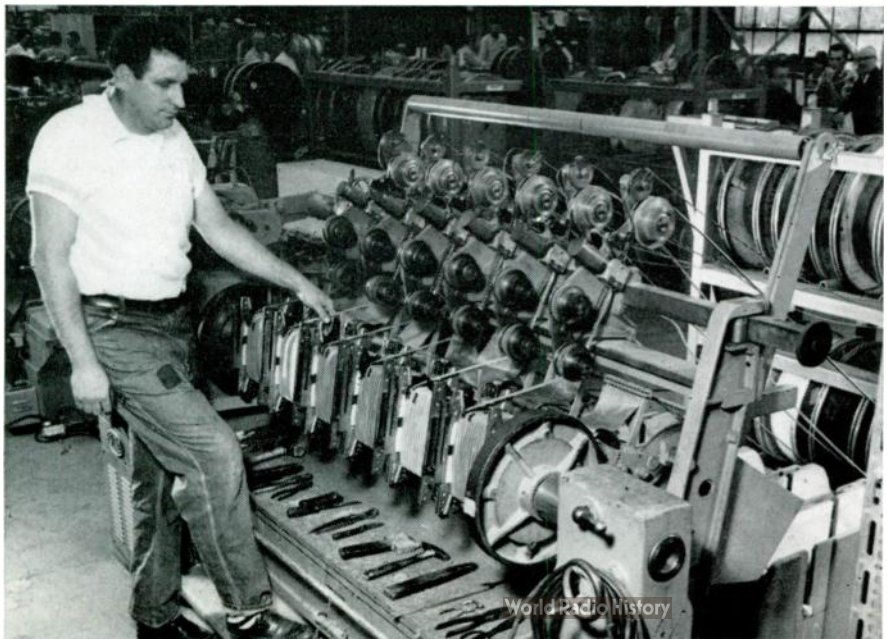
The original method of winding these coils was on a high-sided wooden mandrel; the glass-insulated conductor was manually traversed across the winding space of the coil. The conductors were fed to the coil from round reels of wire, and since the wire tends to revert to its previous shape, the coil itself tended to assume a rounded shape unless held in place. This was accomplished by blocking it into the desired rectangular shape with wood. Subsequent impregnation and curing held the coil in its proper form.

With the new multiple-winding system, six coils are wound simultaneously. The tendency of the coil to revert to a round shape is prevented by forming the conductor over and under back-bending rolls, which bend the conductor slightly in a direction opposite to its coiling direction, thus, in effect, feeding "straight" wire to the coil. Coils wound on the new machine do not require blocking and do not depend upon impregnation to retain their size and shape.

An attendant advantage to this multiple-coil winding process is the greater uniformity of winding, compared to the manual process. With a mechanical traverse system, each conductor can be laid precisely in the proper position, regardless of the number of turns, thus leading to a more consistent end product.

The new multiple-winding technique is now being used on 600-volt coils, used on 25-kva single phase, and 30-, 45-, and 75-kva three-phase dry-type transformers. ■ ■ ■

This machine is now being used to wind coils for dry-type distribution transformers.



A New Method of Voltage Regulation

The results of a thorough study of voltage regulation in distribution systems, undertaken in 1959, led this year to a new method of regulation plus a new regulator. The new system involves increasing the bus voltage at the distribution substation from 125 to 129 volts at peak load, then applying *bucking* voltage regulators at each distribution transformer out to the point on the feeder where the voltage drops to 125 volts. At each regulator, the voltage is bucked down to 122 volts. This method requires fewer regulators than would be required if units were placed further out on the line to boost voltage where necessary; in a typical case, only 12 bucking voltage regulators are required, as opposed to 60 if the boosting regulation method had been used.

This bucking method of regulation required a new device. The only existing method of accomplishing this was the voltage-regulating transformer, which has the regulating mechanism as a basic and integral part of the transformer. This type of design has two drawbacks: because of the integral tap-changing mechanism, the design is more complex; and a utility company must stock two different types of distribution transformers in a variety of ratings and voltage classes. The new device, called the Unoreg regulator, is completely separate from the transformer case; and it can be applied to almost any distribution transformer no matter what the primary feeder voltage, transformer, type, or kva rating. In fact, just two regulators provide the full range of regulation for over 602 different styles of transformers built in eight kva ratings and many voltage ratings.

While the new regulator was designed specifically to fit the needs of bucking voltage regulation, it is by

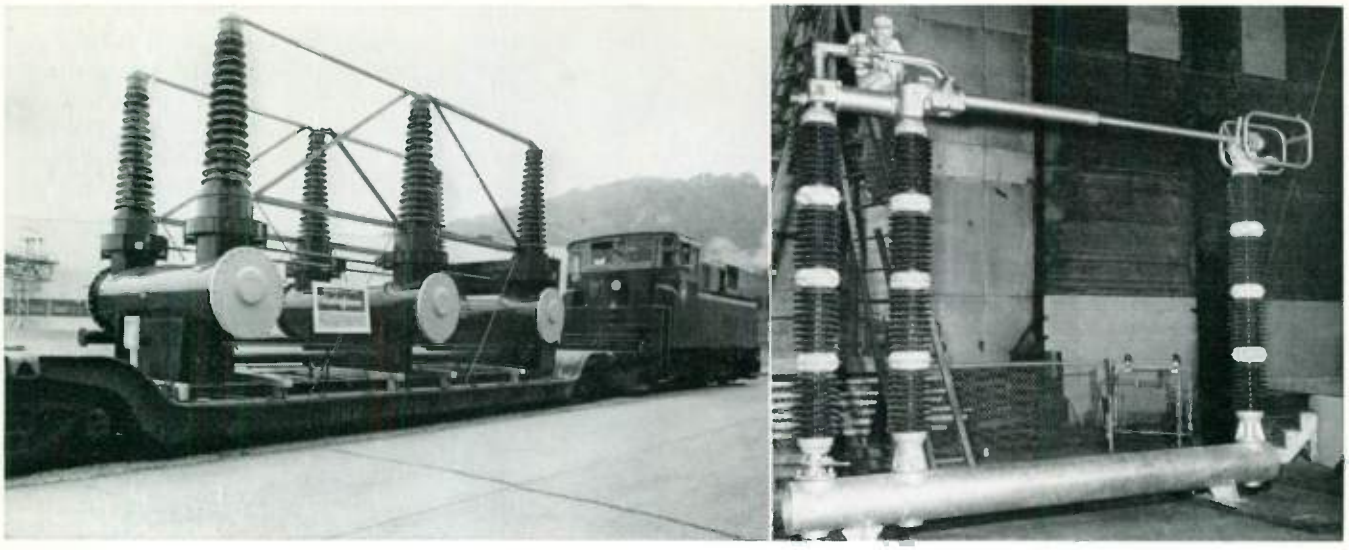


Photo 1 Shown at the beginning of a rail journey to Pennsylvania Power & Light Company, this 230-kv, 15 000-mva SF_6 circuit breaker is the largest rating ever to be shipped fully assembled, with bushings in place.

Photo 2 This is the "heavyweight" of a new line of V-2 outdoor disconnect switches—a 345 kv unit, rated at 1600 amperes continuous current. This switch was designed with two purposes in mind; namely, to minimize field installation expense and to reduce operating effort and maintenance. The V-2 line of switches is available from 7.2 kv through 196 kv with current ratings of 600, 1200, and 2000 amperes. The new design has several outstanding features. First, teflon impregnated bearings are used on the live side of the switch to assure low operating effort and minimum maintenance for the life of the switch, even in corrosive atmospheres. Secondly, a "reverse loop" break jaw configuration insures positive electrical contact during fault currents to prevent contact burning. Third, the break jaw is made from zirconium copper, which has doubled the conductivity of the previously used beryllium copper, yet will retain spring pressure under high temperature. Silver alloy inserts are brazed onto these break jaws.

The V-2 can be converted to a load break switch in the field with the addition of an interrupter unit and auxiliary blade.

no means limited to this use. The regulator can be applied equally well to boost low voltages at the end of long and heavily loaded feeders, or to improve service for those customers with erratic voltages. ■ ■ ■

SWITCHGEAR

Interrupting With Gas

The SF_6 line of high-voltage circuit breakers is fast taking shape. Over 75 breakers for ten different utilities are now in various stages of completion, in voltage ratings ranging from 46 to 230 kv. Herewith, a list of "initial installations" for each voltage rating:

The first 230-kv breaker was installed at the Pennsylvania Power & Light Company's new Brunner Island Steam-Electric Generating Station in October 1960. This was the first order from a utility that specified the use of SF_6 as the interrupting medium in a high-capacity breaker. Pennsylvania Power & Light will use the breaker as one of two (the other is a conventional oil circuit breaker) to protect 45 miles of 230-kv transmission circuit. The breaker will have an interrupting rating of 15 000 mva, maximum current of 39 000 amperes, and a continuous load current capacity of 1600 amperes. This is also the first 230-kv breaker of any type to be shipped completely assembled with bushings, interrupters, and operating mechanism in place.

As we go to press, a second SF_6 230-kv circuit breaker is being installed for field testing at the Lanuna Bell station of the Southern California Edison Company.

Working down the voltage ladder, 161-kv SF_6 breakers, rated at 15 000 mva and 3000 amperes normal load current, are being built for the Tennessee Valley Authority.

Also shipped and installed in 1960 were 138-kv, 10 000-mva SF_6 circuit breakers at the Hell Gate Station of the Consolidated Edison Company of New York.

Next comes the 69-kv, 5000-mva SF_6 breakers for the Cincinnati Gas and Electric Company. The interrupters for this rating are based on the same module used in the 138- and 230-kv SF_6 interrupters.

Rounding out the line of SF_6 ratings is a new line of moderate-mva breakers, using a puffer-type interrupter, in voltage ratings from 34.5 to 69 kv. Features have been borrowed liberally from the higher-voltage SF_6 designs; individual horizontally mounted pole units are tied together mechanically, closed by a single pneumatic mechanism and opened by a spring. "Dead-tank" construction is used; each pole unit consists essentially of a grounded steel tube, which houses the interrupter, with the current-carrying studs brought out of each end through porcelain weather casings. The entire pole unit, including the porcelain, is filled with gas at 45 psig, which is sufficient for both insulation to ground and interrupting duty. The puffer-type interrupter forces gas through the orifice, where it mixes with the arc and interrupts it.

Full-scale interrupting tests have been performed in the High Power Laboratory on a 46-kv prototype. A number of tests up to and above the 500-mva rating have been made, with a maximum interrupting time of 3.5 cycles, well within the 5-cycle time assigned to this rating.

The first 46-kv, 500-mva SF_6 breaker of this type is scheduled for installation on the Georgia Power Company system in mid-1961. ■ ■ ■

Load-Break Switch vs. Faults

The LCB load-break switch for plant distribution systems has been modified to handle fault currents if accidentally closed against a short circuit.

The switch was originally designed to operate under normal load conditions of 600 amperes at 5, 7.2, and 14.4 kv. However, users have emphasized the need for a load-break switch capable of closing against fault currents. This situation could arise, for example, if a maintenance workman should accidentally leave a grounding chain connected. The modified design, designated the LCB-2, can close into faults up to 40 000 amperes.

To handle fault closing, the switch had to be designed to slam shut in a hurry. This was accomplished by modifying the contact structure and the spring-operating mechanism. The new switch is a unitized assembly of pole units, frame, and mechanism which can be mounted in a standard indoor metal-clad cell. ■ ■ ■

Low-Voltage Distribution

A prefabricated recloser feeder structure provides, in one package, the low-voltage side of a 15-kv distribution substation. It includes a structural aluminum frame, a PR recloser with drawout contacts for disconnecting it, bypass devices, lightning arresters, provisions for instrument transformers, plastic-coated bus, and a takeoff for the feeder circuit. A 5-kva distribution transformer can be mounted, if required, to provide 240 volts for operating the recloser mechanism. The factory-assembled package provides a compact and economical installation and saves the user the necessity of providing separate installations to perform the same functions.

A type LV distribution-class lightning arrester incorporates a nonexplosive drop-out at the ground stud to disconnect the arrester in the remote event it is damaged by lightning or some other cause. The arrester has a Mobilarc gap structure similar to that of station-class arresters and a new valve element. These features are assembled in a unit that is smaller and lighter than the previous distribution-class arrester. The arrester is made in standard ratings from 3 kv through 27 kv.

The new type LBU loadbreak open cutout combines the usual protection against overloads and short circuits with a design that permits repetitive manual breaking of the load current without destroying fuse links. Previous load-break open cutouts functioned by breaking the fuse link when operated manually; the new unit has a flipper blade, actuated by opening the cutout, that passes through a narrow slot in the arc chute where interruption is accomplished. The cutout's rating is 15 kv, 100 amperes continuous when fused, and 200 amperes with disconnect blade. ■ ■ ■

MEASUREMENTS, DISPATCH, PROTECTION

Accurate Reliable Telemetering

Recognition of the stringent control channel requirements of automatic dispatching systems for electric utilities has resulted in the development of a new telemetering transmitter and receiver. This new equipment meets the need for more accurate, highly reliable telemetering.

A dc millivolt signal from any sensing device is fed to the transmitter and converted to a proportional-frequency signal in the range of 15 to 35 cycles per second. The remote receiver converts the signal back to a dc milliampere or millivolt signal. Typical quantities transmitted in an automatic dispatching system are station control signals, station powers, VAR outputs, and bus voltages. In the latter case an expanded scale is used so that 25 percent of voltage range is 100 percent of channel width.

This new telemetering system is extremely accurate, stable, and reliable. The overall accuracy of the transmitter and receiver is one percent.

The transmitter and receiver are completely transistorized, with all critical parts mounted on printed circuit boards. The printed circuits employ double printing on front and back of the board so that any failure of a single connection or joint will not disrupt operation. The equipment is readily serviced from a swinging rack, and contains a built-in calibration circuit for testing the overall channel at the 10 and 90 percent range points.

The first application of the new dispatch control transmitter and receiver will be on the automatic dispatching system now being installed on the Cleveland Electric Illuminating Company system. ■ ■ ■

More TBS Instruments

Two years ago, the taut-band suspension principle was introduced by Westinghouse on 250-degree dc switchboard instruments (KX-241). The permanent-magnet moving-coil mechanism has proved particularly successful for applications that require top-grade performance under adverse conditions of shock and vibration. This year, an attraction-repulsion iron movement employing taut-band suspension has been introduced for ac instruments (KA-241). The new movement is being extended to 100-degree ac and dc instruments (KA-251 and KX-251). The 100-degree dc mechanism (KX-251) will be a completely self-shielded core-magnet design, which provides shielding from magnetic fields up to 500 gausses.

In the two years' experience with the KX-241, several thousand instruments have been installed. Field experience has proved what life tests had already indicated—that field service requirements are extremely low. In life tests, the mechanism is energized to full scale and returned to zero about every two seconds; no deterioration in performance has appeared after over 18 million operations. In the same test with conventional pivot-and-jewel movements, excessive friction develops after about ¾-million operations.

The frictionless principle of taut-band suspension has changed instrument design philosophy. In pivot-and-jewel mechanism, weight determines bearing friction, so that the torque-to-weight ratio is of paramount importance. With the new mechanisms, friction is not a factor, so that designers can concentrate on the torque-to-inertia ratio, which determines response time. By use of low restraining torques and low inertias, extremely high sensitivity can be built into instrument mechanisms. Where the practical limit of sensitivity for pivot-and-jewel mechanisms was about 20 micro-amperes for full-scale deflection, taut-band mechanisms are being built with sensitivities of 2 micro-amperes for full-scale deflection.

For Low Power Factors—Taut-band suspension has been put to use in a supersensitive watt-measuring instrument, which might be described as a "galvanometer with feedback."

The device consists of an electro-

dynamic torque-producing mechanism and a dc balancing element, all mounted on the same shaft and utilizing taut-band suspension. When the electrodynamic element is energized, a deflection from the balance position produces an error signal in a photoelectric detecting system, which in turn causes a current to flow in the dc balancing element to develop opposing torque to the electrodynamic element. The magnitude and direction of the balancing direct current required is proportional to the power flow in the measured circuit. This direct current can be used to operate read-out instruments and recorders or telemetering transmitters. Taut-band suspension provides a movement with unlimited resolution—no "dead band" areas.

The sensitive device is particularly suited to low power factor measurements—2 to 20 percent—where normal wattmeter movements cannot function accurately.

The instrument is being developed initially for two applications: measurement of transformer core losses, and measurement of corona loss on high-voltage transmission lines. ■ ■ ■

More Versatility for K-Dar

The K-Dar compensator relay family, now going into its third year of application, continues to grow. Herewith, a summary of this year's additions:

The basic directional-distance relaying method remains the same—compensators (essentially air-gap transformers) vectorially add system voltage and current at the relay point, and apply this resultant voltage to a high-speed induction cylinder (which functions like a polyphase induction motor); the cylinder develops closing or opening torque depending upon the type and location of the fault.

Since the induction cylinder operates instantaneously, some auxiliary means is necessary to provide time delay for tripping zones 2 and 3. In the past, this delay was accomplished with an ac timer. This year, a static timing system was developed (TD-4); the actual timing circuit is a dc resistance-capacitance network, and the final tripping action is performed by an auxiliary relay contact. The TD-4 relay provides adjustable time delays of 0.1 to 3.0 seconds with improved accuracy over the previous ac version.

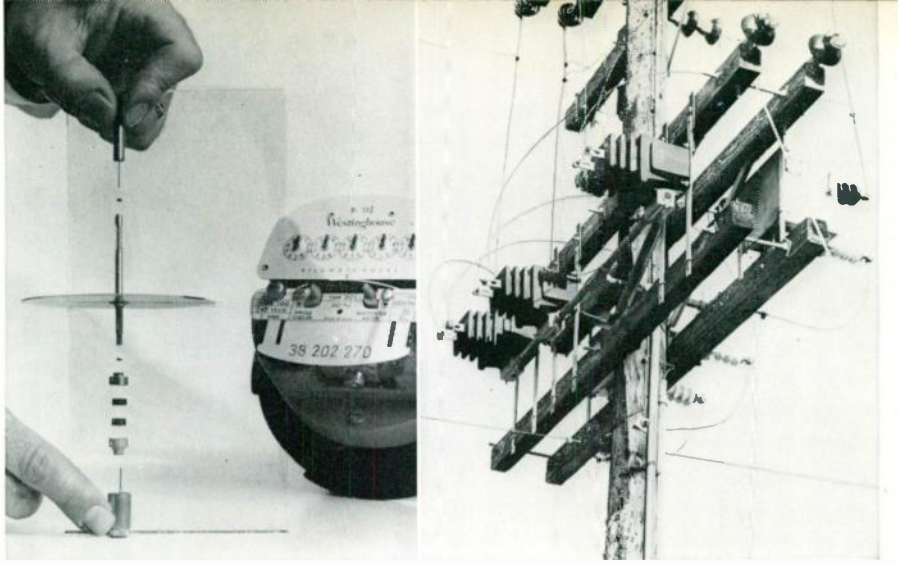


Photo 1 Type D2S Class 200 watt-hour meter, with its magnetic thrust bearing components exploded at left. From top to bottom are the upper mount with its guide pin, upper guide journal, disk and shaft assembly, lower guide journal, upper magnet cup, upper magnet, lower magnet, lower magnet cup, and lower mount with its guide pin.

Photo 2 Indicative of the continuing trend to molded current transformers, this new 15-kv unit replaces a steel fabricated design. Developed in current ratings of 10/5 through 800/5 amperes, the new transformer is smaller and lighter than the previous design, yet has 50 percent more overload capacity. The molded construction reduces maintenance by eliminating the possibility of broken bushings, as well as the need for painting. The unit, type CTOM-15, has a 1 5 rating factor through 600 amperes.

The K-Dar compensator principle has also been applied to generator loss-of-field protection in the new KLF relay. The KLF relay has a wider range of application. This provides increased protection against partial reduction of excitation which causes the machine to exceed its capability. Both alarm or trip features have been provided. ■ ■ ■

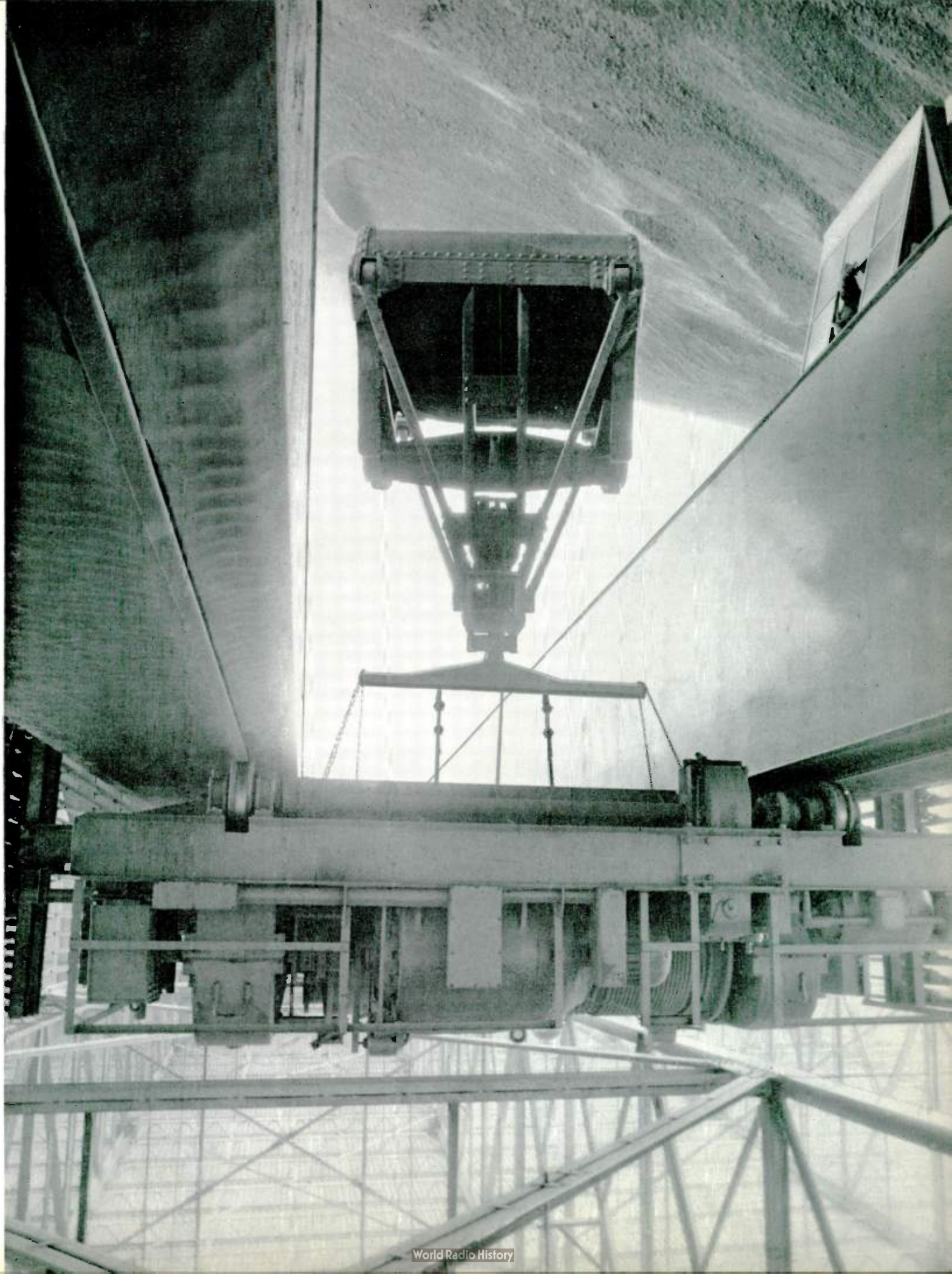
Magnetic Thrust Bearings Support WattHour Meter Rotors

A magnetic thrust bearing in the new Westinghouse single-phase watthour meter supports the meter's disk and shaft assembly in space. Replacing conventional ball-and-jewel bearings, the Magnethrust bearing system reduces friction to a negligible value and gives meters maintenance-free service lives of at least 30 years, ability to withstand shock and vibration well above the levels encountered in transportation, immunity to environmental changes, and tolerance for off-vertical installation.

The magnetic bearing system consists of two ring-shaped barium ferrite magnets in steel flux-return cups, one in the lower bearing mount and the other on the rotor shaft. When assembled, the magnets are in repulsion and about 0.020 inch apart. The combined effects of the small air gap and low flux leakage produce high magnetic efficiency, vertical stiffness, and little susceptibility to external magnetic fields. Guide bearings at the upper and lower ends of the rotating element restrain driving-torque side thrust. They consist of polished steel pins secured in the mounts and graphite journals inserted in the shaft.

The magnetic bearing is made possible by the exceptional magnetic strength and stability of barium ferrite, a ceramic material made by sintering barium carbonate and iron oxide. Barium ferrite's coercive force is about 1800 oersteds—two to three times that of the best alnico materials—and it is the only known material that has full magnetic stability at its greatest magnetic strength. Another important property of barium ferrite is that it is practically impossible to decrease its magnetic strength appreciably by current surges, tampering, or other service hazards. The material's chemical inertness, insensitivity to temperature, low density, and high electrical resistivity also suit it to use in watthour meters.

Magnethrust-bearing meters are made in ratings of 120, 240, 480, and 600 volts and 2.5, 15, and 30 test amperes. They are designed to accommodate loads up to 667 percent of meter rating.



DRIVES AND CONTROLS

Automatic Controls for Metalworking

Automatic controls continue to be the big news in the metalworking industries. They range from those that control the flow of raw materials to those that control the processing of metals into their final form.

One example is an automatic control for a blast furnace stockhouse. This directs the flow of solid materials from a number of bins, over conveyors, and into blast furnace "skip tubs" according to prearranged programs. The control system also prepares a punched tape and a typewritten record of the charging. Heart of the new stockhouse control is a transistorized logic system that is teamed with the motor control center.

A continuous roughing mill in Michigan will have its positioning functions accomplished by Prodac controls. This continuous roughing train consists of a 1500-hp scale breaker, and five roughing stands, two rated at 5000 hp each and three rated at 10000 hp each. Prodac controls will position the roughing mill screwdowns, edger adjustments, and sideguards, as well as the entry scale breaker. The rapid response of the positioning controls is an outstanding feature. This is amply demonstrated by the fact that two slabs, each requiring different settings, can be processed at the same time through the roughing mills.

A 134-inch reversing universal plate mill is scheduled to be the first mill of this type to combine on-line process computer control with punched-card programming. The mill will be programmed for rolling schedules up to 15 passes by a Prodac control system similar to those now operating in other metalworking processes. The digital computer is a newly developed system for industrial on-line production.

The computer will monitor roll pressure and x-ray thickness gauge measurements to automatically determine mill settings before each pass. This involves collecting data and predicting by computation the roll pressure settings for succeeding passes so desired product thickness is obtained. The computer will also automatically control slab elongation in a single-pass roughing stand to control width of skelp that will be furnished by broadside rolling in the reversing mill.

The Prodac control system will automatically direct the positioning of the roughing and main mill screwdowns, side guides, and edger adjustments once information from the punched cards is passed to the control system; it will also control mill and table speed, draft compensation, and cycle operation. The system is so designed that an operator can assume manual control at any point in the rolling cycle and then return the operation to automatic control to complete the sequence.

An automatic gauge control for a two-high nonreversing cold mill will maintain gauge within plus or minus two percent, based on thicknesses between 0.005 and 0.120 inch. The system controls gauge by two methods: the tension at the unwind reel will be automatically varied to maintain gauge over a limited range; and screwdown action will be automatically initiated to maintain gauge when correction obtained by tension control approaches a limiting value. The thickness error signal, obtained from an x-ray gauge, is fed through a preamplifier and then to an integrating amplifier. The signal then goes to a power amplifier, which provides the correction signal to the payoff reel tension regulator. When the tension adjustment approaches a limit, the screwdown control is automatically made available to correct the error. Either tension control or screwdown control can be selected, or a combination of both, by the operator, depending upon the rolling schedule. ■ ■ ■

Left This 22-ton overhead traveling bucket crane handles raw materials in a cement plant. The control for the crane is contained within the hollow bridge girders (see story, p. 14).

Section II APPLICATIONS OF POWER

Digital Control For Paper

Introduction of the Pulsetter control system marks the first use of digital speed-regulating systems for paper mills. The new system provides overall machine steady-state accuracy of 0.01 percent and section-to-section accuracy of 0.025 percent under normal papermaking conditions.

Paper-mill section speeds have heretofore been controlled by systems that are basically analog in nature—a regulator compares a continuous signal whose magnitude is proportional to the actual system speed with a reference signal whose magnitude is proportional to the desired speed. Voltage generating tachometers and reference voltage generators in such systems are subject to inherent drift that limits the system accuracy to about 99.9 percent. While this is excellent accuracy in many applications, it is not as good as desired in modern high-speed paper-making machines.

The Pulsetter control system compares a pulse signal that is proportional to actual section speed with a reference pulse signal. The comparison is made pulse to pulse, without regard for pulse magnitude. Transistors are used as static switches, always operating in an on-off mode, rather than as voltage or current amplifiers of signal magnitude. Because of these features, the system is inherently free of the variations in gain, temperature, and drift that affect an analog speed feedback system. The Pulsetter regulators provide the field excitation for each section's generator, adjusting the generator voltage to keep the section motor speed at the proper value.

The Pulsetter control system is being installed in the New York and Pennsylvania Company's Johnsburg, Pennsylvania mill as part of a new drive system that replaces a drive originally supplied by Westinghouse in 1926. The revamping increases the capability of the drive to a top speed of 1400 fpm maximum against a previous limit of 650 fpm in the past. ■ ■ ■

Digital Measurements

Digital techniques have been employed to provide draw, speed, and length measuring equipment for paper mills with accuracies that were previously possible only under idealized laboratory setups. The first installation of the digital draw and speed indicator was made at the Pensacola Mill of the St. Regis Paper Company early in 1960. Accuracies on this installation are 0.1 foot per minute for speed measurement, and 0.2 fpm for draw measurements. A digital footage counter on the machine winder is accurate to plus or minus one foot, with a capacity of 99 999 feet.

Both the digital draw indicator and the footage counter count pulses magnetically from a notched wheel connected to section drive shafts. Since the method is completely digital, the equipment is completely free from errors due to drift in component properties and component non-linearities, and does not need frequent calibration checks. Numerical readouts are displayed in one-inch high numerals on the face of the control unit.

This degree of accuracy enables machine operators to set the machine up completely for a given grade of paper from settings previously determined, with a minimum loss of running time. Previously, machine setups were a time-consuming operation. ■ ■ ■

Starter Without Contacts

In the development laboratory of the general purpose control department, a two-hp ac motor starts up under full load, runs for five seconds, shuts off for five seconds, then repeats the cycle without interruption. The only sound is the hum of the motor as it starts and runs. As of September, the motor had been repeating this on-off cycle for two-thirds of a year and had completed over a million and a quarter cycles.

A routine life test? Far from it. This is a laboratory test of a completely static motor starter, with no contacts to be closed and opened. In fact, had it been a conventional starter, the contacts would in all likelihood have already been replaced at least once, and possibly several times.

The experimental starter uses the newly developed Trinistor controlled rectifier as a switching device, and therefore requires no contacts. In addition to the potential reduction in maintenance, the new control is quiet in operation, which may be an important advantage in certain defense applications.

A particularly attractive feature of this starter is its capability where interlocking is required; for example, under- and over-voltage protection could easily be applied directly to its Trinistor circuitry. Also the control can use low-energy signals, such as from a computer. The Trinistor motor starter thus is eminently suited for computer-controlled systems, such as in steel mills, chemical plants, automatic steam plants, or in remote operation of pipelines.

While this new motor starter is still in experimental stages, it holds considerable promise as the first all-static motor starter. ■ ■ ■

Huge Crane for Cement Plant

Load-O-Matic crane control tackled its biggest job last year, but in a most unobtrusive fashion. The control handles the operation of a 22-ton overhead traveling bucket crane, but only the most perceptive observer would spot the control—it's tucked away inside the hollow bridge girders of the huge crane.

The system controls the trolley and bridge drives, as well as the hold and "close bucket" drives for a crane that handles raw materials in a cement plant of the Dundee Cement Company. The complete crane is 150 feet long, weighs more than 235 tons, and travels at 450 feet per minute. In its cycle of handling raw materials, a typical 80-second cycle consists of closing the bucket, hoisting 35 feet, trolleying 60 feet, bridging 70 feet, lowering the full bucket 35 feet, discharging the load, and then returning to the starting position in reverse order. Many of these operations are overlapping, which means the operator must control four drives simultaneously. This puts a premium on quick response and smooth operation of the control, as well as ability to respond to the position of the master switch automatically regardless of load.

Two 200-hp motors power the hold and close drives, four 75-hp motors the 150-foot bridge, and two 40-hp motors the trolley. All motors are totally enclosed, fan cooled to protect them from the abrasive dust present in the atmosphere. ■ ■ ■

Static Crane Control Manages 600-Ton Loads

Handling loads of nearly 600 tons with great accuracy is the task of a unique gantry crane at the Niagara Power Project, where 13 waterwheel generators rated at 150 000 kilowatts each are being installed in the new Robert Moses Niagara Power Plant. (See page 2.) The precision-machined generator rotors alone weigh 590 tons, so a high-capacity crane is required for installing and servicing the generators, their turbines, and associated equipment. The crane was built by Milwaukee Crane Division of Novo Industrial Corporation. It travels on steel rails along the power plant's generator deck and can be positioned over each generator pit.

The steel crane structure is 70 feet tall, 63 feet wide, and 95 feet long. Near its top are two main-hoist trolleys mechanically connected to function as one. Each trolley has a single hoist with an 84-inch drum driven by a 150-horsepower wound-rotor motor, and these two hoists support a lifting beam. The hoists are operated by Load-O-Matic controls that use saturable reactors instead of contactors in the motor primaries for current control. The reactors provide stepless speed control, permit static reversing, and enable the hoist motors to do 95 percent of the braking. Both controls can be operated by a common switch in the control cab, or they can be operated independently to level the beam. This main hoist is rated at 630 tons capacity (including the weight of the lifting beam) and has been tested at 750 tons.

A monorail hoist supplements the main hoist for handling light loads. Two track loops in the gantry structure enable this hoist to travel over any part of the working area, and a monorail boom can be swung out to permit the hoist to transport material into or out of the gantry. ■ ■ ■

Hoist Drive With No Regulator

The usual method of improving the performance of a drive system is to add control functions. As a rule, this accomplishes the desired results, but at the expense of added complexity and potential maintenance problems.

Control unit of the digital draw and speed indicator at the Pensacola Mill of the St. Regis Paper Company.

In a new cargo-hoist drive, superior performance has been achieved by incorporating different features into the rotating machines themselves and by some new circuit concepts. This new adjustable-voltage drive is nonregulated, in the sense that no regulator is required; the necessary characteristics are incorporated in the drive itself.

The basic components of this cargo-hoist drive are: a three unit m-g set, consisting of two dc generators and one ac motor (this set serves two winches); a control cabinet, which is mounted on the m-g set; a compound-wound dc motor; a self-adjusting brake; and a five-point master switch.

The first three points on this master switch are basically speed points. On any of these three points, the hoist will lift any load within its ultimate capability, at the relative speed chosen by the operator. The motor will not stall under heavy load on any point. The fourth and fifth points are essentially constant horsepower settings, designed for high speeds for light loads, and slow speeds for heavy loads.

The speed changes on the first three points are accomplished by a special bridge circuit, which permits a small percent of load current to flow through the generator series field in a cumulative direction, thus raising the generator voltage. For the fourth and fifth points, the circuit allows part of the load current to flow through the generator series field in a differential direction.

In the lowering direction, the load becomes overhauling and the hoist acts to restrain fall. However, at the start of the lowering operation power flows to the motor to accelerate it; thus the hoist drive acts as a motor operating in the reverse direction until the armature is up to speed, at which point the power reverses its flow and regenerative braking occurs.

The new hoist drive has been tested under all possible conditions of failure, including simultaneous brake and ac power failure. Even under these extreme conditions, within one and a half seconds after power failure, the speed of the load was reduced to about 40 fpm. This is the equivalent of dropping the load from a height of less than one-tenth of an inch, slow enough to lower any cargo to the deck safely.

Other features of the new drive are a motor with exceptionally low inertia, which allows rapid acceleration and deceleration; and a generator with low field time constant, which enhances the speed of response during rapid movement of the master switch handle.

The new drive was developed for fast loading and unloading of cargo aboard ships; however, its basic features make it suitable for use in other applications where rapid movement of loads, precision handling, and high reliability are important—such as docks, power house, shipyards, foundries, and similar installations. ■ ■ ■

MOTORS

Motors Get More Versatile

As a highly developed mechanism, the electric motor is seldom characterized by radical changes in a short period of time. Nevertheless, the year-by-year improvements are impressive, and motor engineers continue to wring greater usefulness out of their product. Consider a few examples.

Totally enclosed, fan-cooled dc motors and generators of the Life-Line H class now have a 20 percent greater heat dissipating ability, with the result that more horsepower can be packed in a given size. As a matter of fact, 48 out of 57 ratings are now built on a smaller frame size, and some of these are two frame sizes smaller.

Two separate blowers are involved in the new design. One is an internal blower, which circulates air around and through the armature, and across radial fins at the shaft end of the motor. This heat passes by conduction to the exterior of the enclosure, where it is dissipated by interrupted circumferential fins. An external blower removes this heat, as well as circulating air over the exterior of the motor.

The new motors are designed for both constant-speed drives and drives involving fast, wide speed changes and reversals, automatic control, or close regulation. Motor ratings range from ½ to 60 hp at 300 to 3500 rpm; generators are rated from ¾ to 40 kw at 850 to 3450 rpm.

Developed originally as an insulation for large turbine generators, Thermalastic insulation has since found its way into large motors, and, this year to ac motors in the 200 to 700 hp range. Use of this insulation in these motors means that open or splashproof motors can be used in many applications where enclosed motors were formerly required.

The increasing use of high-frequency heating and melting of metals has led to increasingly large motor-generator power supplies. This year three new ratings were developed: 350 kw at 960 cycles; 300 kw at 3000 cycles; and 350 kw at 10 000 cycles. Engineering problems involved in these generators largely concern bearings, insulation, and cooling methods. Special greases and bearings were necessary to solve the problems occasioned by the large size and weight of the armature. Silicone insulation is used to permit maximum output capacity. And special cooling methods were required to assure that the rotor and stator are maintained at the same operating temperature, because air gaps in these high-frequency machines are unusually small. ■ ■ ■

Permanent Magnets Replace Field Coils

Run-out tables in steel mills may require hundreds of motors to power individual rolls. New run-out table motors with permanent magnet poles offer an excellent way to reduce overall mill costs.

With conventional motors, each unit must be supplied with dc power for the main field coils as well as for the armature—which adds up to a lot of wiring and conduit. The amount of wiring and conduit is reduced by using permanent magnets instead of field coils because the permanent magnets require no separate field excitation. And because there are no fields to supply with dc power, the size of the main m-g set can be reduced. Equally important, no field loss relay is required. Required control is simplified and reduced in cost.

Run-out table motors built with permanent magnets are available with all the special features normally available on conventional run-out table motors. These motors are available in ratings from ½ to 5 hp with base speeds of 575 or 750 rpm. They are rated 240 volts dc and are suitable for adjustable-voltage operation. ■ ■ ■

CONTROL AND DISTRIBUTION DEVICES

More Rating, Same Size

In any phase of equipment design, packing twice the rating of previous designs into the same physical size is quite an undertaking. But this has been done with a new oil-immersed contactor, the Type K, which has twice the continuous and interrupting rating of its predecessor.

The basic change has been in the contact structure design. Instead of the usual vertical mounting, the Type K design has its contact structure mounted horizontally. The advantage here is in the contactor's operation during interruption. In conventional contactors of this size, the arc travels vertically, and the vaporized oil bubble formed during interruption is actually partially above the oil level in the contactor. In the new unit, this bubble of vapor is completely under the surface of the oil; this reduces the potential damage to gaskets by the "explosive" force of oil at the surface, possible with the old design.

The continuous rating of the new Type K contactor is 400 amperes and 5000 volts maximum. Interrupting rating is 50 000 kva at 2300, 4160, or 4800 volts. ■ ■ ■

Duplex Circuit Breaker

With the physical sizes of load-center boxes standardized but the use of electricity in homes and in other buildings increasing, a need has developed for increasing the number of circuits that a box of given size can accommodate. An effective solution is putting two circuit breakers into the space normally required by one industry-standard single breaker. Such a unit has been developed, and through careful design all the protective, durability, and reliability features of the larger breakers have been included.

The new duplex breaker—type BR—has two electromechanical breaker mechanisms separated by a partition. Each mechanism protects its circuit two ways: a time-delay bimetal trips the spring-actuated circuit-opening device for ordinary overload protection, or a magnetic actuator trips it instantly at about 10X rating. The breakers are ambient-temperature compensated to protect against environmental influences. Operating handles indicate by their positions whether the breakers are turned off, turned on, or tripped. The handles are color coded to identify each unit's rating.

The new breakers are listed by Underwriters Laboratories in ratings of 15/15 amperes, 20/15 amperes, and 20/20 amperes at 120/240 volts alternating current. ■ ■ ■

Low-Voltage Control Equipment

Circuit breakers made further progress in the compact design trend with the introduction of two AB Deion breakers that are smaller than their predecessors yet have the same ratings. The Type JA 225-ampere breaker is intended primarily for wire protection and for mounting in panelboards, switchboards, and unit enclosures. It replaces the larger Type J breaker. The Type MA 800-ampere breaker, designed to replace the larger Type LM breaker, gives short-circuit and time-delay protection for network branch wiring. A unique feature of the 700- and 800-ampere MA ac units is that the thermal time-delay heater element responds to a combination of iron loss and shorted transformer action. The heater consists of an unlaminated iron core over which an annular copper ring is wrapped; the bimetal is riveted to the ring and core. When alternating current flows, the core is heated by eddy currents and the ring by circulating current in the coil. This is the first application of such a heating principle to small breakers.

Hynetic (for hydraulic magnetic) circuit breakers were developed especially for protecting electronic components. This breaker's time delay results from the time it takes a magnetic force produced by current overload to seat a plunger whose motion is resisted by a viscous liquid. The time-delay period is much shorter than that afforded by a thermal system, a factor that protects electronic components. The unit's small size—2½ by 2 by ¾ inches—also suits it to electronic circuitry. The breaker's time delay is varied by controlling the viscosity of the hydraulic fluid, and its rating is varied by coil design. The Hynetic breaker is made in 30 standard current ratings from 0.02 to 50 amperes, either 120 volts ac (60 cycles) or 50 volts dc, with three different overload characteristics. ■ ■ ■

More Versatile Bus Duct

Openings for plug-in power takeoffs have been added to low-impedance bus duct, to combine the efficiency of low-impedance duct with the convenience of plug-in duct. The openings give access to bared portions of the insulated bus bars at regular intervals, and power takeoffs can be installed at these openings without shutting down the distribution system. Current balance in multiple bars making up a phase is maintained by equalizing straps at each joint between sections. The duct is made in ratings from 600 to 4000 amperes at 600 volts maximum, two pole, three-phase three-wire, and three-phase four-wire.

Plug-in bus duct in 100-ampere rating now extends the range of application for this useful material. Formerly, 225 amperes was the lowest rating in which bus duct was made. The 100-ampere duct makes it possible to use bus duct economically for lighting and small-motor loads, replacing cable and conduit. The new duct is made in sections up to 10 feet long. End cable tap boxes and plug-in

units that clamp to the duct distribute the power. Capacity of the 100-ampere bus duct is 600 volts maximum, two, three, or four pole. ■ ■ ■

LAMPS AND LIGHTING

New in Lamps

It is no secret to fluorescent lamp engineers that the most efficient phosphors are those that produce a green color. However, most people seem to prefer a shade of white light.

This year, however, engineers were able to utilize the high efficiency of green phosphors by carefully blending them with red phosphors to provide a new shade of white light. The efficiency improvement is somewhat startling. Despite the fact that fluorescent lamp outputs have increased steadily during the past few years, the new high efficiency lamp provides substantially higher lumen output. It provides 15 percent more lumens than its counterpart in the Cool White variety; 11 percent more than the White fluorescent; and a whopping 26 percent more light than the Daylight lamp. Actual output of the new high efficiency lamp is 3200 lumens in the 40-watt size, and 6400 lumens in the 96-inch Slimline lamp. Both have a rated life of 7500 hours.

Importantly, this increase in efficiency was obtained with no special ballasts or fixtures being required; the lamps are directly interchangeable with existing types.

During 1958 and 1959, specially designed electrodes, with a tri-chemical emission material, were introduced in mercury lamps of 400, 700, and 1000 watts. This greatly reduced blackening of the arc tubes, with the result that the life of these lamps was raised to 12 000 hours. This year, the same construction was extended downward to smaller sizes, notably the 175 and 250 watt lamps. The importance of the new life rating can be seen in the fact that these two new sizes give 17 and 34 percent more light respectively throughout rated economic life. ■ ■ ■

Inset Runway Light

Much attention has been devoted to the problem of guiding a pilot by some form of lighting during the approach to a landing, and the end result has been the adoption of the centerline approach system. This, in turn, has pointed to the need for better guidance for the pilot in the touchdown area of the runway, referred to by pilots as the "black hole." A new inset runway light is designed to be placed in the runway itself, and has a slope profile that projects only an eighth of an inch above the surface. These lights are designed to be placed every ten feet along the centerline of a runway, as well as on the centerline of high-speed taxiway exits.

The new runway light consists of two pieces. The receptacle contains the electrical contacts and is permanently cemented into the pavement; it fits in an eight-inch diameter, one inch deep hole. The top assembly contains the lamp, lens, contacts, and mounting bolts and gaskets. Either a bidirectional or unidirectional top is used. The lamp is a 45-watt tubular quartz lamp.

The lights are not intended to illuminate the runway, but rather furnish a line of light that the pilot can follow down the center of the runway to a taxiway. The construction of the light, plus its low profile, are such that it cannot be damaged by aircraft rolling over it, or by snowplow blades, or any kind of weather extreme. ■ ■ ■

More Light for Roads

Higher light levels are the trend in home, office and industrial lighting—and roadways are no exception. A new luminaire, called the OV-50, is specifically designed for roadway lighting and efficiently controls the light from 700- or 1000-watt mercury lamps. The use of these higher wattage lamps permits a substantial increase in illumination levels without a corresponding increase in the number of luminaires involved. For example, average maintained footcandles on major traffic arteries can be increased by 50 percent when using the 700-watt lamp, or 90 percent with the 1000-watt lamp as compared to use of the 400-watt lamp. Or, for the same illumination level, fewer luminaires are required than would be needed when 400-watt lamps are used.

The new luminaire is made in two versions, one with an external ballast, and one with an internal ballast, built into the luminaire structure. ■ ■ ■

With Mirrors

The problem: How do you measure the candlepower distribution of a fluorescent lamp luminaire at the recommended distance of 40 feet, when the ceiling height of the room is 12 feet? Added complication: The luminaire must be positioned in its normal operating position, i.e., horizontal.

Lighting engineers came up with an answer this year. They do it with mirrors!

The whole problem arises from the fact that some fluorescent lamps are not perfectly stable in nonhorizontal burning positions. This means that errors are introduced in any photometric measurements if the lamp is operated in, say, a vertical position.

The solution came in placing two mirrors underneath the lamp, and at 45 degree angles to the axis of the lamp. These are placed so as to accurately split the luminaire image into two parts. The mirrors reflect light to photocells placed at appropriate locations. To obtain various readings, the luminaire in normal position and the mirror assembly can be rotated about the photometer axis.

Through use of this new photometer, lighting engineers have been able to obtain candlepower distribution measurements of both indoor and outdoor luminaires in their normal operating position, thus avoiding possible inaccuracies. ■ ■ ■

SEMICONDUCTORS AND ELECTRONICS

Vacuum Tube Improvements—from home to outer space

Highlights in vacuum tube developments run the gamut from improvements on standard devices to some brand-new "gee whiz" concepts. Herewith, some "for examples" from 1960:

Television—Two developments highlight improvements in tubes for home television receivers. At the front end of the set, the "frame grid" is being introduced to tuner and rf amplifier tubes. Conventional grids are wound in a spiral about two supporting rods, and the wire is mechanically attached to the rods each half turn. In the new "frame grid" construction, two cross members are welded top and bottom to larger side supports, forming a rigid "frame." The grid wire is wound on this frame under high tension. As a result, thinner grid wire can be used and grid spacing is more accurate. Tubes employing frame grid construction can be made to give

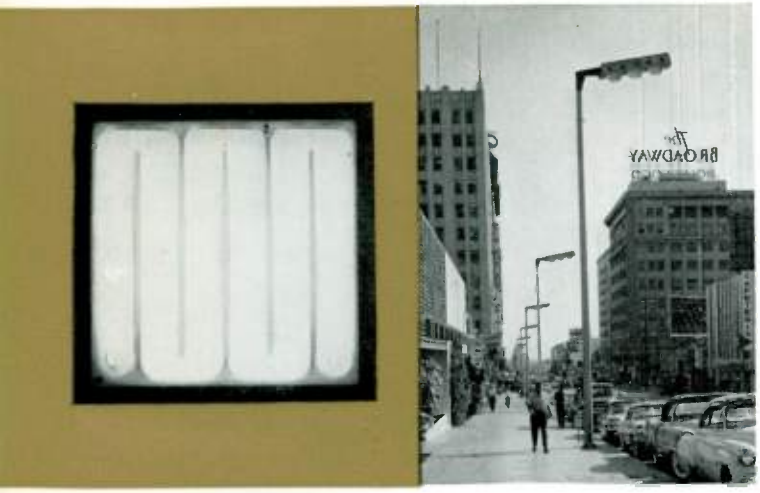


Photo 1 While this bears little physical resemblance to the conventional fluorescent lamp, it operates on exactly the same principle. In fact, except for its shape, it is a fluorescent lamp in every respect. This is the so-called "labyrinth" lamp. The electric arc follows a winding path through passages sealed in the glass. This version is a foot square and about an inch and a half thick including its rear contacts.

The new lamp offers lighting engineers a new dimension in lighting; the lamps can be used singly or in modular fashion for general lighting in walls, ceilings, or even floors.

In the new lamp the light source and diffusing element are combined in one unit. A dirtproof reflector can also be built into the back of the lamp.

Photo 2 This is the famous "Boulevard of the Stars," Hollywood Boulevard. About three years ago, a redevelopment program was undertaken to revitalize this glamour street. Among the projects was a new street-lighting program. In keeping with the artistic motif established for the street, new luminaires were designed. At left is the result. The luminaires consist of three 700-watt mercury reflector-refractor optical systems arranged in tandem in a single aluminum housing six feet long. There are 154 of these luminaires overall, on a 100 foot opposite spacing, and they produce 9.2 foot-candles.

greater amplification and more uniform performance.

In the viewing end of the tv set, the fashion has gone to the "square look." By "squaring" the face of the picture tube, the area of the picture has been increased by approximately eight percent. The picture shape is now more like a movie screen and lends itself to better cabinet styling.

Imaging Tubes — Highlighting a group of devices that might be classed as television on an exotic scale is the Astracon image-amplifier tube, which displays a near-perfect ability to amplify light. When photons of light strike the light-sensitive end of the tube, electrons are released and propelled by high voltages through a series of thin films, each of which release in turn a greater number of electrons. The resulting image on the face of the tube is thousands of times brighter than the original dim or invisible image. A single photon striking the input surface can produce a light output of more than 10 000 photons. Such a tube used with a telescope could increase the sensitivity of the system many times. Another promising area is in nuclear physics, where the tube will permit researchers to see the tracks of cosmic rays and other high-energy particles. (See story, p. 28.) The tube (WX-4342) developed at the Westinghouse Research Laboratories, is now in pilot production.

The limits in payload in contemplated space vehicles have led to a number of developments in devices planned for space application.

A new small-sized vidicon (WX-4315) only ½ inch in diameter, is now in pilot production. This tube could be used in such applications as weather satellites.

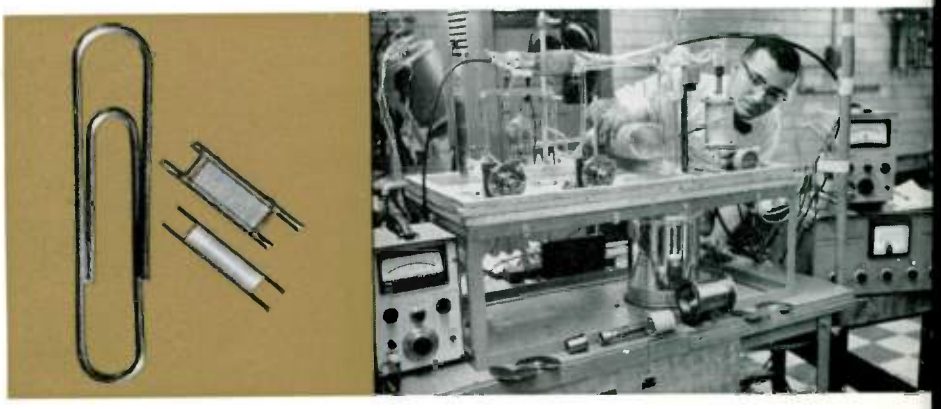
A ruggedized version of the image orthicon (WX-4493) has been developed for low-light applications, such as night viewing or satellite tracking. This sensitive tube employs a storage target so that longer "exposures" can be used.

An electrostatic slow-scan vidicon eliminates the need for the bulky magnetic deflection coils, permitting much smaller cameras. The tube can be used at conventional industrial television scan rates, or in slow-scan applications with a frame time as long as two minutes. The slow scan feature gives the tube the ability to integrate low light level scenes, and permits narrow bandwidth transmission of visual information at audio frequencies. For example, graphic data can be transmitted over a conventional telephone line.

Ionization Gauge for Outer Space— Although scientists can make good estimates of the molecular density of outer space, they have no actual measurements to prove their theories. A new ionization gauge being developed for the U. S. Air Force may make these measurements possible. The new gauge will measure vacuums in the range of 10^{-4} to 10^{-13} millimeters of mercury. The previous standard for ultralow vacuum systems was the Bayard-Alpert gauge, which had a lower limit of 10^{-10} mm Hg.

To get the necessary ruggedness for space expeditions, the tube is made of ceramic brazed to metal components. The tube is built in a compact self-contained package for outer space application.

The space ionization gauge operates on a principle developed by F. M. Penning. Its operation is somewhat similar to a magnetron. Electrons drawn from the cathode are acted upon by a strong magnetic field, bend-



ing them into cycloidal paths, thereby increasing the probability of a molecular collision. The molecules are ionized by these collisions, creating an ion current that can be measured. The magnitude of the ion current is a measure of molecular density.

In application, the tube will be evacuated before being sent to outer space. Once in outer space, the seal will be broken, allowing the "nothingness" of outer space to leak inside for measurement. ■ ■ ■

More Semiconductor Devices

One of the newcomers to the semiconductor field is the Trinistor controlled rectifier, which is already being applied in inverters, switches, frequency converters, and various other devices. Basically, the characteristics of the Trinistor device are similar to those of a thyratron—the device blocks voltage in the forward direction below a critical breakover voltage, and switches to a conducting state when that voltage is exceeded or when a proper gate signal is applied. The device is a three terminal, four layer *npnp* junction device, with a gate electrode attached to one of the middle regions. At present Trinistors will handle as much as 50 amperes and up to 300 volts continuously, and can take peak surge current up to 1000 amperes.

The first commercial product to be made of germanium crystal produced by the controlled dendritic growing process is the tunnel diode. These are heavily doped *pn* junction devices that have a negative resistance region over a segment of the forward characteristics curve. The tunnel diode is basically a highspeed switching device, and capable of operating at high frequencies. This characteristic makes the tunnel diode ideally suited to applications in logic, switching, and computer circuitry where switching times faster than those possible with transistors are required.

Still another new device in the semiconductor family—this time a thermoelectric unit—is a cooler for electronic components. Typical applications are for the cooling of transistors, diodes, tubes, and similar electronic devices. The thermoelectric coolers can be used singly or in multiple arrays, depending upon the heat pumping requirements of the application. Because these thermoelectric coolers are based on the Peltier effect, they are "reversible"; i.e., component heating can be accomplished by reversing current flow through the unit. ■ ■ ■

Static Inverters for Telephone Cable

One of the most interesting devices to come out of the development of high-powered semiconductor switching devices is the inverter—an all-static device for transforming dc to ac. The improved reliability of the static inverter is opening the door to a variety of applications.

A particularly interesting application is the use of static inverters to power underwater telephone cable repeaters. Rechargeable batteries supply 42 to 52 volts to the inverter, which converts this dc voltage to 400 cycles at a power level of 4.5 kva. The 400-cycle voltage is put through a magnetic amplifier controlled transformer-rectifier-filter and fed into each end of a transoceanic telephone cable at about 6000 volts dc to power the telephone repeaters along the cable. An inverter and a spare inverter will be used at each end of the cable.

The battery-inverter system was developed in the interest of improved reliability, to replace the previously used motor-generator sets.

The telephone cable power supply inverter is made up of silicon transistors, silicon diodes, and magnetic amplifiers. ■ ■ ■

X Rays on Television

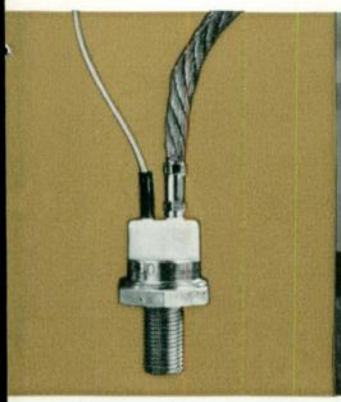
A new "television program" has been developed for radiologists and doctors—a televised image of the fluoroscopic examination. With this new device, called Televex, x-ray examinations can be conducted in a lighted room, and viewed simultaneously by a group of doctors—and the patient, if the examining radiologist so desires.

The Televex system consists of an x-ray image intensifier, which picks up the low-intensity x-ray image and brightens it at least 1000 times, and a specially developed image orthicon camera chain, which results in a system capable of a light amplification of up to 50 000 that of the conventional fluoroscopic screen. The image is presented to the viewer on a 17-inch monitor set.

The input field to the device is a 9-inch diameter circle. For a more detailed look, an electronic image-magnification system is provided. The central 50 percent area of the image Orthicon tube can be magnified approximately 100 percent with a corresponding increase in detail seen on the tv monitor.

The Televex x-ray intensifier makes it possible to conduct an examination with about 20 percent of the radiation dosage to the patient that is required by conventional x-ray examinations without the device.

Westinghouse ENGINEER Jan. 1961



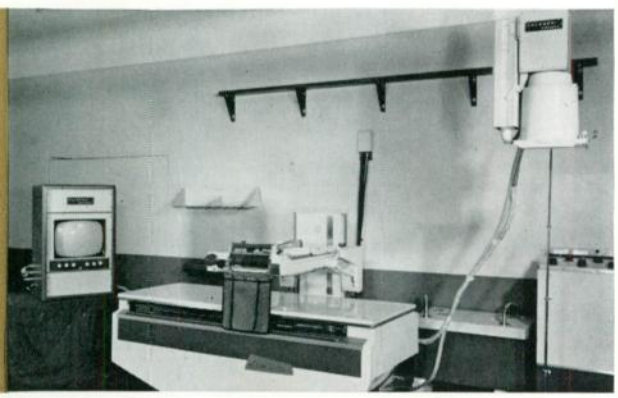
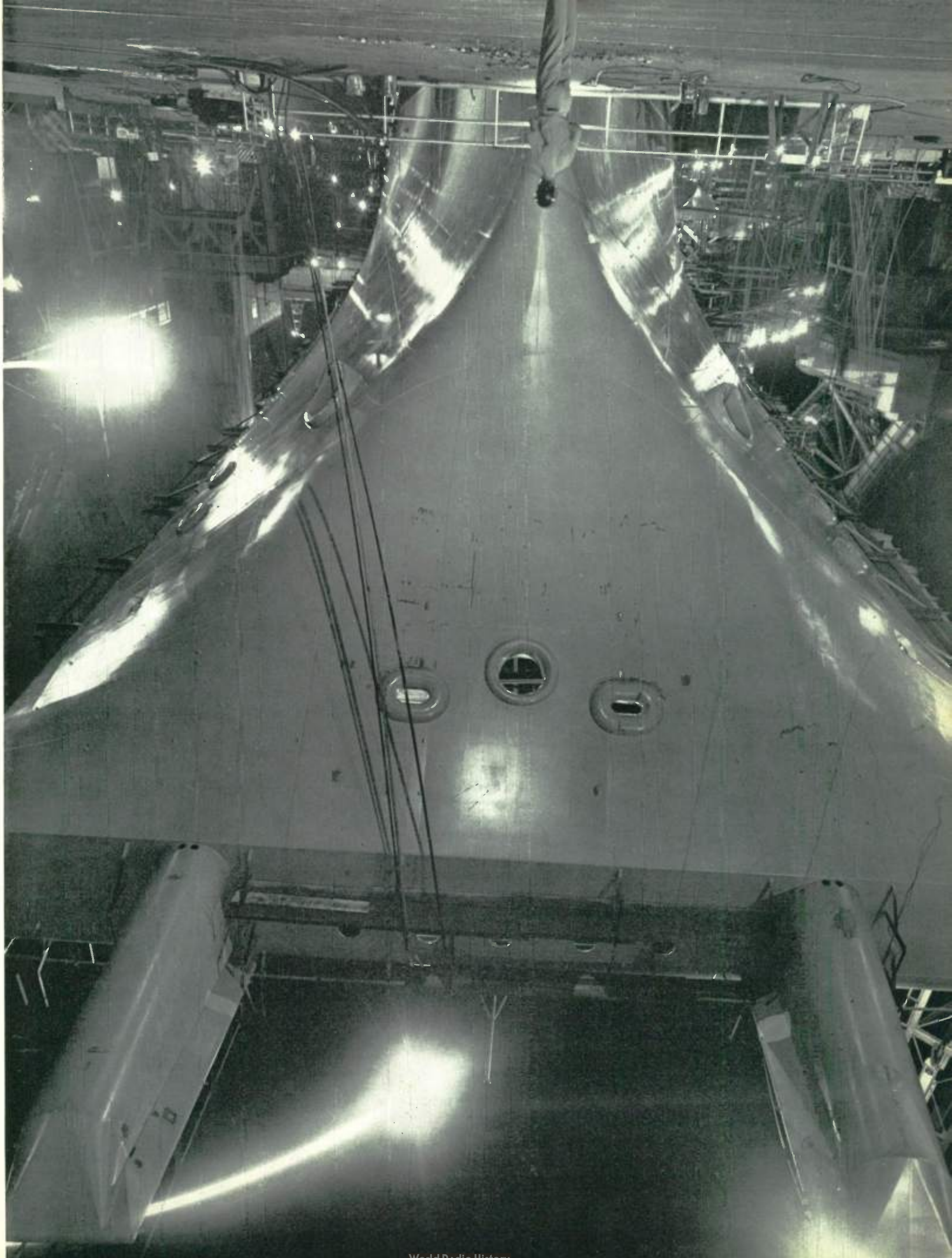


Photo 1 Shown is a new frame grid (top), and a conventional grid (bottom).

Photo 2 Liquid helium techniques were used to obtain the vacuums required to simulate outer space. The ionization gauge under test is the metal cylinder in the upper right corner. Components of the gauge are in the foreground.

Photo 3 This Trinistor controlled rectifier is finding wide use in a number of devices. (See story above).

Photo 4 These components produce x-ray "television"—the monitor, the x-ray table and spot film device, and the image intensifier and tv camera.



Nuclear Navy Expands

While the first firing of the Polaris missile from a submerged submarine was perhaps the year's most spectacular naval feat, it was by no means the only noteworthy event. Two others: The launching of the mightiest ship ever built, the nuclear-powered aircraft carrier *Enterprise*; and the continued growth of the nuclear submarine fleet.

The nuclear plant of the *Enterprise* will consist of eight reactors generating steam to drive four shafts. One unusual feature of this reactor plant is the use of two nuclear reactors in parallel to provide power for a single shaft. This arrangement was tested successfully in 1959 at the Naval Reactors Facility in Idaho when two prototype reactors were so operated in tandem at full power—the first time this had even been attempted.

Aside from her nuclear power plant, the *Enterprise* is impressive in many ways. One is sheer size. The flight deck is over a fifth of a mile long, and large enough that the liners *United States* and *America* could be fitted on her deck side by side. The flight deck is so big that aircraft can be launched by catapult while other aircraft are landing on the deck. Each of her four propellers stands as high as a two-story house. And her crew is the largest ever assigned to a ship—a total of 4600 officers and men.

But despite her size, the *Enterprise* will not be slow. Her eight reactors form the most powerful nuclear propulsion plant in the world, and drive her at speeds faster than 25 knots.

The advantages of nuclear power for aircraft carrier propulsion are many. Since a reactor makes no smoke or fumes and requires no air, boiler uptakes and smoke stacks are eliminated, thus allowing the superstructure to be located anywhere on the flight deck. Air operations can be continued by the *Enterprise* for about twice as long as by a conventional carrier because of the greater storage capacity for aviation fuel; storage space for fuel oil for propulsion purposes is not needed. Also the cruising range of the carrier is greatly extended; estimates indicate that the *Enterprise* will be able to cruise at full speed some 20 times further than a conventional carrier without refueling.

Construction and propulsion plant testing continued during the year on the *Long Beach*. Launched on July 14, 1959, the guided missile launching cruiser will have two reactors of the same type used in the *Enterprise*.

Meanwhile, the nuclear underwater fleet was steadily increasing. Only six years ago, in January 1955, the first nuclear submarine, the *Nautilus*, went to sea for the first time. As of mid-1960, a total of 26 attack submarines, 14 *Polaris* missile submarines, one radar picket submarine, and one guided missile submarine had been built or authorized.

Among the noteworthy events involving nuclear submarines during 1960 was the first firing of the *Polaris* missiles from the *George Washington*. While submerged, two missiles were fired at a target 1150 miles away, and both scored.

Another news item was the completion, in September, of the first east-to-west polar transit, by the *Seadragon*. The trip, which started from Portsmouth, New Hampshire, and ended at Pearl Harbor, continued the oceanographic surveys made by the previous polar trips of the *Nautilus*, the *Skate*, and the *Sargo*.

Also of interest during 1960 was the fact that the first two nuclear submarines rejoined the fleet—the *Nautilus* after refueling and first overhaul, and the *Seawolf* after installation of a pressurized water reactor plant similar to plants installed in other nuclear submarines.

The nuclear fleet, nonexistent six years ago, has already become a vital force in our national defense, and will become increasingly so in the future. The nuclear reactors for the submarines named, and for the *Enterprise* and *Long Beach*, were developed and designed at the Bettis Atomic Power Laboratory under the direction of and in technical cooperation with the Naval Reactors Branch of the AEC. Westinghouse operates the Bettis Laboratory for the AEC. ■ ■ ■

Magnetic Amplifiers Used in Marine Propulsion Plant

The commissioning of the diesel-electric hopper dredge *Markham* by the U.S. Army Corps of Engineers marks the application of magnetic amplifiers to seagoing dredge propulsion. A Magamp system controls the vessel's propeller speed and also maintains constant propeller horsepower at voltages within a specific range regardless of conditions affecting the propeller load. Because the magnetic amplifier is a static device, it requires less maintenance than do the rotating regulators commonly used in diesel-electric marine propulsion machinery.

The hopper dredge can be compared to a seagoing vacuum sweeper. It proceeds slowly over the area to be dredged, sweeping the bottom with a pair of drag-arm pipes through which dredge pumps suck up a mixture of sediment and water. The mixture is deposited in hoppers in the vessel, where the solids settle out and the water drains off. The filled hoppers can be dumped by opening doors in their bottoms, or they can be pumped out by the dredge pumps.

The *Markham* has two completely independent main generating plants that power the ship's propellers, dredge pumps, drag-arm winches, and auxiliary equipment. Each generating plant consists of a 4250-horsepower diesel engine that drives a 2100 kilowatt 600/720-volt dc propulsion generator, an 800-kilowatt 600-volt dc pump generator, and a 350-kilowatt 450-volt ac ship's service generator.

Each propulsion generator powers one of the two propulsion units, con-

Section III
MARINE
AND
AVIATION

Left Towering over its construction dock, the bow of the nuclear-powered carrier *Enterprise* gives an indication of the size of the world's mightiest ship (see story above).

Photo Courtesy of Newport News Shipbuilding & Dry Dock Company

sisting of two 1325-hp series-connected motors driving a propeller shaft through a reduction gear. Each propulsion unit's speed and direction of rotation are governed by the amount and polarity of the generator output voltage, and this is controlled by varying the strength and direction of the energizing current applied to the generator's shunt field. The energizing current is supplied by a variable-voltage exciter whose output is controlled by a two-channel magnetic amplifier—one channel for forward operation and one for astern operation. The propulsion equipment can be controlled either from the engine room or from the pilothouse.

The electrical system permits the *Markham's* diesel engines to operate at constant speed even though the propulsion machinery must operate in both directions and at various speeds and loads. It also permits the prime movers to perform triple duty—propulsion, dredging, and ship's service power generation.

A unique feature in American seagoing dredges is the *Markham's* bow thruster. This is a motor-driven propeller in a transverse tunnel that pierces the bow below the waterline. The propeller provides lateral thrust that greatly increases maneuverability at slow vessel speeds and helps the vessel maintain dredging course in spite of adverse winds and currents. Two tandem-connected wound-rotor motors, powered from the ship's service system, drive the bow-thruster propeller. ■ ■ ■

New Vibration Test System

In a new approach to vibration testing, the vibration generator and table have been combined into a single compact unit. Called the Duopower shaker, this unitized vibration-testing system has eliminated the extensive fixturing formerly required with conventional shaker heads.

In industry parlance, the Duopower shaker is a "slip table," driven by two shaker heads, one mounted at each end of a rugged magnesium plate. The plate rides on an oil film above the surface of an optically flat granite block. The 22- by-32-inch table, sliding on the oil film, can therefore handle large, heavy loads.

This arrangement eliminates the mechanical linkages formerly used with a conventional shaker head and separate table, and therefore provides greater uniformity of table stroke acceleration and deceleration. It also eliminates the setup and calibration generally required in prior methods of comparative tests.

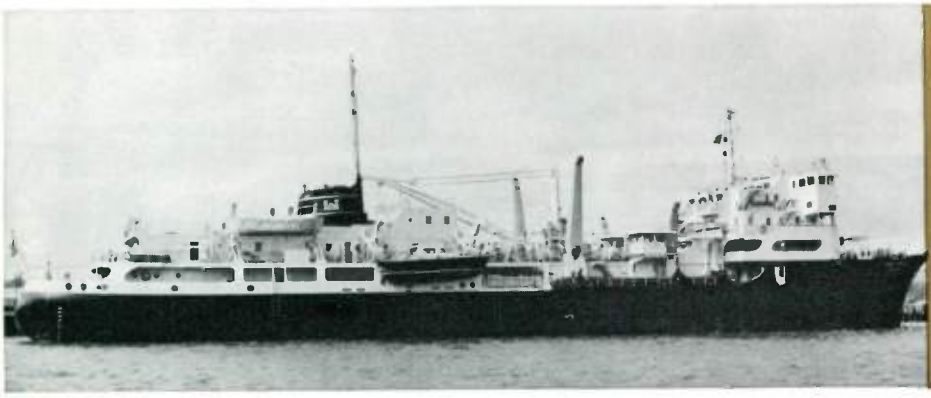
The shaker heads operate much like huge electromagnetic speakers; each head consists of a moving armature located in the air gap of a large dc-excited electromagnet. The armatures are rigidly connected to the slip table so that when an ac voltage is applied to the armature windings, the table is vibrated in a horizontal direction at the frequency of the applied source. The shaker table can develop a vector force of 3000 pounds, with a ± 0.5-inch stroke, and operate over a frequency range of 5 to 2000 cps.

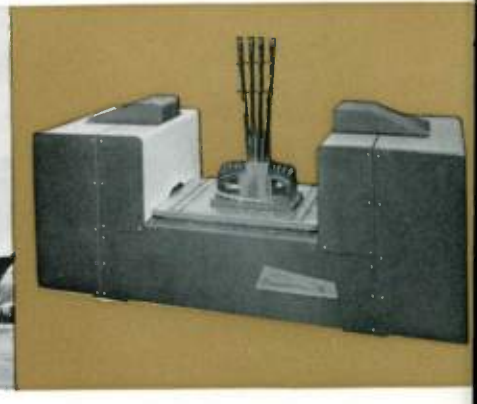
The ideal excitation source for the Duopower shaker is an electronic power amplifier, which can provide sine-wave or complex waveshape voltages. Hence, the table will simulate the wide range of vibratory forces and frequencies needed for environmental testing in such fields as missiles, aircraft, or industrial equipment. ■ ■ ■

The *Polaris*, the solid fueled intermediate range missile, is shown after launching from a submerged submarine. The compressed-air launching system, developed by Westinghouse, is designed for either surface or underwater launching. Under a U.S. Navy contract, Westinghouse is building the launching and handling systems for a total of 14 missile submarines.

Arc Heater Produces Sustained Flow of High-Temperature Gas

A high-energy continuous-arc heater has been developed to produce a sustained stream of gas at high temperatures and pressures and with very little contamination of the gas stream. The heater's immediate application is in supplying hot air at high velocities for wind-tunnel simulation of the extreme conditions encountered by aircraft, missiles, and spacecraft in high-speed flight and re-entry. Other possible applications include melting refractory





materials and inducing difficult chemical reactions—applications in which low system contamination usually is vitally important.

The extremely high temperature of the electric arc has long made it theoretically attractive for heating gas in continuous-flow systems. However, knowledge of the laws governing arc control and heat damage to electrodes and arc-chamber walls was insufficient to prevent arc instability and consequent contamination of the gas. This has heretofore limited the arc's usefulness in continuous-flow gas-heating systems, but the new heater's unique design overcomes the difficulty.

The heart of the heater is a pair of hollow toroidal (doughnut-shaped) electrodes, each located adjacent to and concentric with a toroidal dc field coil. The electrodes are connected to manifolds, and cooling water passes through them. An arc is initiated between the electrodes and is continuously rotated by flux patterns generated in the field coils. The combination of water cooling and arc rotation keeps the electrode material from heating beyond its structural endurance. Either alternating or direct current can be used as the arc power supply.

A water-cooled heat shield protects the arc-chamber walls. A working fluid, such as air or nitrogen, enters the arc chamber, passes into the arc through openings near the heat shield, and leaves through a water-cooled nozzle.

Heat-transfer efficiency in the prototype unit exceeds 50 percent. The unit has been operated at a power input of 1700 kilowatts and a nozzle temperature of 10 000 degrees F. A nozzle flow velocity of 3400 miles per hour has been attained, and operating pressures have reached 730 pounds per square inch. The maximum system contamination level is 0.2 percent, and still further reductions seem possible.

A 30 000-kilowatt power input and arc-chamber temperatures and pressures approaching 20 000 degrees F and 15 000 psi are considered feasible. Although these conditions go beyond expected nozzle capabilities, they will be useful for ablation studies at subsonic velocities and for investigations of the properties of real gases at these and other conditions. Arc air heaters of this type can be expected to power wind tunnels with test-section velocities approaching 25 000 fps. ■ ■ ■

Low-Inductance Capacitors

One of the main advantages of using capacitors for storing energy is that the energy can be released in a very short time, making a large amount of power available from a relatively small amount of stored energy. This characteristic is being exploited more and more to produce large pulses of power for research and industrial purposes. However, as the rate of energy release (capacitor discharge) increases, the circuit inductance must be made smaller. Standard dc capacitors have more internal inductance than is compatible with low-inductance circuits, so special capacitors with very low internal inductance have been developed.

The low-inductance capacitors have flat "pancake" insulators for compact construction with resulting short internal connections, and they use improved dielectric materials for increased reliability at high voltage. Manufacturing techniques have been evolved to build these units with mass-production factory equipment.

Low-inductance capacitors are used for such purposes as producing extremely high temperatures in studies of controlled thermonuclear reactions and for forming metal by the electrohydraulic process (in which an electric spark discharge rather than an explosive charge generates energy for "explosive" forming). ■ ■ ■

Wind Tunnel Range Extended

Extending the range and versatility of a 16-foot transonic wind tunnel is the task of a supplementary air removal system installed at NASA's Langley Research Center, Langley Field, Virginia. Boundary-layer air (stagnant air that collects along the walls) reduces the effective area of a conventional tunnel's test section. The supplementary air removal system whisks this boundary-layer air away, thereby making the effective area of the test section nearly equal to its actual area.

The test section was modified by making openings in its walls and enclosing it in a plenum chamber. A powerful compressor exhausts air from the plenum chamber when the tunnel is operating, continuously bleeding off the boundary-layer air through the openings in the test-section walls. The compressor is a nine-stage axial-flow unit with adjustable stator blades. It delivers air at 966 000 cubic feet per minute and at a pressure ratio of 3.33. The compressor is driven through speed-increasing gearing by a wound-rotor induction motor rated at 36 000 horsepower at 552 rpm.

A liquid rheostat controls the drive motor's speed by varying the secondary resistance. The rheostat's 36-inch electrodes are cone-shaped instead of the conventional flat plate shape. This conical design increases the range of resistance possible with a given electrode travel, and it also provides more nearly balanced resistance values in all three cells when the electrodes are close together. Another feature of the rheostat is that the electrodes are individually and remotely adjustable instead of being coupled together as they are in standard designs. Consequently, the operator can adjust the electrodes at any time to keep the secondary resistance, and therefore the secondary currents, balanced between phases. This prevents the motor

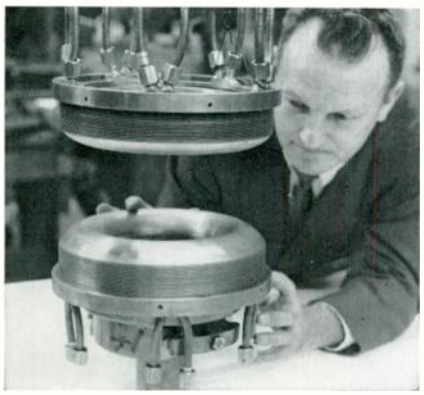


Photo 1 The U.S. Army Corps of Engineers seagoing dredge *Markham* is powered by a diesel-electric system that uses magnetic amplifiers to ensure reliable control.

Photo 2 A turbine blade assembly is shown mounted on the Duopower shaker to determine structural resonances developed under sine-wave motion.

Photo 3 Hollow construction of the arc heater's electrodes permits effective water cooling, and the toroidal shape permits continuous arc rotation to further reduce electrode temperature.

from exciting the drive system with harmful torsional oscillations.

The compressor and drive are so arranged that, when desired, they can be used as the primary air-removal system for an adjacent tunnel. ■ ■ ■

Capacitors Fire Hot-Shot Tunnels

Successful design of high-speed aircraft and rocket vehicles demands that many model tests be made before a new design is ever flown. An effective device for simulating the conditions encountered in high-speed flight and re-entry is the hypervelocity impulse wind tunnel—called a hot-shot tunnel in the aerospace industry. Compressed air or other gas is heated by an electric discharge in an arc chamber and then released suddenly into the test section, from which air has previously been evacuated. A large number of tests can be run quickly and at much lower cost than that of flight testing.

Handling and storing the tremendous amounts of stored electrical energy released in the arc discharge has necessitated many engineering advances with implications ranging beyond the wind-tunnel applications.

Two new hot-shot tunnels store energy in banks of capacitors. The larger one, installed at the McDonnell Aircraft Corporation, St. Louis, Missouri, has 2320 capacitors charged by high-voltage equipment to a predetermined level up to 12 000 volts. Discharging the full capacity delivers seven megajoules of energy in a maximum time of three milliseconds with a peak current of four-million amperes. The intense arc heats compressed gas in the arc chamber to 14 000 degrees F and increases its pressure to 100 000 pounds per square inch. The heat vaporizes a diaphragm separating the arc chamber from the tunnel, and the hot high-pressure gas bursts into the test section. The flow of the gas over a model simulates speeds from Mach 9 to Mach 24.

The entire main capacitor bank of the energy-storage system can be charged in 30 seconds. Inexpensive current-limiting fuses of a type developed for this application protect each capacitor. The capacitors are bussed together in groups of 10, and cables connect the buses to a large coaxial conductor called the collector. Special connections make it easy to remove cables from the collector when only a portion of the stored-energy capacity is to be used. The cables are all of the same length to equalize the current carried in each cable.

To fire the system, five capacitors in a triggering bank are first discharged through a triggering-circuit wire that passes through the center of the collector. This ionizes the gas between the electrodes, and the main capacitor bank then discharges.

The very high peak current of the discharge produces tremendous forces in the collector, so it had to be designed for great structural strength. Complicating the problem was the need to reduce the front end of the collector from its optimum electrical diameter to the much smaller diameter required for the mechanical connection with the arc chamber. A unique connector was devised that withstands the fearful forces imposed at this point and yet permits disconnection of the collector from the arc chamber in five minutes.

The collector can be disengaged from one tunnel, swung 45 degrees, and connected to another tunnel. This permits operation of two tunnels with one power supply. Also, to keep pace with the industry's need for increasingly high test pressures and temperatures, the energy storage system is so designed that its capacity can be increased to 10 megajoules.

The other hot-shot energy storage system, installed at the Martin Company in Baltimore, is a capacitive system similar to the McDonnell unit. Its initial capacity is 800 000 joules, but it can be expanded to 2 megajoules.

Capacitive systems capable of storing such huge amounts of energy and releasing it quickly show promise for meeting other needs in research and industry. One application is in explosive forming of metals that are difficult to shape by other means. Shock waves from a high-intensity arc can be transmitted to the metal through water or other fluid to force the metal into a die. This process is cleaner and more easily controlled than chemical explosive forming, and it can be repeated more rapidly. ■ ■ ■

"Checking Out" Electrical Systems

Testing the complex array of electrical systems and components for a modern military aircraft can be a time-consuming process, requiring major test apparatus. Two new test devices simplify the job.

One is a set for synthetic testing of regulators, which enables high-speed automatic checkout for aircraft voltage regulators. Signals are fed to the regulator from magnetic tape, rather than from a generator. The test set senses output voltages, contact closures, currents, resistances, frequencies, and time delays, and compares them to preset values in a comparator. When a "no-go" signal occurs, the test set automatically runs the magnetic tape to a special trouble-shooting section which analyzes the failure.

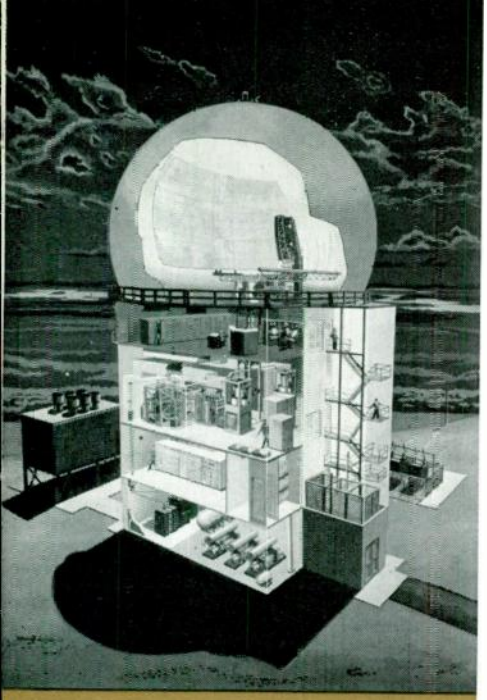
To check different regulators, the only change required in the test set is a different adapter cable and another reel of magnetic tape. The new test set eliminates the need for a drive stand, aircraft generator, and load bank, formerly required for these

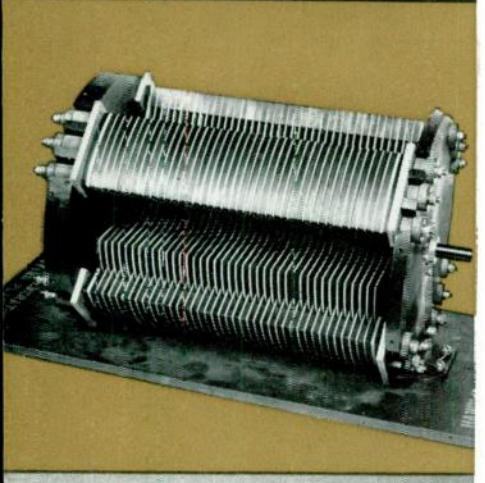
Photo 1 The AN/FPS-27 radar is a long-range, stacked-beam three-dimensional radar which features the most modern anti-jamming techniques. The equipment is presently undergoing extensive testing at Crystal Springs, Mississippi.

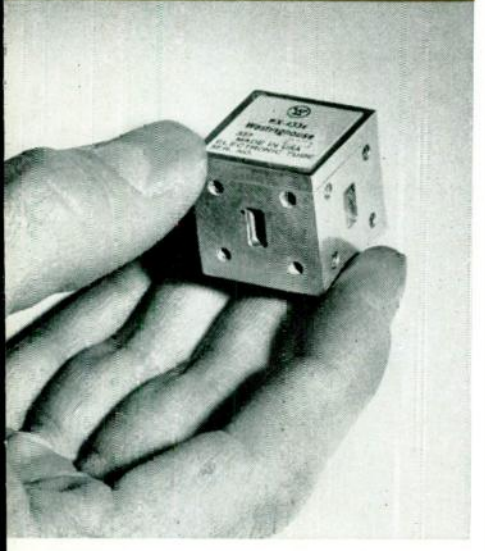
Photo 2 To develop a brushless generator suitable for operating in a vacuum, engineers went back to a principle used in some of the earliest methods of electric power generation—the electrostatic generator. As shown, the rotor and stator consist of groups of plates. High voltage is produced by charging the groups of stator plates when the capacitance is high and by then decreasing the capacitance to produce an increase of voltage across the stator plates as they discharge through the load. The effective spacing between groups of stator plates is varied by the changing position of the rotor plates as they rotate, thus varying the capacitance between groups of stator plates. This generator, because of its ability to operate in a vacuum, has potential for use in space propulsion systems.

The effort associated with the depicted generator is sponsored by Wright Air Development Division, Air Research and Development Command, Flight Vehicle Power Branch, U.S. Air Force.

Photo 3 This tiny discriminator cavity (WX-4334) is a simple, rugged frequency stabilizing device for use with parametric amplifier pumps, navigation systems, beacon radars, or any system that requires a stable high-frequency source. It is a dual mode, transmission type cavity designed for operation at a fixed frequency of 35 kilomegacycles. The cavity is vacuum sealed and incorporates invar construction to minimize frequency shift with ambient temperature change.







tests. It is adaptable to handle any present or foreseeable aircraft voltage regulator, as well as many other electronic components.

The second test set packs in a small suitcase, and weighs only 50 pounds. It is designed to monitor the aircraft generator for proper output, check the electrical system, and to simulate faults to check the system control and protection features. This set is used on the installed electrical system, and eliminates the collection of voltmeters and ohmeters formerly required. ■ ■ ■

Digital Computer Can Fly—Physically and Mathematically

The fastest military airborne data processor known to have operated successfully is being applied to an airborne track-while-scan radar system, soon to be flight tested. The computer's function in this system is to keep track of multiple target information and to display the tactical situation. For example, it will provide range, range rate, and angular data on each of a number of targets.

The general-purpose computer (DP-167) can be applied to a variety of airborne systems, such as fire control, space guidance, and navigation.

The DP-167 computer adds or subtracts at 167 000 operations per second, multiplies at an average rate of 24 000 operations per second, and divides at an average rate of 16 000 operations per second. Operation times quoted include two complete memory cycles. The unit consists of three computer elements—an operand memory, an instruction memory, and an arithmetic and control unit—plus a power supply. The operand memory has an access time of 0.8 microseconds, and can store 640 words, each word consisting of 19 binary digits and algebraic sign. The instruction memory's access time is 1.5 microseconds, and its capacity is 2048 instruction words of 20 bits each.

Both the operand and the instruction memories are of modular construction, and can easily be expanded to 2048 words of operands and 8192 words of instructions. The arithmetic and control unit provides three index registers for programing flexibility. The use of the separate instruction and operand memories allows an exceptional degree of command overlap in real time.

An improved version (DP-400) is now being designed for use in advanced detection and tracking systems. The DP-400 will have 2.5 times the speed and capacity of its predecessor.

An advanced memory system employing multi-aperture magnetic cores has been developed and will be used in the WDP-400 computer. This system will permit a memory speed increase of 6 to 1 over the present conventional single-aperture core memory. The read system will be nondestructive, so that a word can be read from the memory and the information will still remain in the memory without the necessity for an extra regeneration operation, yet the contents of the memory can be altered electrically when changes are needed. These are important features in both military and industrial systems.

Reliability is stressed in both computer designs. Low-cost, medium-speed silicon transistors are used in a transistor-diode gating system. Components operate at 20 percent of normal voltage and power ratings, and circuits are designed to accommodate wide swings in component parameters without failure. Ambient temperatures up to 85 degrees C require only circulating-air cooling. Plug-in etched-circuit board construction permits high component packing densities and allows rapid replacement of modules for ease of maintenance. ■ ■ ■

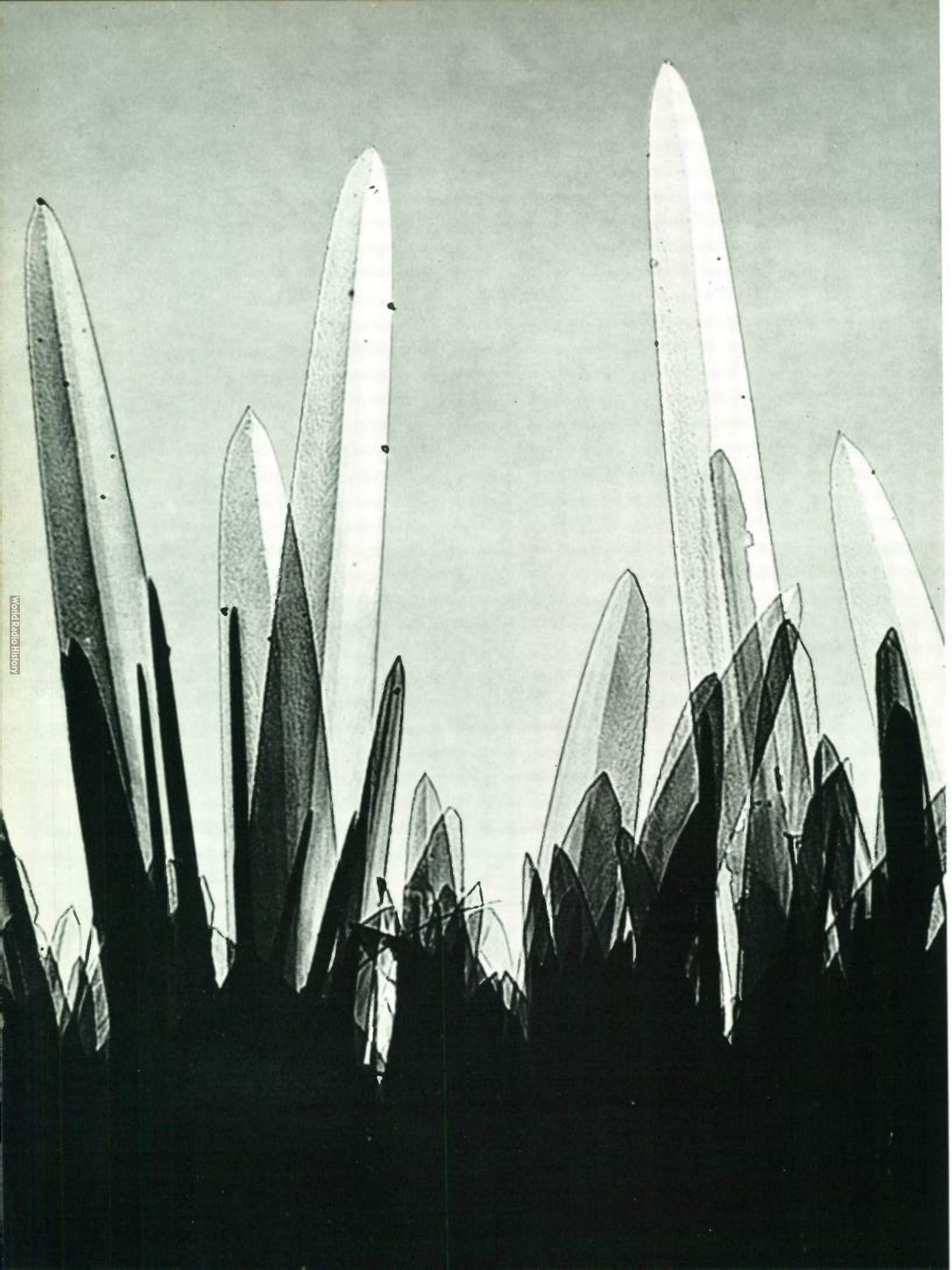
Developments in Parametric Amplifiers

A 5000-megacycle parametric amplifier is now being field tested for service in the U. S. Air Force scatter communications system (AN/TRC-66).

The fundamental advantage of a parametric amplifier is its extremely low internal noise characteristic. Hence, the addition of this device at the front end of a receiver permits the receiving system to pick up extremely weak signals. In this particular application, receiver sensitivity has been improved by about 5 decibels.

Basically, the scatter communications method consists of beaming a high-power uhf signal into the troposphere, where changes in refractive index cause the energy to be scattered. An extremely sensitive receiver is required to gather the small amount of scattered energy that reaches the receiving site, several hundred miles from the transmitter.

The parametric amplifier uses a new varactor diode and a pumping frequency source of 13.5 kmc. The amplifier is tunable over a 600 mc band.



A Basic Theory About Rust

Rusting of iron is a billion-dollar mystery. While this chemical reaction is one of the most destructive and wasteful known to man—an estimated annual waste of some six to seven billion dollars is attributed to corrosion of iron—the basic cause has defied scientists for centuries.

This year two Westinghouse scientists proposed a new theory that may provide the basis for an eventual complete understanding of corrosion. This theory suggests that hydrogen ions, or protons, may be the real culprits. These hydrogen ions, present in water vapor, penetrate the iron and enlarge the sites at which oxygen normally combines with the metal; this spreads the reaction throughout the surface of the iron, causing it to rust destructively.

The basis for this theory was provided by a series of experiments that exposed iron under closely controlled conditions to dry oxygen and then to water vapor atmospheres. Pure iron wires were reacted with dry oxygen at a temperature of 835 degrees F; then, under identical conditions, other wires were reacted with vapor.

The results were startlingly different. With dry oxygen, the iron forms a protective oxide coating, from which grow billions of tiny round oxide whiskers less than a millionth of an inch in diameter and 30 millionths of an inch high. Each whisker grows from a specific growth site on the wire's surface.

When water vapor is used in place of the dry oxygen, the oxide surface undergoes a dramatic change. From the growth sites, thin, pointed, blade-shaped platelets of iron oxide erupt and spread across the surface. These platelets are about a millionth of an inch thick, 30 millionths of an inch wide, and 300 millionths of an inch high. As they grow in size, they cover 50 times the area of the sites observed under dry oxygen conditions, reaching a density of about one billion per square inch of surface area. The amount of iron rust they represent is 250 times that which forms when water vapor is absent from the reaction.

While the new theory does not rule out the standard electrochemical explanation of corrosion, it does suggest that a more fundamental reaction may be present. The theory also suggests two control measures: hydrogen must be prevented from entering the metal, and the growth of reaction sites must be inhibited by the addition of suitable alloying agents to the iron. ■ ■ ■

Left This is rust, as photographed through an electron microscope. Part of a research project on corrosion of iron, this photo was taken to demonstrate the effect of water vapor. In an atmosphere of pure water vapor, the surface erupts into thin blade-shaped crystals, which reach a density of nearly one billion per square inch (see story, above).

TE and MHD

The science of converting energy from one form to another, and particularly heat energy to electrical energy, is undergoing intensive study today in laboratories all over the world.

Section IV RESEARCH AND ENGINEERING

The specific purposes for this extensive research are many and varied; so are the approaches to the problem, and the goals. But the potential gains to be achieved are great, and in many cases substantial progress is being made. Consider, for example, two methods of converting heat energy directly to electric power—thermoelectricity and magnetohydrodynamics, more commonly known as MHD.

Thermoelectricity—Interest in thermoelectric principles as a basis for generating practical amounts of electric power was revived a few years ago with the development of new materials capable of raising the power output and efficiency of thermoelectric devices. Since that time, progress has quickened. One example: during 1957, Westinghouse scientists were working with devices whose output was slightly over one watt; during 1960, they developed a thermoelectric generator rated at 5000 watts.

This five-kw generator was developed for the Bureau of Ships of the Navy, and is an experimental unit intended for evaluation of power generating materials and fabrication techniques. For maximum flexibility of design, the generator is built of thermoelectric modules, which can be arranged electrically to give a wide range of output voltages and currents; these combinations range from 10 volts at 500 amperes to 120 volts at about 42 amperes. The modular construction also makes the physical design versatile, permitting the generator to be built as two identical subgenerators, which are connected to give the full power output, or which can be used independently as separate 2500-watt power plants. The thermoelectric portion of each 2500-watt subgenerator resembles a hollow cylinder about 30 inches in diameter and 30 inches high. The thermoelectric modules form the walls of the cylinder, with their hot inner surfaces exposed to the flame of burning kerosene and their outer surfaces cooled by water piped to them.

Six different thermoelectric materials are used in the new generator. Since thermoelectric materials differ widely in their ability to withstand high temperatures, and each material has a limited range over which it operates most effectively, different thermoelectric materials are combined in each thermocouple. These are arranged in series from hot to cold, so that each material operates in the temperature region at which it performs best. The new generator operates at temperatures as high as 1200 degrees F while its cool side is at about 50 degrees. No single thermoelectric material could efficiently span this range of temperatures.

Magnetohydrodynamics—Faraday discovered that a conductor moving in a magnetic field could be made to generate an electric current; the usual method of applying this law is to rotate copper bars past energized field windings. However, the principle holds equally well for a fluid conductor moving through a field, and this, in brief, is the principle of the MHD generator.

In an MHD generator, hot ionized gas travels through a magnetic field applied at right angles to the flow; the gas flows past electrodes, and electrons in the stream are deflected and flow to the anode. They then flow through an external load, to the cathode, and back into the gas stream.

The most serious problem to be faced with MHD generators is the temperature at which they must operate to maintain sufficient ionization of the gas. Even with "seeding" with such metals as potassium or cesium, adequate electrical conductivity requires temperatures of 4000 to 5000 degrees F. This points squarely to the need for materials that can withstand high temperatures, as well as chemical attack. The requirement also indicates the reason why most experimental MHD generators have operated for but a few seconds continuously. A major exception is a generator developed at the research laboratories, which has run for 4 minutes continuously and generated as high as 10 kw.

This generator is being used for a variety of studies, including operating characteristics, power distribution in the generator, and many other aspects. Obviously, much more research is necessary before the MHD generator will have practical application as a means of generating large amounts of power continuously, although meanwhile it may have potential for specialized application, such as satellite communications systems. ■ ■ ■

Photographing Cosmic Ray Tracks

A new electronic tube, so sensitive it can "see" individual particles of light, has enabled Westinghouse scientists to photograph the faint tracks of cosmic rays as they move through a solid crystal at speeds near the velocity of light.

The high-energy-particle camera used in performing the photography is one of the newest tools of the nuclear physicist. Although cosmic rays or other high-energy particles remain within the crystal only about a billionth of a second, they leave luminous tracks which reveal their identity and behavior. These tracks, however, are much too dim to be seen or photographed without some means of greatly increasing their brightness.

In the experiments, the brightening is accomplished by a new light amplifier tube called the Astracon. The Astracon takes incoming particles of light (photons) and uses them to release electrons from a light-sensitive input surface. The emitted electrons are accelerated and guided successively onto a series of thin films. At each film, an incident electron ejects five or six additional electrons, which move on to the next film. After being multiplied in this way through several stages, the electrons strike a phosphor screen similar to that in the viewing end of a television picture tube. Here they re-emit about 10 000 photons of light (in a four-stage tube) for each photon that originally entered the tube. As a result, dim images on the tube's input surface are increased in brightness at the output as much as several thousand times.

These experiments demonstrate the feasibility of using the Astracon in high-energy particle research. The degree of light amplification the Astracon provides should make the scintillation crystal an increasingly effective tool of modern physics, where it will supplement the more familiar cloud chamber and bubble chamber in nuclear and cosmic ray research.

The light that is generated along the path of a cosmic ray or other high-energy particle moving through the crystal is focused by a mirror system onto the input surface of an Astracon tube. The image produced by the tube then passes through a lens system, which focuses it onto the input surface of a second Astracon tube. This second tube is triggered to operate only when a desired flash of light occurs in the crystal. Thus, it acts as a shutter that can be opened or closed in a small fraction of a second and also as an amplifier of light during the time it is turned on. The final image produced by the second Astracon tube then is directed onto a photographic film, which records the pictures of the path of the particle.

An advantage of this system is the unusual simplicity and compactness of the required equipment. Each Astracon image tube is about four inches in diameter and six inches long. The entire assembly—scintillation crystal, Astracons and their focusing magnets, coupling lens systems and camera—is little more than three feet long; the necessary power supplies and other equipment take up only a slightly larger amount of space.

Another advantage is the unusually small "dark current" inherent in the Astracon tube itself. This is the current that normally flows in an imaging device when not receiving the light impulses it is designed to strengthen. Dark current shows up as spurious flashes and background illumination that interfere with the desired image. The dark current characteristics of the Astracon are more than adequate for nuclear track photography and other low-light-level applications. The Astracon already has been used experimentally in astronomy for increasing the brightness of the images and spectra of distant stars. Additional applications are forecast. ■ ■ ■

High-Temperature Transistor

The first transistor capable of operating above 650 degrees F is made from silicon carbide, a hard crystalline material which, in impure form, is used as an abrasive in grinding wheels.

Although still in the laboratory stages of development, the high-temperature capabilities of the new transistor make it a significant advancement in the technology of semiconductor devices. Present-day transistors manufactured almost exclusively from germanium and silicon, can operate at temperatures no higher than about 200 degrees F (germanium) to 400 degrees F (silicon). Laboratory tests show that the new silicon carbide transistor amplifies and has power gains greater than unity up to 670 degrees F, and with further development, the Westinghouse scientists foresee its upper operating temperature at more than 925 degrees F.

The new device is a unipolar transistor, which differs in operating principle from the bipolar type usually made from germanium and silicon. The bipolar transistors regulate the flow of an electric current through them by the injection of electric charge carriers across a junction built into the semiconductor material. The unipolar transistor, on the other hand, acts more like a valve that opens or closes to regulate the electron flow across the junction.

Two advances have made possible the unipolar silicon carbide transistor. They are: the availability of silicon carbide crystals of exceptional purity,

and the perfection of techniques to form the semiconductor junction in the material, and to clean, etch, solder, and otherwise handle the inert silicon carbide crystals.

The silicon carbide transistors are made from crystals about two-thousandths of an inch thick. These crystals have less than one part impurity in 10 million parts of silicon carbide. The semiconductor junction is built into the material by exposing it to vaporized aluminum at the white-hot temperature of 3900 degrees F. The aluminum atoms diffuse into the silicon carbide crystal, changing its electrical behavior from n-type material to p-type. The junction is formed where the two types meet, and the diffusion process is controlled to within a few millionths of an inch.

To construct the input and output terminals of the transistor, the wafer is etched at two points until the junction within the body of the crystal is reached. Electrical connections at these two points and to the body of the wafer complete the transistor.

A typical finished transistor is about 80-thousandths of an inch long and 40-thousandths of an inch wide, and the "working" area of the crystal surface is smaller than the head of a pin. The finished transistors have a power gain of about 60 at room temperatures. This ability to amplify continues as the temperature is raised up to the 670-degree-F figure. The device was developed under sponsorship of the Electronics Research Directorate of the Air Force Cambridge Research Laboratories. ■ ■ ■

Measuring Ultra-Low Pressures

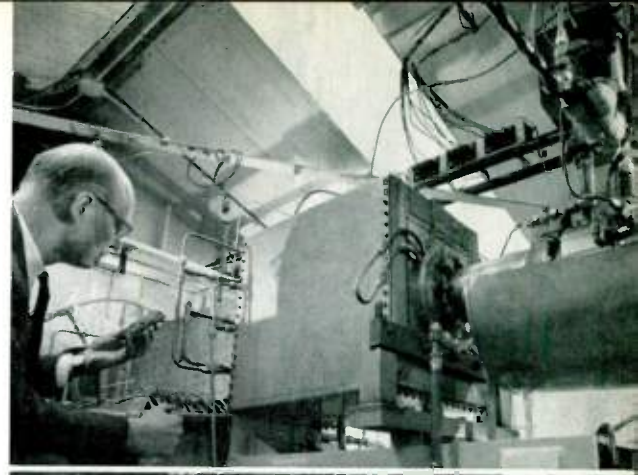
Measurement of pressures less than one-thousandth of one-billionth of atmospheric pressure at the earth's surface can be accomplished with a new laboratory tool.

The device, known as a photomultiplier ion gauge, was developed as part of an ultra-high vacuum research program supported by the U. S. Atomic Energy Commission's Project Sherwood. The new instrument has advantages over conventional low-pressure-measuring devices for many critical ultra-high vacuum experiments.

Instruments that measure extremely low pressures do so by placing electrical charges upon the gas particles remaining in a vacuum system and counting the rate at which these charged particles, or ions, form. Conventionally, these charges come from electrons that are boiled off the surface of a hot tungsten filament located inside the vacuum system and in contact with the gas being measured. In many instances, the gas interacts with the hot filament surface, breaking the gas down and converting it to an entirely different substance. Thus the very act of measuring the gas pressure contaminates the gas and upsets the entire experiment.

The new pressure-measuring device overcomes these undesirable effects by doing away with the heated filament completely. Instead of a hot surface, a beam of ultraviolet light is used to produce the required ionization of the gas. The light is beamed onto a metal surface that has the ability to release electrons under the stimulus of the ultraviolet rays. These electrons are guided onto a series of similar surfaces, which multiply the electrons in speed and number. These electrons then are used to form the ions that are collected and counted in the usual fashion. The series of surfaces that releases the electrons and increases their number is a photomultiplier, from which the name of the new pressure-measuring instrument is derived.

The photomultiplier ion gauge will be useful in a variety of key ultra-high vacuum research experiments, being ideally suited to low-pressure studies of hot filament-gas interactions such as those encountered in the ordinary fluorescent lamp, in electronic tubes and in thermionic energy converters.



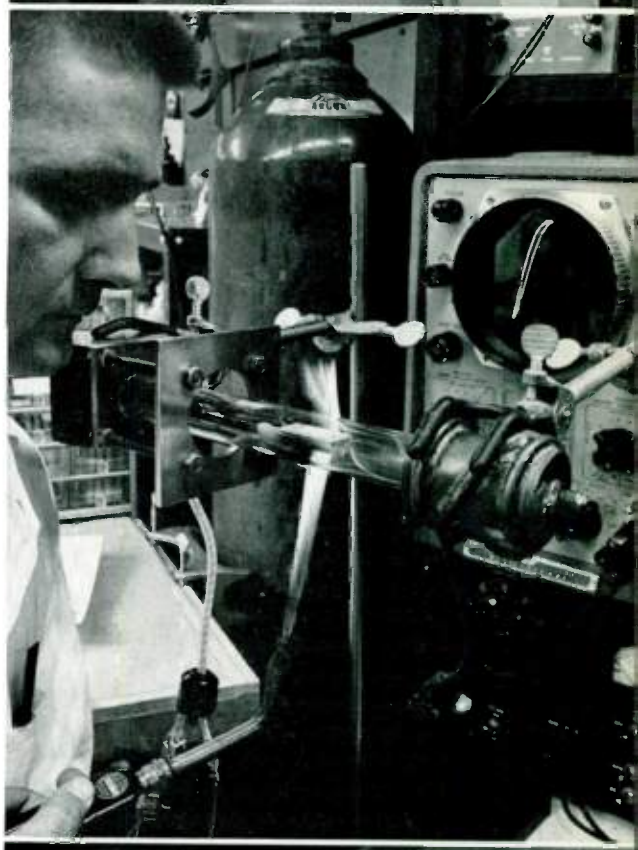


Photo 1 This magnetohydrodynamic power generator is the first to operate in the kilowatt range for a sustained period (four minutes). It is the first sizable MHD unit to burn natural fuels in producing electricity (see story, p. 27).

Photo 2 The first transistor capable of operating at temperatures above 650 degrees F is shown here being demonstrated. Trace on oscilloscope indicates that the silicon carbide transistor is operating perfectly even under temperatures at which conventional germanium or silicon transistors fail (see story, p. 28).

Photo 3 The new instrument in the foreground is a photomultiplier ion gauge for measuring pressure. Ultraviolet light shining into the gauge releases electrons, which are multiplied and used to form ions. The rate at which ions are formed is a measure of pressure (see story, left.)

The gauge is linear with pressure over the range from one-thousandth (10^{-3}) to one-tenth of one-billionth (10^{-10}) millimeter of mercury. This range of pressures is equal to that encountered in space at distances between 50 and 650 miles above the surface of the earth. In fact, the new device already has found use in pressure measurements and other experiments aimed at understanding the concentration and interactions of the particles found in outer space through duplication of outer space conditions in the laboratory. ■ ■ ■

New System for Infrared Seeing

A new infrared system is sensitive enough to see moving objects near room temperature solely by means of the invisible heat rays they emit.

Known as the phothermionic image converter, the all-electronic device changes the infrared radiation emitted by an object into a visible picture on a television screen. The speed with which it responds to infrared is roughly equal to that of the human eye to visible light.

The phothermionic image converter operates in the "far" infrared, that is, on infrared radiation of relatively long wavelengths. Such radiation is emitted by comparatively cool objects such as the human body. Hotter objects, for example those that actually glow red hot, emit more energetic radiations of shorter wavelength in the "near" infrared, and are easier to detect.

Infrared is becoming increasingly important, particularly in its military applications—for missile guidance, fire control, reconnaissance and warning systems. The outstanding advantage of such systems is that they are undetectable by the enemy. No telltale signals are broadcast. All objects above the temperature of absolute zero constantly emit infrared radiation, and infrared systems simply pick up these naturally occurring signals through space.

These systems operate upon the broad principle of sensing the heat energy radiated by a body and converting it, by means of some form of heat-sensitive detector, into equivalent electrical signals that can be amplified and made visible to the human eye. The traditional method has been to use a sensitive crystal, or infrared cell, to detect the radiation, and a mechanical scanning system to make the image visible.

The newer approach is an all-electronic imaging system, because such a device has the potential advantages of faster response, higher sensitivity and better picture detail. The phothermionic converter marks an important forward step in bringing this type of system to reality.

The key component in the newly announced system is a unique infrared-sensitive detector, or retina. The retina is a three-layer sandwich only a few millionths of an inch thick.

The center layer of the sandwich is an ultra-thin support film of aluminum oxide about one millionth of an inch thick. This film is made by chemically dissolving away all of the aluminum metal in a piece of suitably treated household aluminum foil, leaving only the thin layer of aluminum "rust" that coats the foil's surface.

The front surface of the oxide support film is coated with an even thinner layer of nickel, deposited in such thickness that it strongly absorbs infrared radiation. The back surface of the film is coated with a thin layer of a photoemitting material called cesium bismuth—a chemical compound capable of releasing electrons when light shines upon it. Of key importance is the fact that the photoemitter's ability to release electrons under the stimulus of light varies with its temperature, changing two or three percent for every degree.

To increase the overall sensitivity and performance of the detector, it is cooled to a temperature of about 180 degrees below zero Fahrenheit.

In use, the infrared radiation from an object is focused on the heat-absorbing layer of the retina, forming a temperature pattern of the scene. This temperature pattern transfers through the thin support layer to the photoemitting surface, where it can be perceived simply by scanning a spot of light across the surface.

As the light spot scans the photoemitting surface, many or few electrons flow from the surface in exact conformity to the heat pattern on it. These electrical signals are then amplified and fed to a standard television picture tube, where a visible picture appears. Thus, a point-by-point description of the temperature scene is created on the television screen.

The development, first in a series of such devices, was sponsored mainly by the Wright Air Development Center of the U. S. Air Force. ■ ■ ■

Progress With EL

Electroluminescence was a purely scientific phenomenon but, a few years ago, "turned the corner" as a practical source of light. The best indication of this is the availability of several standard products: an electroluminescent night light; a family of readout lamps, with numbers or letters ranging in size from four inches down to one-half inch; and square electroluminescent panels ranging in size from 2 by 2 inches up to 30 by 30 inches, with a rated service life of over 5000 hours.

Moreover, electroluminescent panels have been developed for a number of other applications, including such diverse uses as tracing tables for mapmakers and draftsmen, and information display devices.

Despite the fact that electroluminescence has achieved a product status, however, research and development continue on a broad basis, because the full potential of electroluminescent light is far more extensive than present applications.

One of the most interesting aspects of electroluminescent light sources is the wide variety of shapes, colors and construction that are possible. Basically, an EL lamp is an electrical capacitor. A typical lamp consists of a flat sheet of glass with a transparent conducting coating on one surface; the phosphor is embedded in plastic and applied to the conducting surface of the glass; then a second electrode of vacuum-deposited aluminum or silver paint is applied to the back surface of the plastic. The back of the lamp may then be coated with plastic for protection against moisture.

However, electroluminescent lamps are by no means limited to this type of construction, and this broadens their application potential considerably. For example, this year engineers at the lamp research laboratories developed a flexible plastic lamp; an experimental multicolor lamp that can produce either red, green, or blue light—any combination of colors; a new type of red lamp (the most difficult color to achieve with adequate brightness); and a virtually unbreakable plastic lamp.

The flexible plastic lamp was built to rigid military specifications, which required good strength under flexing, as well as high resistance to moisture. The results of this work laid the groundwork for future construction of flexible lamps for military applications, and for such things as flexible draperies and similar uses. The lamps have been built for 120 and 240 volts at frequencies up to 400 cycles.

The experimental multicolor lamp consists of three emission layers, each designed to emit its characteristic light. The cell is so constructed that light from the lower layers is transmitted through the upper layers. This means that light from the lower layer (green) passes through five transparent electrodes and two phosphor layers before being emitted.

A key part of this project was the development of an improved transparent conducting electrode that could be sandwiched between the emission layers and transmit a large portion of the light produced in lower layers. These lamps have been produced both in rigid glass base cells and in a flexible version, and operate at 120 volts at frequencies up to 1000 cycles. At present, these multicolor lamps are expensive to produce and therefore are considered experimental devices. Nevertheless, they do point to possibilities for the future.

The new red lamp uses a cascade principle. Because of the difficulty in obtaining a red phosphor with adequate brightness for some applications, engineers took another tack. They used a fluorescent dye in a plastic film overlay, which is applied to a green lamp (the most efficient color). The dye converts the green light to red, and the result is higher brightness and longer life than can be achieved with red phosphors alone. The type of lamp has possibilities for use in instruments, for signs of various kinds, and many other applications.

The solid all-plastic lamp has the same general light emission characteristics as the glass-based lamp, but has the added advantage of being practically unbreakable. This makes it particularly suitable for use in aircraft and automobiles, as well as such things as decorative lighting. Another advantage is that these lamps could be heat formed to virtually any shape. ■ ■ ■

A Better Look at the Sun

The National Observatory of AURA (Associated Universities for Research in Astronomy) is building the world's largest solar telescope, to be located at Kitt Peak Mountain near Tucson, Arizona. The instrument will be manufactured, tested, and installed by Westinghouse. The completed telescope will have a 300-foot focal length and will form a bright image of the sun 34 inches in diameter in the observer's room.

The instrument and its general arrangement is shown below. The sun's rays will be intercepted by the heliostat mirror at the top of the incline; they are reflected down the 32-degree optical tunnel (equal to the latitude of Kitt Peak) to a parabolic mirror underground at the bottom of the incline; from here, the image is reflected back to the number 3 mirror, which deflects the beam down through a 72-inch diameter vacuum spectrograph 75 feet long to a spectrographic plate.

The heliostat, which supports the mirror that follows the sun across the sky, will be guided by a light-sensitive servo system. All three large mirrors (with diameters of 80 inches, 60 inches, and 48 inches) will be furnished by the National Observatory.

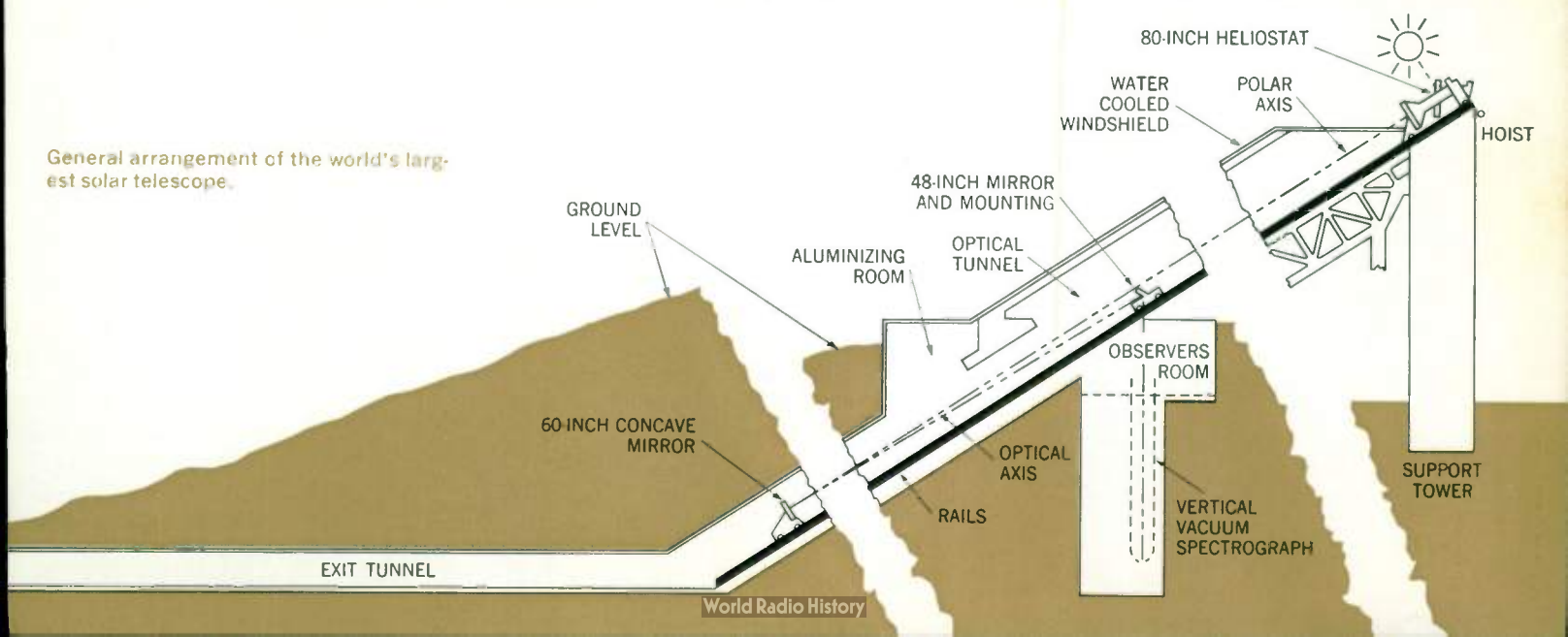
The solar telescope will be used for spectrographic analysis of the sun's surface. Geophysicists have for a number of years been engaged in important scientific study of the sun. Eruptions of fast moving gases, radiation, electromagnetic forces, and other phenomena contribute to atomic research, meteorology, and other fields. ■ ■ ■

Kromarc . . . A New Weldable Stainless Steel

Hot cracking, the tendency of metal alloys to crack under the heat and stress of welding, is a serious problem in the fabrication of welded stainless-steel structures. In a detailed metallurgical study recently completed, the effects of 18 different alloying elements on the hot cracking characteristics of chromium-nickel stainless steel were studied. The results of this study contributed to the development of a new family of super-weldable stainless steels, called Kromarc.

Several one-ton pilot heats of Kromarc steel have been made at the Westinghouse materials manufacturing department, and the material has undergone forging, casting, welding, and mechanical tests. The steels have been applied experimentally to the making of welding rod and the component parts of laboratory vacuum systems.

Scientists predict that the new steels will soon find their way into larger and



General arrangement of the world's largest solar telescope.

more complicated structures that must be fabricated from stainless steel.

CPT Test—Key to the study was a metallurgical test devised by a Westinghouse scientist, called the "cast pin tear" (CPT) test. This new test provides a fast, simple, and inexpensive method for predicting hot-cracking susceptibility of metal structures weighing many tons, yet requires a test sample weighing less than an ounce.

The test is based upon the fact that the tearing of a metal casting as it cools and shrinks from a liquid to a solid is comparable to the cracking of a weld as it freezes. A 20-gram sample is melted by the process called levitation melting, where the sample "floats" inside a coil that carries high-frequency electric current. The magnetic field around the coil supports the sample in space, and at the same time, heats it white hot and gives it a vigorous stirring action.

The molten metal is deposited in a copper mold which has the shape of a slightly tapered pin. The top and bottom of the pin lock in place to prevent normal contraction of the metal, establishing tensile stresses in the pin as it cools. By designing molds of different lengths and diameters, a scale was developed to measure susceptibility to hot cracking.

The basic composition chosen for the study was an austenitic stainless steel containing 16 percent chromium and 20 percent nickel. Some 1200 samples were tested, using 16 additional alloying elements in more than 100 different alloy compositions.

Test Results—The blueprint used for the design of Kromarc stainless steels can be summarized from the test results:

Manganese was found very effective in decreasing the hot-cracking susceptibility of stainless steel; hence, manganese content must be much higher than that normally employed in chromium-nickel steels.

Molybdenum and tungsten, which are effective elements for increasing the strength of steel, were also found to improve resistance to hot cracking. Vanadium, another common steel strengthener, is essentially neutral in its effect.

If even greater strength is required, tantalum is preferred to titanium or columbium (niobium). Both titanium and columbium were found to seriously promote hot cracking, whereas the effect of tantalum is less serious.

Many stainless steels and other high-temperature alloys contain small amounts of boron or zirconium to increase strength, ductility, and workability. However, these two elements were found to cause the most extensive cracking of all those tested.

And finally, the concentration of carbon and silicon should be low, although nitrogen content can be relatively high. ■ ■ ■

Estimating Lightning Performance

An exhaustive study of the methods used to calculate the effect of lightning strokes on transmission lines has resulted in a theory which closely matches observed performance. The need for a new method of predicting transmission line lightning performance was brought about by the large discrepancy between the originally calculated performance of the 345-kv lines and operational experience. Calculated performance had indicated that 0.3 to 0.5 outages per 100 miles per year could be expected—the line was predicted to be practically lightningproof.

However, during operation of the line in the last several years, the outage rate has averaged 7.2 outages per 100 miles per year. This meant that existing methods for calculating voltage across the insulator string when the tower is struck by lightning were apparently in error.

To solve the complex problem, engineers went back to Maxwell's field theory equations. By use of these equations and additional field theory, new calculations were made. Using assumed lightning stroke current fronts of 2.0 to 4.0 microseconds, calculated performance ranged from 8.2 to 6.6 flashovers per 100 miles per year, which agreed with observed performance of 7.2.

The largest single change in the new approach from previous methods was the inclusion of the effect of lightning charge above the tower. This charge had been omitted from previous performance calculations.

Unfortunately, field theory calculations are much too complicated and unwieldy for general application. Therefore, the field theory method is being reduced to a more usable form. Conventional circuit theory is used to calculate the voltage effect of the current fed into the system from the stroke; simplified electrostatic theory is used to determine the effect of the changing charge in the stroke above the tower. Calculations with the simplified theory have shown good agreement with field theory results.

Lightning Stroke Characteristics—Calculations of the lightning flashover performance of transmission lines can be no better than the accuracy of the lightning stroke characteristics used in the calculations. Prior to 1960, there were no truly reliable data on lightning stroke characteristics. During the 1960 lightning season, Westinghouse engineers had 80 Kine-Klydonographs installed on transmission towers of four electric utility systems. This was a season of very low thunderstorm activity, and only three records were obtained.

While this number of records is statistically insufficient, every one of them indicated that there are major stroke current components having fractional-microsecond rise times in addition to longer time components as presently used by the industry.

There are also unknown details regarding the magnitudes of the charges accumulated by thunderclouds. A new instrument was designed for measuring the electric field intensities due to thunderclouds. Limited experience with these instruments has shown great promise. One record (right) shows an electric field intensity of 1000 volts per cm, which is about three times previously measured values. Continued activity on the determination of lightning characteristics is planned for the next several years.

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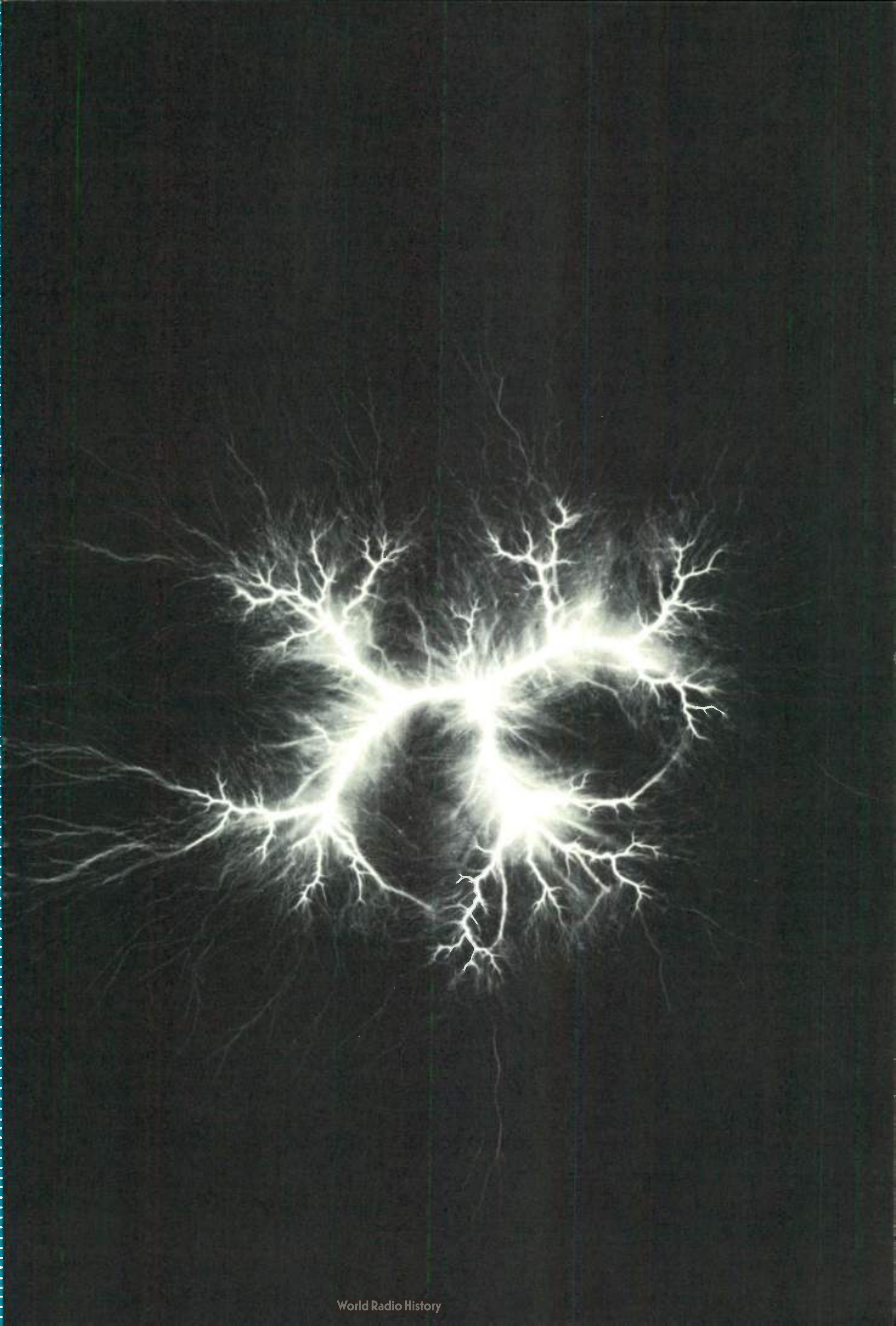
Right To those schooled in the art of lightning measurement, the interesting figure at right is a film record of the electric field intensity developed by a thundercloud. The measurement was made with a specially developed Klydonograph capable of recording voltages about three times those obtainable with conventional Klydonographs. In essence, the record is produced on a sheet of photographic film that is placed between a probe electrode and a grounded plate—the greater the field intensity, the larger the figure. In this example, the record shows that an electric field intensity of approximately 2500 volts per inch existed just prior to the lightning stroke.



This model plane is a special scale mock-up of the aircraft to be used in the first airborne educational television program. Studies conducted with this mock-up determine how far the transmitting antenna must project downward from the fuselage of the plane—an important consideration since reflected signals from the craft's underbody would tend to interfere with the broadcasts. Westinghouse is equipping and installing the transmitting facilities in two DC-6 A/B planes, which are scheduled to begin broadcasting educational courses to a six-state area in the Midwest in 1961.