Westinghouse ENGINEER

November 1965

A continuous bright-annealing line that anneals metal strip in an atmosphere of dissociated ammonia to prevent surface contamination has been put into operation at the Westinghouse Materials Manufacturing Division, Blairsville, Pennsylvania. Jet-cooling equipment quenches the material immediately after annealing, a procedure that is especially valuable in attaining superior properties in high-temperature alloys.

The line is used to anneal the nickel-iron alloys, electrical steels, and high-temperature alloys produced by the Division. It also is made available to other companies—as are the Division's casting, rolling, and forging facilities—for processing their materials. The line handles strip from 6 to 20 inches wide and from 0.001 to 0.060 inch thick.

The gas-fired vertical furnace in the line can reach 2100 degrees F. (In the photograph, strip is seen entering the furnace in center background.) Temperature, strip speed, atmosphere, and cooling rate are precisely controlled, allowing grain size to be held within ± ½ of a standard ASTM grain size. In addition, the Division's laboratory facilities permit immediate analysis of an annealed coil to insure conformity to specifications.

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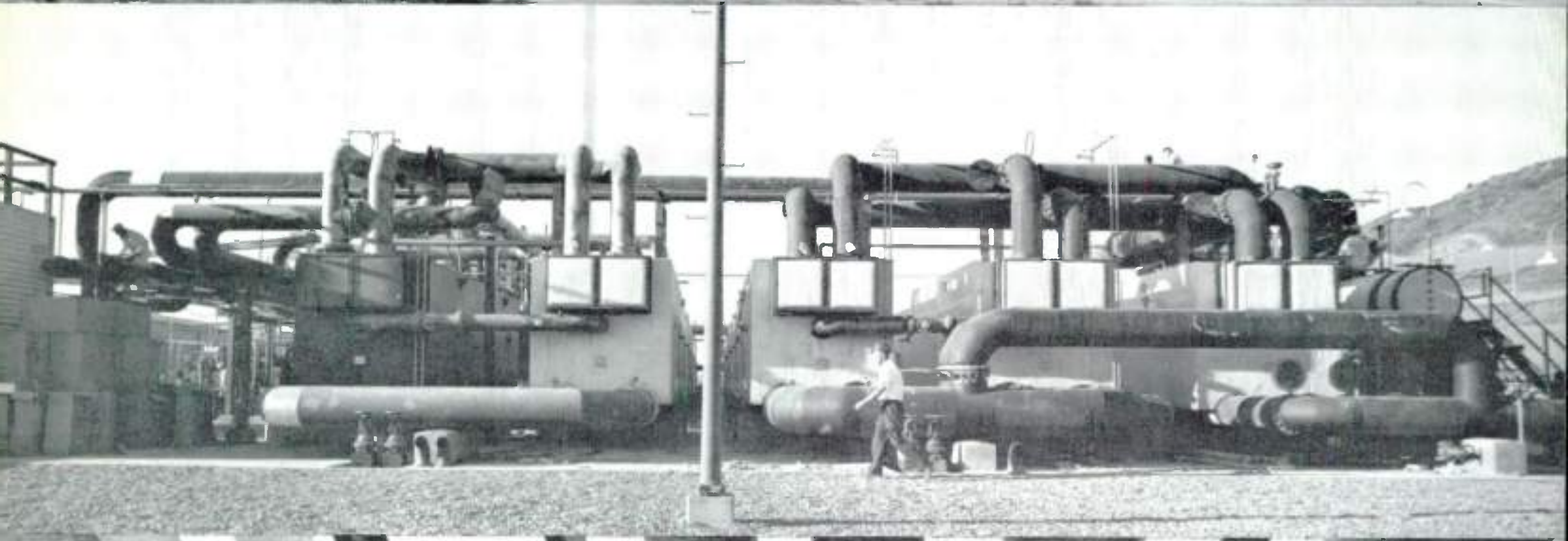
Cover Design: The concept of pure water from the unlimited supply of the ocean is conveyed in this month's cover by Thomas Ruddy, using a flash-evaporator plant against a backdrop of the sea.



Pure Water Via Flash Evaporation—1

by R. E. Gaunt

Flash Evaporation—Its Principles and Capabilities

Of the various processes in use or under investigation, flash evaporation is presently the most promising for producing large quantities of potable water economically from seawater. And, in many instances, it is also the most practical means for making extremely pure water—from either salt or fresh water—for such applications as boiler feed makeup or industrial plant process supply.

During the formative years of the flash evaporator, which from a practical standpoint began with the multistage unit built by Westinghouse for the Kuwait Oil Company in 1957, most of the technical problems were solved. Experience with a variety of flash-evaporator plant configurations has pointed out the preferable design approaches and provided the necessary operating data for accurately predicting plant performance.

The criterion for a flash-evaporator distillation plant is primarily one of economics. The costs of tapping conventional water sources are steadily rising. Today, the estimated cost of obtaining a new source of pure water by conventional means ranges from 13 to 70 cents per thousand gallons. By 1980, these costs are expected to rise to 20 to 90 cents.

In the meantime, the costs of producing pure water by flash evaporation have decreased dramatically. Ten years ago, these costs ranged from $3 to $4 per thousand gallons; today, they stand at about $1 to $1.50 per thousand gallons for existing plants of relatively small capacity. Westinghouse studies now indicate that with modern technology, large amounts of water could be converted for about 25 to 35 cents per thousand gallons in large dual-purpose flash-evaporator plants. Thus, flash evaporation is already competitive with some of the more expensive methods for obtaining new water supplies for residential and industrial use. As time goes on, it will become increasingly competitive and by 1980 should be competitive with all but the lowest cost alternatives (see Fig. 1).

Principles of Flash Evaporation

In principle, flash evaporation merely consists of spraying hot water under pressure into a chamber that is at a lower pressure and temperature. A portion of the water "flashes," i.e., changes almost instantaneously into vapor, passes through wire mesh separators, and then is condensed, providing pure water. Flashing occurs because of the difference in heat-storage ability of water under different pressures. When the high-pressure water is sprayed into the lower pressure chamber, the excess heat is released in the form of steam or vapor.

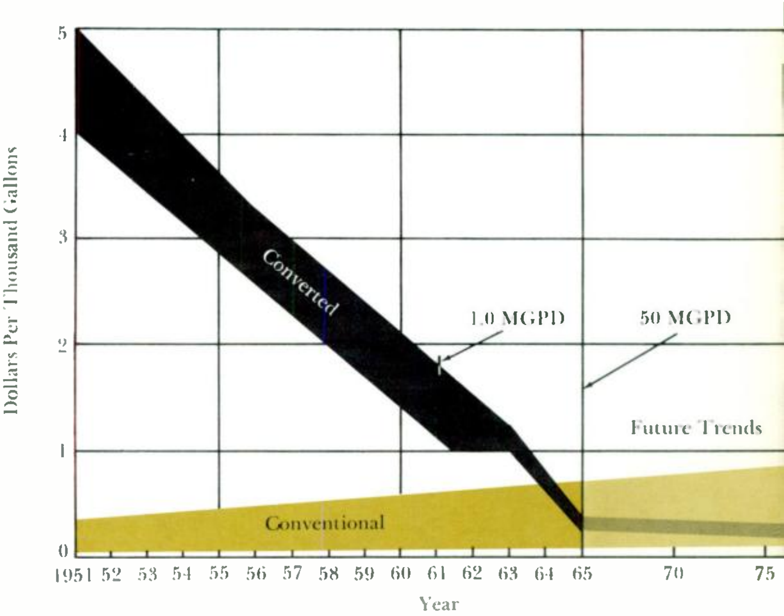
A typical single-stage evaporator consists of a heat-input section, a heat recovery section, and a heat-rejection section (Fig. 2). In most applications, the heat recovery and heat rejection sections are combined in a single package.

The heat-input section, commonly called the brine heater, consists of a shell-and-tube heat exchanger. The most common heat source is steam from a boiler or turbine cycle, but other sources, such as exhaust gas from a gas turbine or stack gases from a boiler, can also be used.

The heated brine is forced through an orifice to the flash chamber; here, the heated brine partially "flashes" and becomes a mixture of vapor and liquid. The amount of vapor produced from one pound of brine depends on the temperature drop of the brine across the orifice. As a rule of thumb, about one percent of the brine flashes to vapor for each 10-degree F drop in temperature, within the range of 100 to 200 degrees F.

The vapor passes through moisture separators, constructed in the form of wire-mesh grids, which remove liquid droplets that the vapor might otherwise carry along. The vapor then passes over tubes, which condense it to pure distillate. This condensation of vapor on tubes at lower temperature maintains the necessary pressure drop in the flash chamber and recovery section.

The unflashed brine is recirculated through the heat recovery section to the brine heater. The desired brine concen-



1—**Estimated costs of fresh water** by conversion and by conventional means. Cost of conversion for 1965 is for a large plant.

Left—Three views of the desalting plant built at Point Loma, Calif. for the Office of Saline Water, U.S. Department of the Interior. This plant was subsequently moved to Guantanamo Bay during the water crisis. At top is the overall plant; center, the flash chambers; and at bottom, part of the complex of piping of such a plant.

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tration is maintained by adding makeup seawater from the heat rejection cooling water and "blowing down" a portion of the recirculating brine.

Since the flash evaporator does essentially no work, the heat-rejection section receives practically all of the energy supplied to the heat-input section. This heat is rejected to a heat sink, such as the ocean, river, or cooling tower. The temperature of the rejection section coolant (heat sink) establishes the minimum flashing pressure.

In the usual single-stage flash evaporator, one pound of heating steam produces about one pound of distillate. This is not good energy economy, but it can be improved by using the latent heat in the vapor to reheat the circulating brine, rather than rejecting it immediately to the heat sink. This is accomplished in the heat-recovery section, which is divided into a number of stages, with each stage maintained at a lower pressure and temperature than the preceding stage (Fig. 3). Brine flows from stage to stage, giving up additional vapor as the pressure drops; vapor condensed in each recovery stage returns heat to the recirculating brine flowing in heat-recovery tubes back to the brine heater. The latent heat of vapor formed in the heat-rejection section is rejected to the heat sink.

The makeup feedwater is deaerated before it is introduced into the recirculating brine stream, prior to entry into the brine heater and the last stage flash chamber (Fig. 3).

The capacity of a flash evaporator can be altered to meet changing input conditions or output requirements in three ways:

1) Changing the steam pressure to the brine heater, thereby changing the top temperature of the brine;

2) Changing the flow of the recycled brine;

3) Changing the quantity of cooling water fed to the heat-rejection section.

This operational versatility gives the flash evaporator a distinct advantage: It can be conveniently adapted to a variety of conditions that it might encounter when integrated with some other cycle.

The heat performance (Btu's of input required to produce a pound of distillate output) of the flash-evaporation cycle is determined by the effectiveness of the physical design in conserving heat. The thermal performance of a multistage flash evaporator can be influenced by a number of factors:

1) Number of stages;
2) Tube side velocity (i.e., velocity inside tubes);
3) Length of stages;
4) Tube diameter, material, and gauge.

Whether additional stages are added or each stage is made more efficient, the more heat that can be recovered the less heat is required in the brine heater. From an economic standpoint, the end result can be summarized as the heat performance for a given configuration versus its capital cost. The designer selects the minimum-cost arrangement to produce the desired distillate-to-steam ratio consistent with the environment in which the flash evaporator will operate.

The heat performance (or capital cost) that can be justified for a given application is dictated by operating cost, fuel cost, capitalization rates, and electric power cost. Thus, in a high-fuel-cost region, additional capital expense is justified to reduce the energy requirements of the plant; in a low-fuel-cost region, capital cost can be minimized.

Applications for Flash Evaporators

Although the flash evaporator was originally developed to reduce the cost of producing potable water from seawater, it has found widespread application in the electric utility and industrial field, where extremely pure water is often necessary. Three major areas now exist for application of flash evaporators:

1) Single-stage units for supplying boiler feed makeup water;

2) Multistage units for supplying boiler feed or process makeup water;

3) Multistage units for providing a potable water supply.

Single-Stage Boiler Feed Makeup Plants—When a flash evaporator is applied to a turbine heat cycle, the heat-input section is a brine heater taking its heat from a turbine extraction point; the heat-rejection section is an evaporator condenser placed in the condensate stream. With this arrangement, essentially no heat is lost from the overall steam cycle because the heat rejected by the flash evaporator is used to heat feedwater in the steam generation cycle. Most single-stage flash-evaporator applications are limited to this type of arrangement, where the relatively high heat rate of the single-stage unit does not represent a heat loss to the overall system.

The flash evaporator can be connected into the regenerative feedwater heating cycle in several places. However, the larger the temperature difference between the steam extracted for brine heating and the condensate used for cooling, the smaller the evaporator plant can be. On the other hand, the higher the temperature of the steam extracted for brine heating, the greater the heat cost. By locating the flash-evaporator condenser in the condensate stream ahead of the feedwater heater where steam extraction occurs (Fig. 4), the capability loss of the steam turbine is reduced to almost nothing, and the flash evaporator can be operated with virtually no thermal penalty to the turbine heat rate.

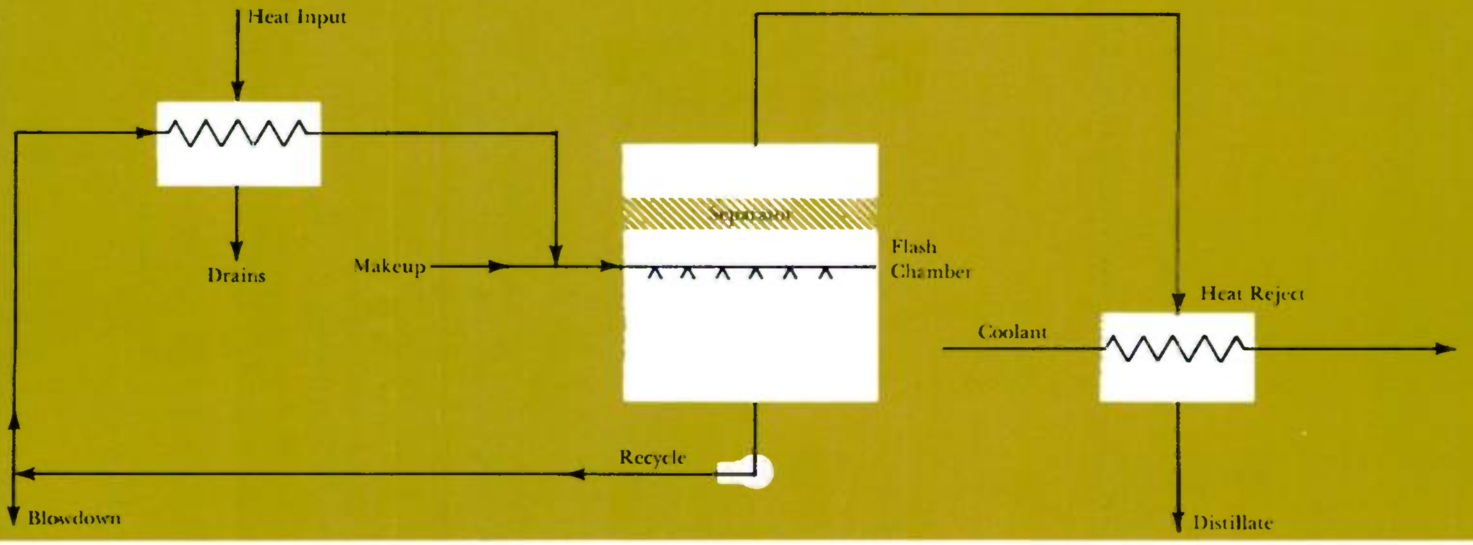
Multistage Boiler Feed Makeup Plants—Multistage flash evaporators for boiler feed makeup are most frequently justified for two types of applications:

1) Older electric utility plants that are operated on peaking service. These have high makeup water requirements, and a single-stage unit usually is not capable of making enough

2—**Heat-input, flash chamber, and heat-rejection section** of single-stage flash-evaporator cycle.

3—**Multistage** flash-evaporator cycle.

4—**Single-stage evaporator** in a turbine cycle; condenser in condensate stream is located ahead of the heater where steam extraction occurs.


Heat Input
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Chamber
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Coolant
Recycle
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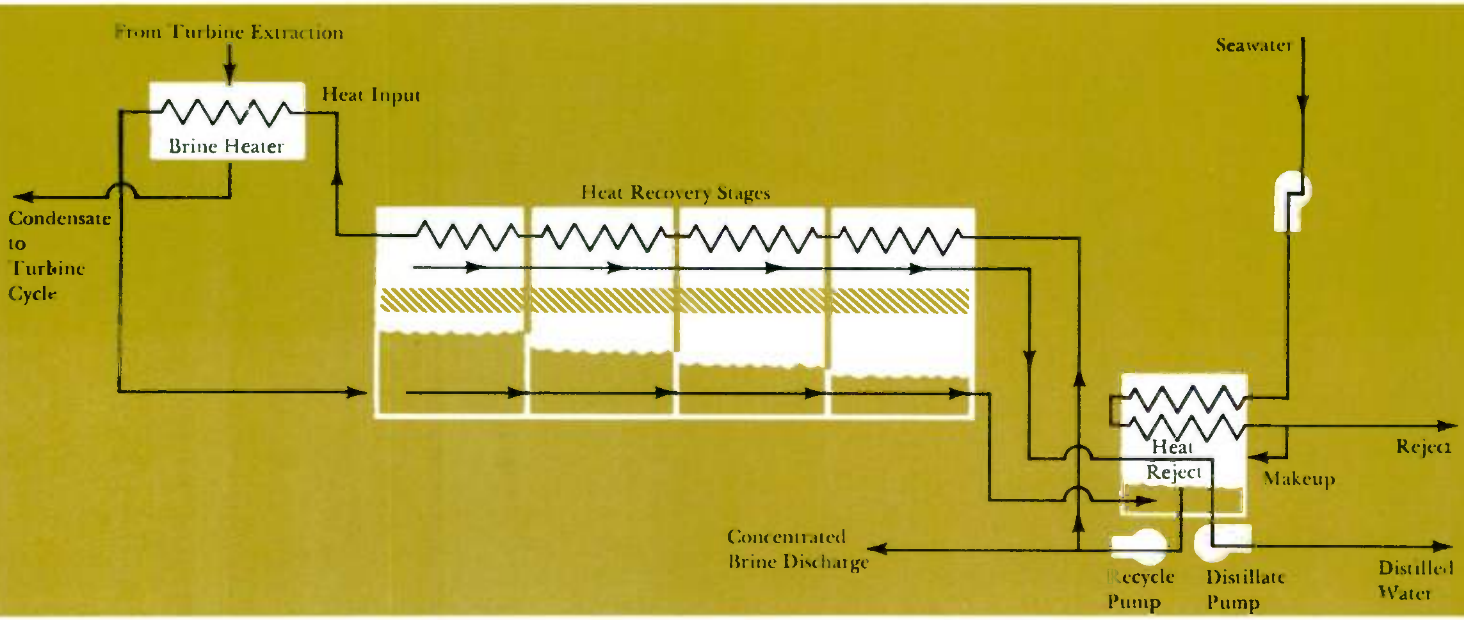
Distillate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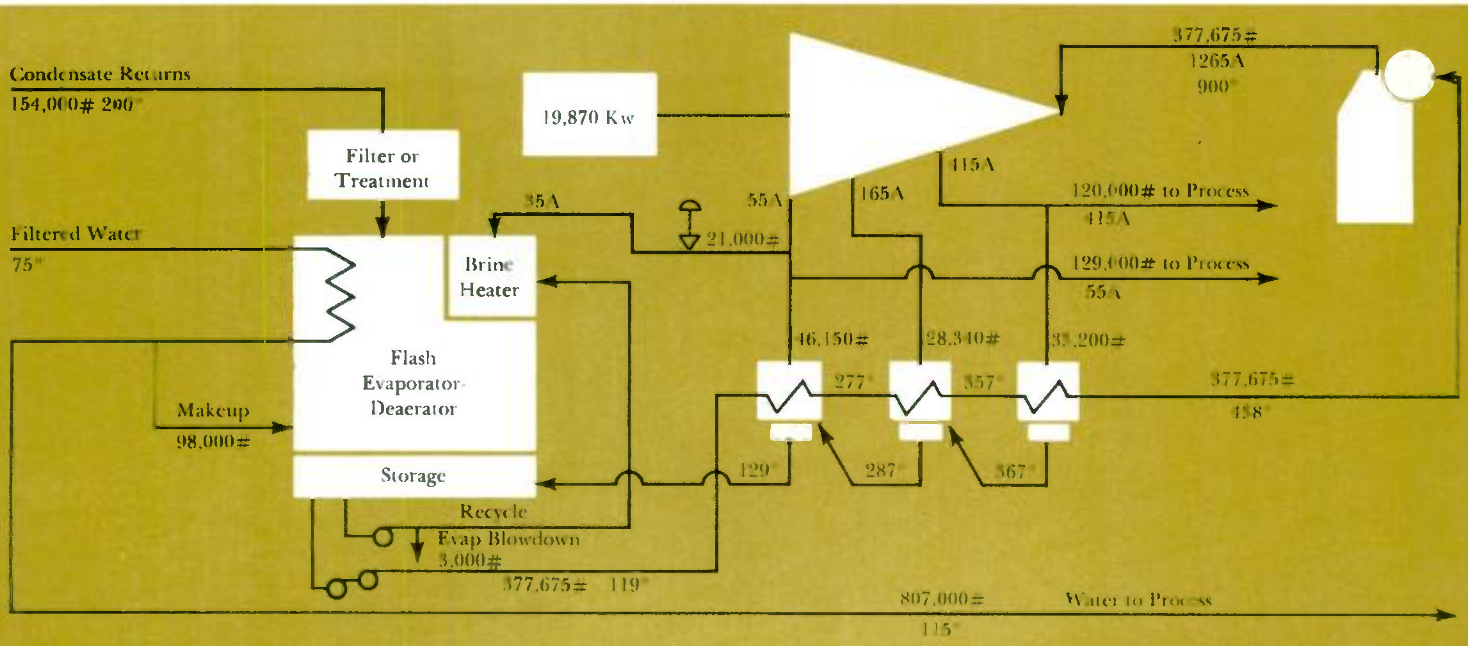
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19,870 Kw
377,675#
1265A
900°
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Treatment
35A
55A
21,000#
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Brine
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Flash
Evaporator-
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Makeup
98,000#
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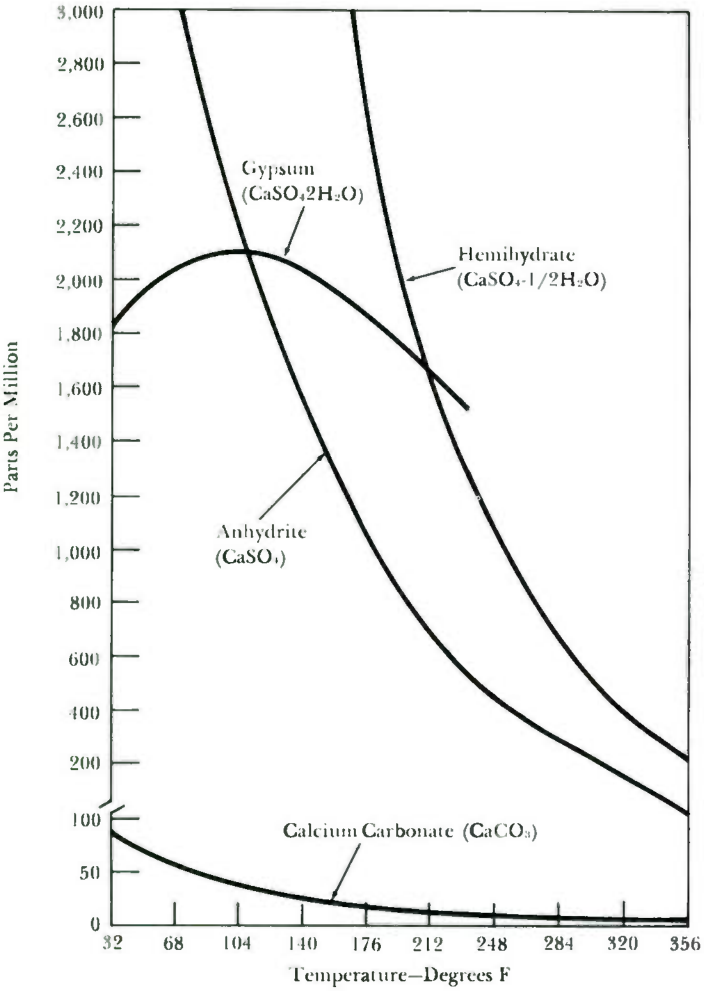

5—Inverted solubility curves for scale-forming compounds.

water during the short periods of peaking operation. Under these circumstances, heat-recovery stages in the flash evaporator usually can be justified, because of the increased output per pound of steam used in the heat-input section.

2) Industrial plants that have large boiler makeup water requirements, such as plants that supply steam to a process or a central heating system.

The trend to higher pressure boilers has created a need for extremely pure boiler feed makeup. As a result of recent evaporator separator development, distillate can be supplied with either single or multistage evaporators with the following guarantees of total dissolved solids content: 0.03 ppm with 3000 ppm solids impurity of the recirculating brine in the evaporator shell; 0.10 ppm with 6000 ppm shell concentration; and 0.25 ppm with 70,000 ppm shell concentration.

The silica, iron, and copper content can be guaranteed to be no more than: silica, 0.005 ppm; iron, 0.035 ppm; and copper, 0.015 ppm. In addition, the distillate is deaerated, sterile, and its pH is close to neutral 7.

Multistage Potable Water Supply Plants—Flash evaporators designed to produce potable water differ from those used for boiler feed makeup water, primarily in two respects: the distillate need not be as pure; to be economically competitive with other sources of water of the same purity, the total cost of the product water must be extremely low.

Fortunately, most potable water supply plants are much larger than boiler makeup flash evaporators so that the inherent economic advantages of larger water desalting plants can be realized.

Scale Control

Untreated seawater that is heated and concentrated as required by modern efficient recirculation-type distillation plants forms precipitates that deposit as scale on heat-transfer surfaces and other surfaces of evaporator equipment. These scale deposits act as thermal insulators and reduce the efficiency of the evaporation process. However, improvements in treatment to prevent scale formation have made it possible to operate over long periods of time without such formation.

The three principal types of seawater evaporator scale deposits are calcium carbonate ($CaCo_3$), magnesium hydroxide ($MgOH_2$), and calcium sulfate ($CaSO_4$). The formation of these scale deposits is influenced by: (1) maximum brine temperature, (2) concentration of recycle brine, and (3) hydrogen-ion concentration (pH). While pH strongly affects calcium carbonate and magnesium hydroxide, it probably has little effect on the formation of calcium sulfate scale. The latter can be prevented by not exceeding its solubility. This requires that the maximum concentration in the recycle brine be limited. All of the scale-forming compounds have inverted solubility curves (Fig. 5), so that as temperature increases, the compounds become less soluble.

Thus far, the scale-control technique that usually has proved most successful in flash-evaporator plants is pH control. Since carbonates and hydroxides are made more soluble by lowering pH, acid is fed to the makeup seawater to maintain a pH normally ranging from 7.0 to 7.5, thereby preventing scale of these compounds from depositing.

Another scale-control technique that shows promise is the "seed recycle" process. Here, seed crystals (magnesium hydroxide, for example) are introduced into the system and the seeds present sufficient surface that scale deposits on the crystals rather than on other surfaces. Thus, the flash evaporator parts remain scale free because all scale-forming substances exist as particles in suspension.

Experience has shown that there is no technical limitation on plant size. It is technically feasible now to build flash evaporator desalting plants as large as anyone wants—50, 100, or 150 million gallons per day—with life expectancy comparable to that of power plants, that is, 30 to 40 years. The necessary research work has been done—only rigorous engineering effort is required.

Pure Water Via Flash Evaporation—2

by R. E. Gaunt

Flash Evaporator Installations—Present and Future

The potential of the flash-evaporator process for producing pure water reaches far beyond what has been accomplished thus far. However, experience with a variety of plant cycles, water conditions, and operating situations has multiplied rapidly during the past four or five years, creating a large fund of technical know-how.

While Westinghouse experience in building equipment to convert impure water to fresh water in quantity dates back to 1948, the first application of the multistage flash-evaporation cycle was in four 630,000 gpd units built for the Government of Kuwait in 1956 and placed in operation in 1957 and 1958. These units were the result of an extensive research and development program conducted from 1953 to 1956, aimed at finding better and less expensive methods of producing potable water from seawater.

In total, Westinghouse has completed, is building, or has on order flash-evaporator plants with a total capacity of over 13 million gallons per day. Over 40 plants have been built, in sizes ranging from the 2.52 million gpd Kuwait flash-evaporator plant, down to a 28,800 gpd unit for boiler feedwater makeup. (See list of some plants in Table 1.)

One of the most significant facts about the flash-evaporation process is its adaptability to different problems. While

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Table 1—Westinghouse Flash Type Evaporators

Plant	*Capacity (gallons per day)*	*In-Service Date*
Government of Kuwait, Kuwait, Arabia	2,520,000 (total 4 units)	1957
Harvey Aluminum, St. Croix, U.S. Virgin Islands	1,500,000	1965
Office of Saline Water, Department of Interior, Point Loma, California*	1,400,000	1961
Virgin Islands Government, St. Thomas	1,000,000	1965
Monsanto Co., Chocolate Bayou Plant, Texas	762,000	1962
Guantanamo Naval Base, Unit #1	750,000	1964
Guantanamo Naval Base, Unit #2	750,000	1964
Canary Islands, Lanzarote	650,000	1964
Arabian Oil Company, Neutral Zone, Arabia	500,000	1962
Virginia Electric and Power Co., Mount Storm #1	328,320	1965
Virginia Electric and Power Co., Mount Storm #2	328,320	1966
Tennessee Valley Authority, Paradise #1	209,000	1963
Tennessee Valley Authority, Paradise #2	209,000	1963
Pacific Gas & Electric Co., Moss Landing #6	188,000	1965
Pacific Gas & Electric Co., Moss Landing #7	188,000	1966
Virginia Electric and Power Co., Possum Point #4	187,000	1962
Southern California Edison Co., San Onofre (Nuclear)	172,500 (total 2 units)	1966
Tennessee Valley Authority, Bull Run #1	169,600 (total 2 units)	1965
Companie Orientale des Petroles Belayim, Egypt	158,000	1965
Texas Electric Service, Handley #3	144,000	1963
Philadelphia Electric Co., Richmond Station	144,000	1960
Pacific Gas & Electric Co., Morro Bay #3	123,000	1962
Pacific Gas & Electric Co., Morro Bay #4	123,000	1963
Kentucky Power Company, Big Sandy #1	116,500	1962
New England Power Company, Brayton Point #1	111,000	1963
New England Power Company, Brayton Point #2	111,000	1964
Pacific Gas & Electric Co., Contra Costa #6	104,500	1964
Pacific Gas & Electric Co., Contra Costa #7	104,500	1964
Philadelphia Electric Co., Chester Station	100,800	1962
Oasis Oil Company, Libya	100,000 (total 2 units)	1962
Comision Federal de Electricidad, Tijuana #1	63,300	1963
Comision Federal de Electricidad, Tijuana #2	63,300	1963
Comision Federal de Electricidad, Tijuana #3	63,300	1963
Kansas Power & Light, Hutchinson #4	57,600	1965
San Diego Gas & Electric Co., South Bay #2	57,600	1962
San Diego Gas & Electric Co., South Bay #3	57,600	1964
City of Owensboro, Kentucky, Elmer Smith Generating Station #2	57,600	1964
Hawaiian Electric Company, Kahe #1	52,600	1962
Hawaiian Electric Company, Kahe #2	52,600	1964
American Independent Oil Co., Kuwait, Arabia	50,000	1962
Government of Indonesia, Surabaya #1	28,800	1963
Government of Indonesia, Surabaya #2	28,800	1963

*Moved to Guantanamo Naval Base, April 1964 the largest multistage units have been used primarily for producing potable water from seawater, smaller single and multistage units are being used for producing much purer water for electric utility and industrial use, from a wide range of water sources.

Boiler Feed Makeup from Tidewater

One of the first Westinghouse single-stage flash evaporators to go into service (1962) in the feed heating cycle of an electric utility steam turbine was at the Possum Point Power Station of the Virginia Electric and Power Company, located on the Potomac River 35 miles south of Washington, D.C.

The Potomac River at this point varies in salinity throughout the year, depending upon the surface runoff of the watershed. From early spring until late summer, the river is low in chlorides, averaging 5 to 15 ppm. However, during the remainder of the year, the saline waters of Chesapeake Bay back up the river, raising the chloride content as high as 2000 ppm.

Prior to 1959, the Possum Point Station used coagulated, filtered, and softened river water during periods of low river salinity, and well water, similarly treated, during periods of high salinity. However, when one of the two station wells went dry and another well of sufficient capacity and quality could not be located, the utility had to develop another source of supply. An economic evaluation of several possible sources of makeup water showed that a single-stage flash evaporator, operated in the heat cycle of a new turbine unit that was planned for the station, would be the most economical alternative.

The flash evaporator was designed to operate either in the heat cycle of the new unit or with auxiliary steam from existing units. The design provided for a combination of condensate and river water cooling to increase the output of the evaporator. The unit (Fig. 1) can furnish 187,000 gpd, which is sufficient for the needs of the complete station.

This flash evaporator was originally designed to evaporate river water with no pretreatment other than filtration. Circulating brine is controlled with sulphuric acid for scale prevention. Total solids content of the distillate was found to vary from 0.002 to 0.12 ppm when the concentration ratio of brine to raw water was varied. The reason for this unusual range is thought to be the increased foaming characteristics caused by concentration of the detergents found in the raw river water (which averages about 0.5 ppm).

Total cost of making distillate, including the addition of chemicals for antifoam control and pH control, is about 46 cents per thousand gallons when operating in the heat cycle. This low production cost coupled with the fact that the river water at the Possum Point Station does not lend itself to year round demineralization, even with pretreatment, makes the flash evaporator particularly attractive for this station.

Industrial Plant Makeup

In 1962, the Monsanto Company placed into operation a large petrochemical plant, located 40 miles south of Houston, Texas, on the Brazos River. The plant uses extracted and exhausted steam from turbines to meet plant process steam demands. About 60 percent of the steam condensate can be collected and returned to a deaerating heater for use as high-pressure boiler feedwater. The remaining 40 percent of boiler feedwater requirements must be supplied by makeup water.

The Brazos River has a history of widely varying chemical content, and has had total solids content as high as 1500 ppm. Thus, to maintain boiler water concentration below the required limit of 5 ppm, demineralization or evaporation of the makeup feedwater was required, after initial treatment in Zeolite treating units.

An analysis indicated that a flash evaporator that would produce approximately 5 pounds of distillate per pound of heating steam was the most economic choice.

All stages of the unit are combined in a single rectangular vessel (see Fig. 2). A separate cylindrical brine heater is mounted adjacent to the first stage. Makeup water is preheated by passing it through the two heat-rejection stages. Heating the makeup water by this means improves plant efficiency and permits deaeration of the makeup water. The flash evaporator plant can produce 762,000 gallons per day with a top brine temperature of 250 degrees F.

In this application, conditions were ideally suited to a flash-evaporator application—low-cost steam, low cost of cooling-tower capacity to the flash evaporator (because the same tower is used by the chemical plant), and relatively high level of impurities in the water to be treated.

Brine Heating With Gas-Turbine Exhaust

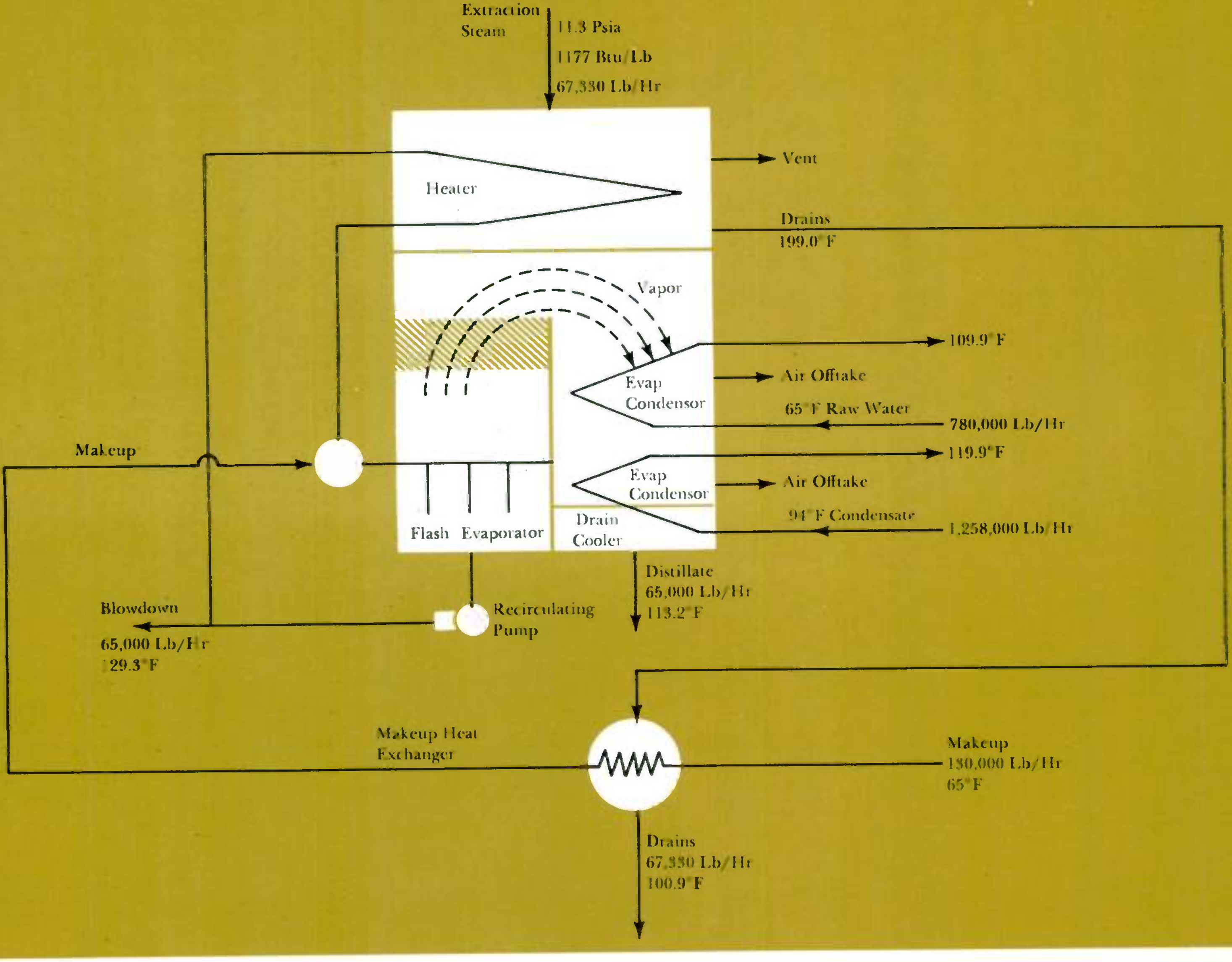
The 500,000 gpd flash-evaporator installation on the Arabian Gulf for Arabian Oil Limited is similar in design to the Monsanto evaporator. However, the brine heaters are installed on the stacks of two gas turbines, each of which drives a 10,000-kw generator. The brine heaters are connected in parallel so that any one can supply the total heat requirements of the evaporator plant. Seawater from the Arabian Gulf provides both makeup and cooling requirements. Top temperature of the recirculating brine is 190 degrees F, and a mixture of lignin sulponic acid (a dispersing agent), polyalkylene glycol (an antifoaming agent), and inorganic phosphates is used for scale control. Guaranteed water purity is 50 ppm.

Water Desalting With Titanium

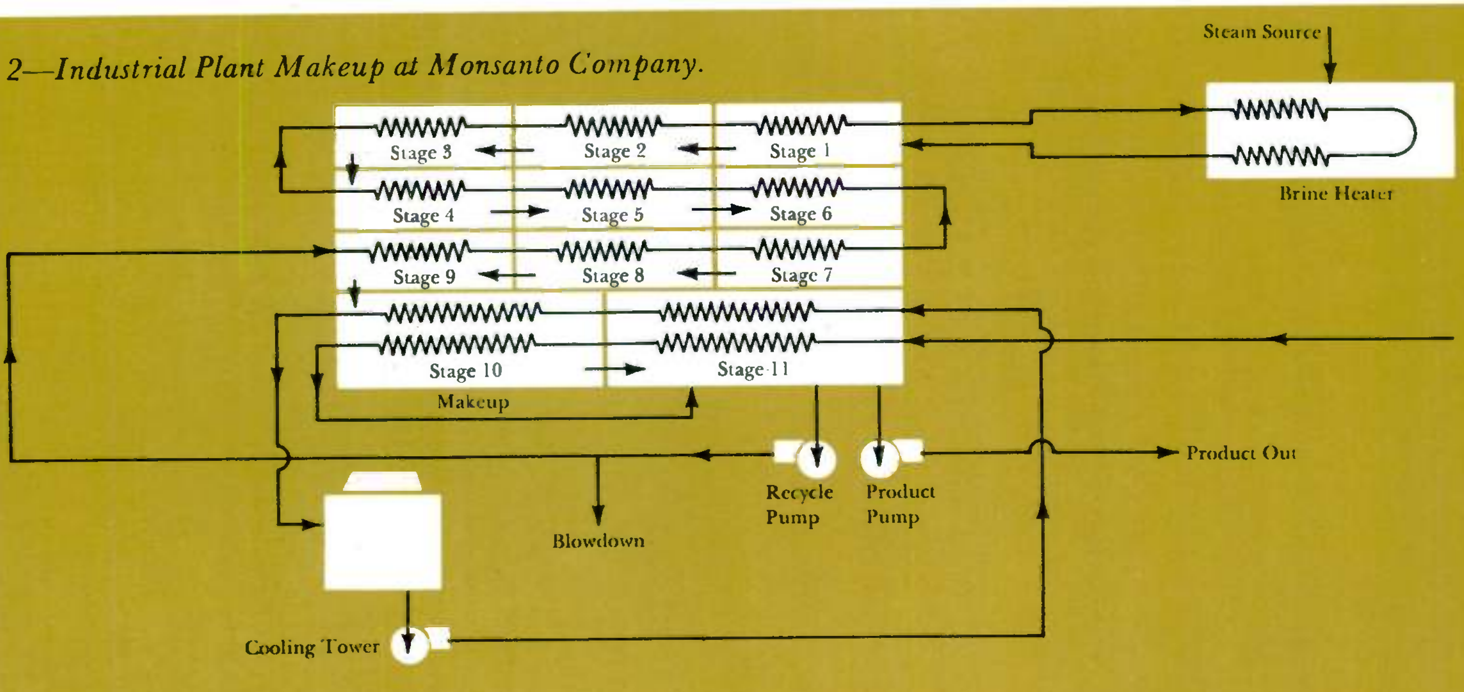
A water desalting plant installed on St. Croix in the U.S. Virgin Islands will convert raw seawater into ultra-pure fresh water for process use in an alumina plant and power plant being built for Harvey Aluminum. This plant introduces titanium tubes and tube sheets as construction and heat-transfer materials for flash evaporators. Its outstanding resistance to corrosion and erosion in seawater makes titanium very attractive for use in flash-evaporator water desalting plants.

Titanium is an effective heat-transfer surface material because of its tendency to be "nonwetting." Furthermore, thin wall titanium tubing can be used without sacrificing

1—Boiler-Feed Makeup from Tidewater at Possum Point.



2—Industrial Plant Makeup at Monsanto Company.



strength or life; this, combined with its ability to resist fouling in service, promises optimum operating efficiency and performance.

The special titanium tubing was produced and supplied by Harvey Aluminum. The tubing was developed specifically by Harvey for application to flash-evaporator desalting systems.

Operating costs for the desalting plant are minimized by using exhaust steam from the turbines of a nearby power generation plant. With this arrangement, the optimized design that balances capital cost with plant efficiency was found to be a plant with a performance ratio of six pounds of distillate produced for each pound of heating steam.

For maximum operating economy, steam from the nearby power plant is bled from the main turbines at 250 psig, 575 degrees F, and used to drive brine-circulating pump turbines in the desalting plant. Steam is exhausted from the pump drive turbines and is introduced into the brine heater to provide the heat for the desalting plant.

This flash evaporator is designed for a maximum capability of 1,500,000 gpd when operating at 250 degrees at top brine temperature.

The distillate will contain a maximum of 5 ppm dissolved solids. At this level of purity, the converted seawater will meet all requirements of the process plant, as well as serving as boiler makeup when required.

For maximum flexibility of operation, Harvey has chosen to have the plant piped and instrumented to permit either once-through or recycle operation. Unlike the conventional recycle arrangement where only a portion of the circulating brine is blown down, once-through operation passes the entire seawater feed through the cycle and rejects all but the distillate to waste from the last flash stage. Fresh seawater is pumped back through the heat-recovery tubes for preheating prior to final heating in the brine heater.

Advantages have been claimed for both once-through and recycle operation. Theoretically, once-through operation should provide slightly higher efficiency because of the smaller losses associated with lower brine concentration and boiling-point elevation. However, this advantage is usually more than offset by the higher cost of feed-treatment chemicals needed to inhibit scaling in the brine heater at high operating temperatures. Corrosion is also accelerated because the makeup water is not deaerated before it is introduced into the once-through system. The Harvey plant will permit a direct comparison of the merits of these two methods of operation.

Large Potable Water Plants

Use of the multistage flash-evaporation cycle for large-scale production of potable water from seawater began with the original Kuwait installation in 1957. Here, a relatively simple four-stage flash cycle was used (Fig. 3) because the extremely low cost of waste gas from the oil fields did not justify high-efficiency equipment. Purified water with solids of less than 100 ppm is provided from the Persian Gulf (impurity content 42,000 ppm) at a cost of approximately 63 cents per 1000 gallons.

Recent plants have not been located in such favorable fuel cost regions, so that much more efficient flash evaporator cycles have been required.

The largest single-plant installation built by Westinghouse since the Kuwait installation is the seawater conversion plant now operating on the U.S. Naval Base at Guantanamo Bay, which produces a total of 2,250,000 gallons per day. This plant consists of three multistage, flash-type evaporator units, each rated at 750,000 gallons per day.

The first unit to be installed was the seawater conversion plant originally built by Westinghouse at Point Loma, California, for the Office of Saline Water, and modified to conform to the different operating conditions on Guantanamo; the other two units are of more advanced design.

All three units obtain heat from steam that is automatically extracted from two 7500-kw turbine-generator units. The flash evaporators are operating with a top brine temperature of 195 degrees F and polyphosphate water treatment.

Point Loma Demonstration Plant—Prior to its modification for the Guantanamo installation, the Point Loma plant was rated at one-million gallons per day. It was built for the Department of the Interior, Office of Saline Water, as one of the five OSW demonstration plants authorized by the U.S. Congress to test the economics and technical feasibility of various basic water-conversion methods.

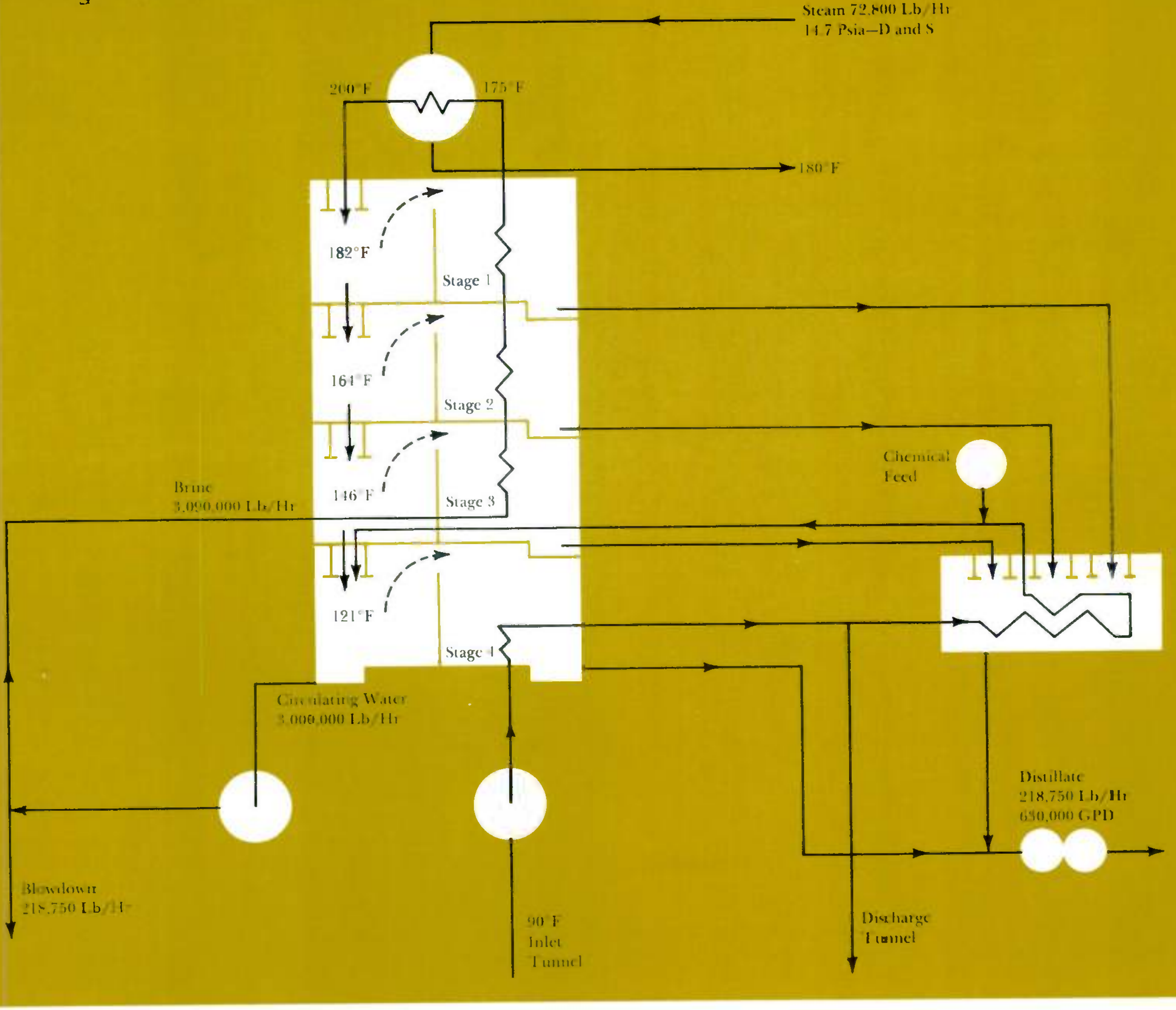
The original plant design, selected by Westinghouse, used a recycle design with 36 stages (Fig. 4). All of the seawater supplied to the plant flowed through the 35th and 36th stages, which acted as the heat sink for the plant. Approximately 60 percent of this warmed seawater was then admitted to the brine stream as makeup. In normal operation, the concentration of the recirculating brine was approximately double the concentration of seawater.

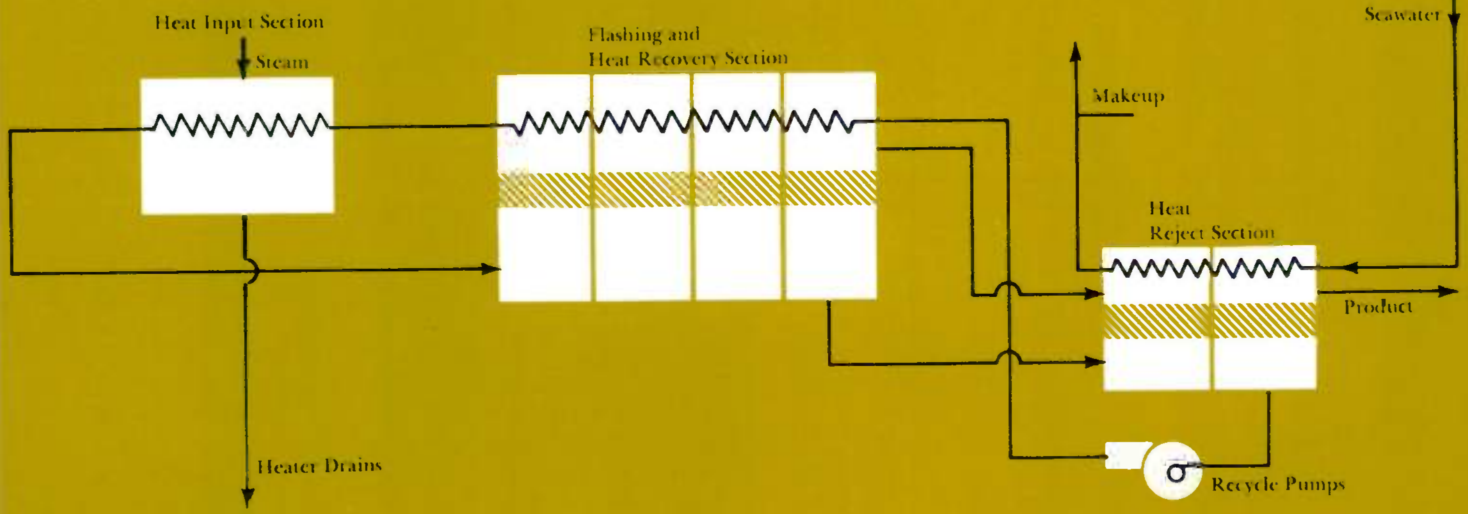
Because it was a demonstration plant, the Point Loma facility was designed and equipped to permit variations in seawater velocity, the number of stages in operation, and inlet temperatures over the range of 200 to 250 degrees F. The plant operated with two separate brine streams flowing in parallel in the condenser tubes and flash chambers. With this arrangement, two methods of chemical treatment could be tested simultaneously. Many construction materials were used to provide performance information on a range of materials.

Lighted observation windows were provided at each stage, positioned so that the surface of the shell-side brine, as well as the wire-mesh moisture separators, were visible.

The plant burned residual oil in a conventional packaged boiler to provide steam to the brine heater. Fuel cost used for the design optimization was 50 cents per million Btu. The purified water was cooled and aerated by passing it through a cooling tower before pumping it into the water system of the City of San Diego.

The warranted characteristics of the original Point Loma plant were:


3—Large Potable Water Plant at Kuwait.


4—Demonstration Water Plant at Point Loma.

1) Product water output of 1,000,000 U.S. gallons per day, with purity of 50 ppm;

2) Performance ratio of 11 pounds of distillate per pound of brine heater steam;

3) Electrical energy consumption of approximately 135 kw at design capacity.

Although the purity guarantee of the distillate was 50 ppm, the distillate produced had an impurity content of less than 5 ppm. The design capacity of the plant was met with 200-degree brine top temperature; however, by adding pH control and raising brine temperature to 250 degrees F, plant output was increased to 1.4 million gallons per day. Thus, the cost of water from the demonstration plant was reduced from about $1.25 per 1000 gallons at the rated one-million gpd rate to about $1 with pH control and higher operating temperature.

The process used for the Point Loma plant, but built on a much larger scale, could produce fresh water at significantly lower cost. And where the *capital cost* of the one-million gallon per day Point Loma plant was about $1.60 per gallon per day capacity, the very large plants now under consideration can be built for much less.

When the Point Loma demonstration plant was moved to Guantanamo, it was modified to conform to a different set of operating conditions, such as higher cooling water temperature. The unit now operates at a correspondingly lower rating of 750,000 gallons per day. Brine pumps were converted from steam-turbine drive to motor drive to simplify piping arrangements.

Future for Multistage Flash Evaporation

Every potential flash-evaporator installation requires an economic analysis to determine the physical arrangement that will produce water for the lowest total cost. The cost of heat and pumping power, as well as amortization costs, must all be factored into the analysis.

Determining the heat performance of a multistage unit, an essential step in the economic analysis, presents a complex design problem. The solution of this problem has been expedited at Westinghouse by programming the problem for large-scale digital computer solution. For example, the design of the Point Loma plant was optimized by computer. The solutions to several computer studies have been integrated with field test data to refine the program for future use.

The installed capacity for saline water conversion is presently doubling every two or three years, and has been growing at this rate for the past 15 years. If this growth rate persists, over 20 billion gallons per day capacity will be in operation by 1985. Although this is small compared with the world's requirements, it will require some very large and extensive projects over the next 20 years. As mentioned in the previous article, however, experience has shown that there is no technical limitation on plant size.

The cost of desalting for potable water supply is largely the cost of generating heat, which is primarily a function of fuel cost. For a given area, little can be done to reduce fuel cost other than to choose the most economical fuel in the area. However, large potable-water flash evaporator plants could be designed to take advantage of the economies that result from combining water production with power generation.

In utility and industrial applications that require boiler feed makeup and process water, the combined cycle is already well established and will be used more and more frequently as the supply of conventional sources of pure water decreases. In the large potable water plants that will be built, the most logical approach is also a combination of flash-evaporation plant and large electric generation plant. Such a combination plant would provide economies in the form of capital cost savings due to shared facilities as well as conservation of total energy requirements.

The flash evaporator's present operating temperature makes it ideally suited for combined operation with electric power plants. Heat for the flash evaporator could be supplied either by extraction from the steam turbine, or by simply replacing the condenser and last row turbine stages with a flash evaporator brine heater. The overall plant would be designed specifically to fit the situation of the particular conditions.

There are great potential economic and technical advantages in combining atomic power with water desalting. A basic advantage in the combination is that the larger the plant, the more economic an atomic-power heat source. Such a nuclear desalting plant might be a dual-purpose installation for the production of both electricity and water, or it could be a single-purpose plant for the production of water alone. Again, the feasibility of the plant merely becomes one of economics: heat can be provided by the fuel that is the most economic for the given location and circumstance, be it coal, oil, natural gas, or nuclear.

As new technologies develop, new plant configurations become possible. For example, consider one interesting application for a 33-megawatt gas-turbine peaking plant: A very recent innovation, water or steam injection into the turbine combustor, increases the mass flow through the turbine and raises the peaking rating of a 33-megawatt machine to 125 megawatts. With a waste-heat recuperator to recover stack-gas heat, this waste heat could provide input to a flash evaporator to produce water when the machine is operating at base load. The flash evaporator would also be a convenient source of pure water for injection into the turbine during peaking operation. Thus, the overall result of such a combination would be a base-load machine rated at 33 megawatts with more than 90 megawatts of peaking capacity—and water production capability of four million gallons per day. Since the machine is operating normally at base load, the peaking capacity is spinning reserve.

This suggested configuration is only one of many that will be possible by exploiting new ideas in a variety of combinations. The variety of choice will continue to increase as new technologies develop. The adaptability of the flash evaporation cycle makes it ideally suited to such combinations.

Pure Water Via Flash Evaporation—3

by W. G. Rogal

Dual-Purpose Plant for St. Thomas

The flash evaporator now going into service on St. Thomas, U.S. Virgin Islands, is a part of a combination power-water plant that will produce 7500 kilowatts of electric power and one million gallons of fresh water daily. The combined plant will provide water to the town of Charlotte Amalie and electricity for the 20,000 residents of St. Thomas, plus the large tourist influx.

The island's previous source of fresh water was primarily rainfall, augmented by barge shipments from Puerto Rico at a cost of $2 per thousand gallons, and by an existing evaporator that produces 300,000 gallons of water per day at a cost at times exceeding $3 per thousand gallons. While exact costs for the new plant are not yet available, similar desalting plants have produced water at costs ranging from 90 cents to $1.25 per thousand gallons.

The new combined power-water plant consists of a multistage flash evaporator, a 7500-kw automatic extraction turbine-generator unit, and an oil-fired boiler plant.

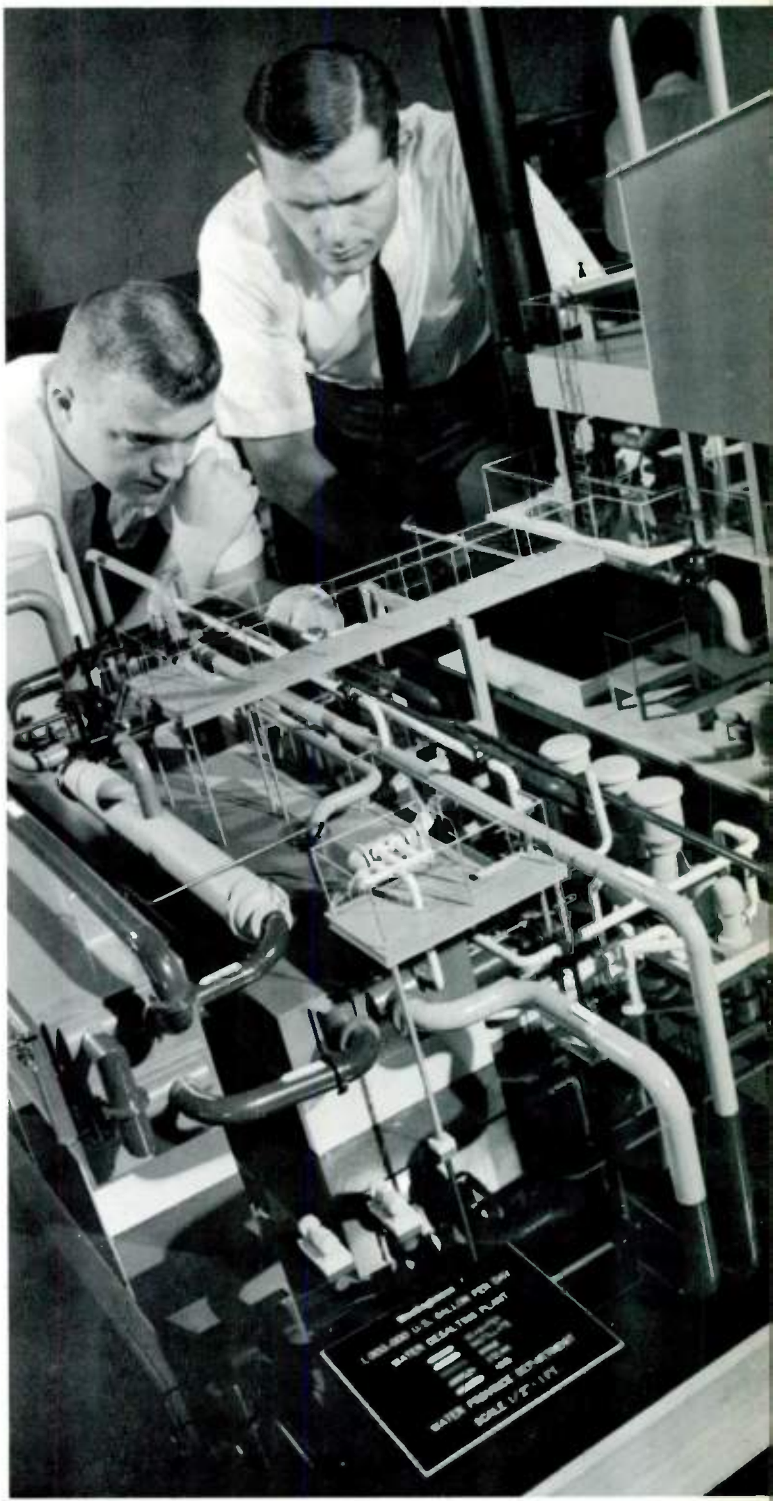
Power Generation

The power plant uses a conventional regenerative steam cycle. The condensing automatic-extraction turbine is designed for steam input conditions of 600 psig, 750 degrees F at the throttle. A 5000-square-foot, two-pass surface condenser provides an exhaust pressure of 2.5 inches of mercury when supplied with seawater at 82 degrees F. Condenser drains are returned to the turbine feed cycle through a deaerator by condensate pumps. Throttle steam for the turbine is produced by two outdoor-type pressurized package water tube boilers, each capable of producing 65,000 pounds of steam per hour. The boilers are fuel-oil fired.

The generator is a horizontal-shaft machine, totally enclosed, air cooled, and rated at 9375 kva at 0.8 power factor. Its electrical characteristics are 13.8 kv, three phase, 60 cycles. The generator operates at 3600 rpm and is guaranteed to operate satisfactorily in parallel with the other generators on the St. Thomas system. All other station electrical equipment, such as the station auxiliary transformer, high-voltage metal-clad switchgear, low-voltage metal-enclosed switchgear, duplex control switchboards, motors and motor control centers, are completely coordinated from the 13.8-kv generator terminals to the outgoing feeder terminals. Power is distributed on the St. Thomas transmission system at 13.2 kv. The plant will be operated as a base-load station.

Water Production

Low-pressure heating steam for the flash-evaporator brine heater is extracted automatically from the main steam turbine at 25 psig. The flash evaporator also can be operated independently of the turbine by means of a desuperheated steam



Model of combined power-water plant illustrates the integrated approach to plant design.

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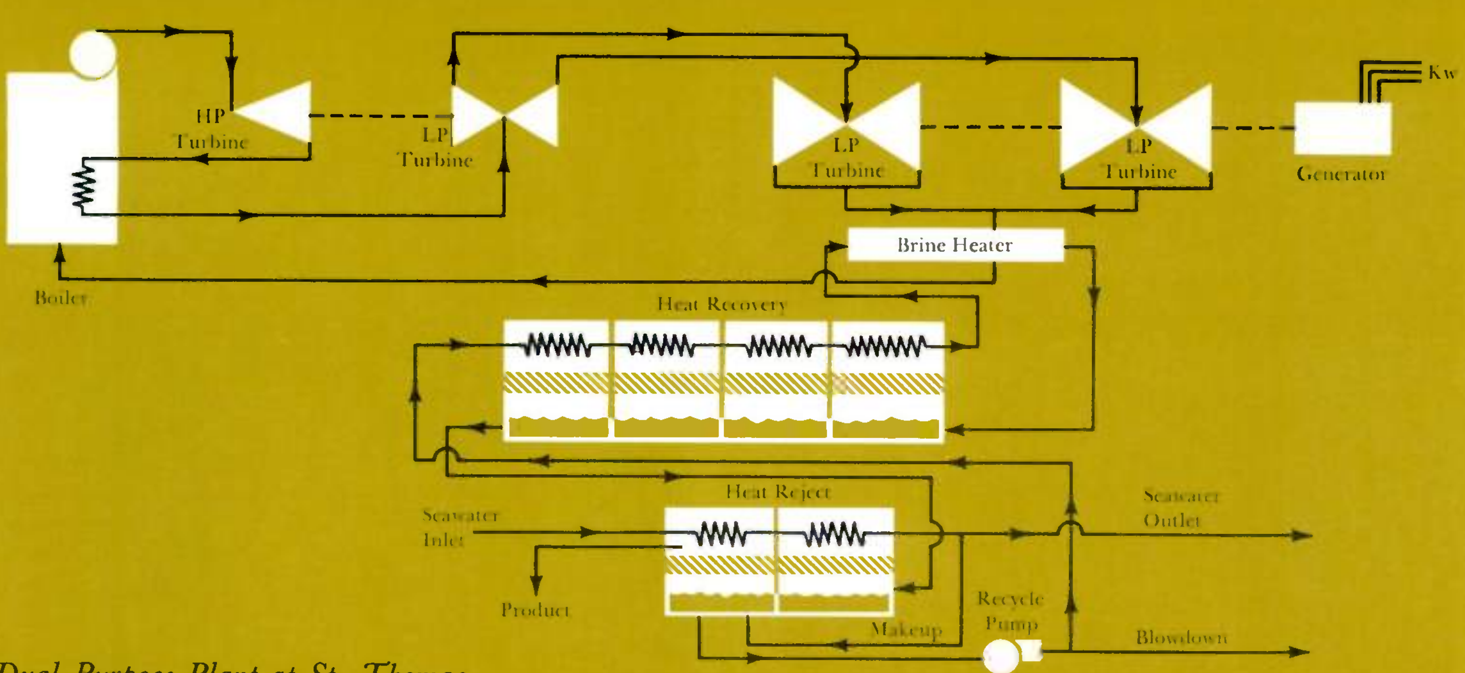

Dual-Purpose Plant at St. Thomas

line directly from the boiler. This flexible arrangement allows either turbine or evaporator to be operated independently.

Incoming seawater is pumped through the tubes of the heat-rejection stages, after which the excess over that required for makeup to the recirculating brine stream is discharged. Makeup seawater enters the deaerator with stripping steam supplied from a higher pressure stage. The deaerated seawater introduced into the lowest temperature last stage makeup is combined with brine and then pumped for recirculation and blowdown. The design concentration in the recirculating brine stream is maintained by continuous blowdown from the last stage. The combined brine and makeup constitute the recycle stream that is pumped back through the tubes of heat-recovery stages to the brine heater. The recycle stream is heated to 250 degrees F in the brine heater and introduced to the shell side of the highest temperature first evaporator stage.

The shell-side brine flows from stage to stage until it reaches the last stage, at which point it is pumped back through the evaporator tubes as previously described.

Water vapor is flashed off in each stage, condensed, and collected in a common trough. The condensate flows from stage to stage and leaves the system at the last stage by means of a product pump. The flash evaporator will produce fresh water at a guaranteed purity of 10 ppm.

Existing Water Desalting Plant—The existing 300,000 gpd water plant can also be operated from steam produced in the new plant. Low-pressure steam bled from the main turbine through the automatic extraction plant (at 25 psig) is fed through a reducing station to the existing water plant.

Physical Plant

The St. Thomas plant is located on a site that is 10 feet above the water level immediately adjacent to Little Krum Bay. Semioutdoor-type construction allows the steam generator, fans, flues, and ducts to be located outdoors. This provides a substantial savings in the cost of the building structure without affecting station operation, reliability, or performance.

The power plant building superstructure is steel frame. The building can withstand wind-pressure loads of 40 pounds per square foot. The columns in the turbine room and crane bay are capable of carrying crane loads when lifting the top half of the turbine casing, the turbine rotor, or the generator rotor, in addition to supporting anticipated roof and horizontal wind loads.

The seawater intake extends approximately 1000 feet out into Little Krum Bay from the shoreline and consists of a 30-inch concrete pipe, laid in a trench extending from the inlet to the bay. The inlet is located 15 feet below low water level, and seawater flows by gravity into a pump pit on the shore line. A multistage seawater pump provides seawater to the plant. Seawater entering the plant is chlorinated to control marine fouling in the seawater intake system.

Discharge brine is returned to the seal well and carried to a point sufficiently removed from the intake structure to prevent recirculation of warmed circulating water.

Design Optimization

Under a "turnkey" contract, Westinghouse has had complete responsibility for the design, manufacture, and construction of the St. Thomas water-power facility. In developing the overall plant, the cost of producing fresh water was minimized by considering three significant factors:

1) Cost of energy, which includes fuel costs to produce steam, electrical power, etc.;

2) Fixed charges on investment, such as amortization, taxes, insurance, and maintenance costs for the initial investment;

3) Operating costs, which include labor, supervision, chemicals, and supplies.

To minimize the cost of producing fresh water, an optimum balance between energy costs and fixed charges was determined. Thus, the final design was the result of an economic evaluation of location and fuel costs for the St. Thomas plant.

AC Motor Rerate—A New Industry Standard

by R. F. Woll

The present ac motor rerate program revises standards for industrial sizes of ac motors on the basis of recent technological advances. The revised standards provide the means to achieve better value in several ways, including considerable size and weight reductions. A subsequent article will describe the Westinghouse approach to achieving the better values in ac motors.

Improvements in materials, design art, and manufacturing capability are continuous throughout the years, so existing standards become outmoded after a period of time. Consequently, the standards must be revised periodically to catch up with the prevailing state of the art. One of the "catching up" stages in ac electric motor standards is now past due and has been undertaken in the rerating of integral-horsepower induction motors by NEMA (National Electrical Manufacturers Association).

The revision of the NEMA standards is extensive, for it includes changes in rating/frame assignments, shaft extension dimensions, insulation system class for standard motors (from Class A to Class B), service-factor and temperature ratings, locked-rotor and breakdown torques, and dimensions for standardized flange mountings.

The ac motor rerate program thus presents a dual challenge to every motor manufacturer: first, to develop, through NEMA, new industry standards that take full advantage of the latest technical advances in materials, design, and manufacturing and that promote better value to both the motor user and the motor manufacturer; second, to redesign his own line of motors incorporating these latest advances to achieve the better value.

Many factors were involved in the decision by NEMA's member companies in the motor and generator section to embark on the present rerate program. Among them were:

1) Increased use of electronic computers to make design calculations. Computers give the ability to optimize designs, resulting in more effective utilization of active electromagnetic materials.

2) The need for improved size compatibility with motors of European manufacture, but with retention of the superiority of American motor designs in such areas as torque capability, thermal endurance, and overload capacity.

3) Recognition of the rapid progress made by the insulation materials industry in originating higher-temperature insulating components that are reliable, rugged, resistant to moisture and contamination, and relatively economical.

These and other factors applicable to the motor industry as a whole formed the basis for moving ahead with proven assurance that motors can be made both smaller and better. Accordingly, NEMA has set new Suggested Standards for

Table 1—NEMA Rating and Frame Assignments for Polyphase Squirrel-Cage Designs A and B Induction Motors

	3600 RPM				*1800 RPM*				*1200 RPM*		*900 RPM*	
	Open		*Enclosed*		*Open*		*Enclosed*		*Open and Enclosed*		*Open and Enclosed*	
Rating (hp)	*Present*	*Revised*	*Present*	*Revised*	*Present*	*Revised*	*Present*	*Revised*	*Present*	*Revised*	*Present*	*Revised*
0.5	—	—	—	—	—	—	—	—	—	—	182	143T
0.75	—	—	—	—	—	—	—	—	182	143T	184	145T
1	—	—	—	—	182	143T	182	143T	184	145T	213	182T
1.5	182	143T	182	143T	184	145T	184	145T	184	182T	213	184T
2	184	145T	184	145T	184	145T	184	145T	213	184T	215	213T
3	184	145T	184	182T	213	182T	213	182T	215	213T	254U	215T
5	213	182T	213	184T	215	184T	215	184T	254U	215T	256U	254T
7.5	215	184T	215	213T	254U	213T	254U	213T	256U	254T	284U	256T
10	254U	213T	254U	215T	256U	215T	256U	215T	284U	256T	286U	284T
15	256U	215T	256U	254T	284U	254T	284U	254T	324U	284T	326U	286T
20	284U	254T	286U	256T	286U	256T	286U	256T	326U	286T	364U	324T
25	286U	256T	324U	284TS	324U	284T	324U	284T	364U	324T	365U	326T
30	324S	284TS	326S	286TS	326U	286T	326U	286T	365U	326T	404U	364T
40	326S	286TS	364US	324TS	364U	324T	364U	324T	404U	364T	405U	365T
50	364US	324TS	365US	326TS	365US	326T	365US	326T	405U	365T	444U	404T
60	365US	326TS	405US	364TS	404US	364TS	405US	364TS	444U	404T	445U	405T
75	404US	364TS	444US	365TS	405US	365TS	444US	365TS	445U	405T	—	444T
100	405US	365TS	445US	405TS	444US	404TS	445US	405TS	—	444T	—	445T
125	444US	404TS	—	444TS	445US	405TS	—	444TS	—	445T	—	—
150	445US	405TS	—	445TS	—	444TS	—	445TS	—	—	—	—
200	—	444TS	—	—	—	445TS	—	—	—	—	—	—
250	—	445TS	—	—	—	—	—	—	—	—	—	—

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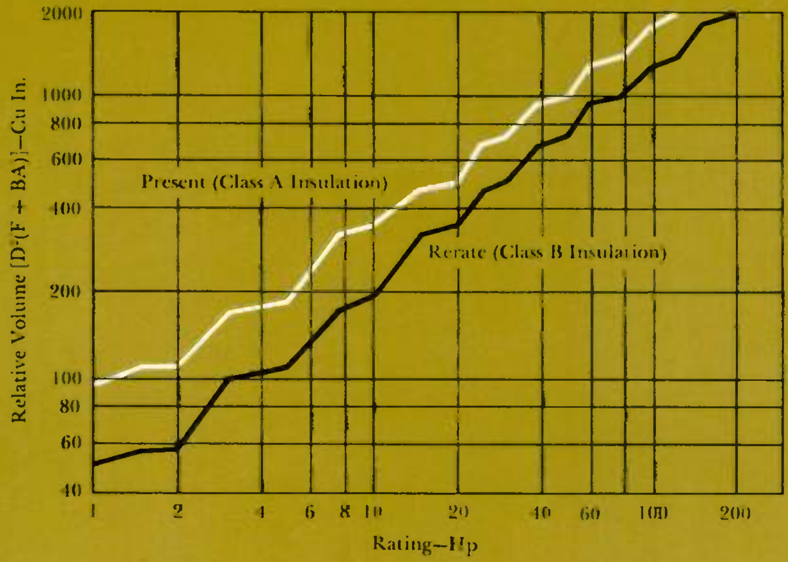

Table 2—Drive-End Shaft Extension Dimensions (Inches)

	Present “U”-Frame Motors							*New “T”-Frame Motors*						
	Frame Number	*N-W*	*U*	*V (min)*	*Key Width*	*Key Thick.*	*Key Length*	*Frame Number*	*N-W*	*U*	*V (min)*	*Key Width*	*Key Thick.*	*Key Length*
Belted	180	2 1/4	7/8	2	3/16	3/16	1 3/8	140T	2 1/4	7/8	2	3/16	3/16	1 3/8
	210	3	1 1/8	2 3/4	1/4	1/4	2	180T	2 3/4	1 1/8	2 1/2	1/4	1/4	1 3/4
	250U	3 3/4	1 3/8	3 1/2	5/16	5/16	2 3/4	210T	3 3/8	1 3/8	3 1/8	5/16	5/16	2 3/8
	280U	4 7/8	1 5/8	4 5/8	3/8	3/8	3 3/4	250T	4	1 5/8	3 3/4	3/8	3/8	2 7/8
	320U	5 5/8	1 7/8	5 3/8	1/2	1/2	4 1/4	280T	4 5/8	1 7/8	4 3/8	1/2	1/2	3 1/4
	360U	6 3/8	2 1/8	6 1/8	1/2	1/2	5	320T	5 1/4	2 1/8	5	1/2	1/2	3 7/8
	400U	7 1/8	2 3/8	6 7/8	5/8	5/8	5 1/2	360T	5 7/8	2 3/8	5 5/8	5/8	5/8	4 1/4
	440U	8 5/8	2 7/8	8 3/8	3/4	3/4	7	400T	7 1/4	2 7/8	7	3/4	3/4	5 5/8
	500U	8 5/8	2 7/8	8 3/8	3/4	3/4	7 1/4	440T	8 1/2	3 3/8	8 1/4	7/8	7/8	6 7/8
Coupled	320S	3 1/4	1 5/8	3	3/8	3/8	1 7/8	280TS	3 1/4	1 5/8	3	3/8	3/8	1 7/8
	360US	3 3/4	1 7/8	3 1/2	1/2	1/2	2	320TS	3 3/4	1 7/8	3 1/2	1/2	1/2	2
	400US	4 1/4	2 1/8	4	1/2	1/2	2 3/4	360TS	3 3/4	1 7/8	3 1/2	1/2	1/2	2
	440US	4 1/4	2 1/8	4	1/2	1/2	2 3/4	400TS	4 1/4	2 1/8	4	1/2	1/2	2 3/4
	500S	4 1/4	2 1/8	4	1/2	1/2	2 3/4	440TS	4 3/4	2 3/8	4 1/2	5/8	5/8	3

N-W—Length of shaft extension from pulley shoulder to end of shaft.
U—Diameter of shaft extension.
V—Usable length of shaft extension.

Table 3—Front (Opposite Drive End) Shaft Extension Dimensions (Inches)

	Present “U”-Frame Motors							*New “T”-Frame Motors*						
	Frame Number	*FN-FW*	*FU*	*FV (min)*	*Key Width*	*Key Thick.*	*Key Length*	*Frame Number*	*FN-FW*	*FU*	*FV (min)*	*Key Width*	*Key Thick.*	*Key Length*
Belted	180	2 1/4	7/8	2	3/16	3/16	1 3/8	140T	1 5/8	5/8	1 3/8	3/16	3/16	7/8
	210	2 1/4	7/8	2	3/16	3/16	1 3/8	180T	2 1/4	7/8	2	3/16	3/16	1 3/8
	250U	3	1 1/8	2 3/4	1/4	1/4	2	210T	2 3/4	1 1/8	2 1/2	1/4	1/4	1 3/4
	280U	3 3/4	1 3/8	3 1/2	5/16	5/16	2 3/4	250T	3 3/8	1 3/8	3 1/8	5/16	5/16	2 3/8
	320U	4 7/8	1 5/8	4 5/8	3/8	3/8	3 3/4	280T	4	1 5/8	3 3/4	3/8	3/8	2 7/8
	360U	5 5/8	1 7/8	5 3/8	1/2	1/2	4 1/4	320T	4 5/8	1 7/8	4 3/8	1/2	1/2	3 1/4
	400U	6 3/8	2 1/8	6 1/8	1/2	1/2	5	360T	4 5/8	1 7/8	4 3/8	1/2	1/2	3 1/4
	440U	7 1/8	2 3/8	6 7/8	5/8	5/8	5 1/2	400T	5 1/4	2 1/8	5	1/2	1/2	3 7/8
	500U	4 1/4	2 1/8	4	1/2	1/2	2 3/4	440T	5 7/8	2 3/8	5 5/8	5/8	5/8	4 1/4
Coupled	320S	3 1/4	1 5/8	3	3/8	3/8	1 7/8	280TS	3 1/4	1 5/8	3	3/8	3/8	1 7/8
	360US	3 3/4	1 7/8	3 1/2	1/2	1/2	2	320TS	3 3/4	1 7/8	3 1/2	1/2	1/2	2
	400US	4 1/4	2 1/8	4	1/2	1/2	2 3/4	360TS	3 3/4	1 7/8	3 1/2	1/2	1/2	2
	440US	4 1/4	2 1/8	4	1/2	1/2	2 3/4	400TS	4 1/4	2 1/8	4	1/2	1/2	2 3/4
	500S	4 1/4	2 1/8	4	1/2	1/2	2 3/4	440TS	4 3/4	2 3/8	4 1/2	5/8	5/8	3

FN-FW—Length of shaft extension from pulley shoulder to end of shaft.
FU—Diameter of shaft extension.
FV—Usable length of shaft extension.

1—Motor size reduction as a result of using the higher-temperature Class B insulation in standard motors is illustrated by plotting motor volume against horsepower for 1800-rpm dripproof motors. Weight also is reduced, though to a lesser degree.

Future Design that are the cornerstone from which the better value evolves. (It should be remembered that NEMA standards are completely voluntary in their application and in no way demand compliance with them from either the purchaser or the manufacturer of motors. However, the many advantages to users and manufacturers are such that the suggested standards probably will be widely adopted.)

Motor Size Reduction

Providing a given rating in a smaller physical size is the basic and most obvious gain in the new standards. Present and revised rating/frame assignments are compared in Table 1. The use of higher-temperature Class B insulation for the new motors, as opposed to Class A for the present ones, is the primary reason they have a smaller frame assignment for a given rating. Through 10 horsepower, the new motors have about half the volume of the present motors; above 10 horsepower, about ¾ of the present volume (Fig. 1). The reduced motor size also carries with it lower rotor inertia for a given horsepower rating, with a consequent gain in the motor's reversing capability.

Somewhat more expensive materials and processes are used to meet the revised requirements. However, because they reduce size and weight they result in better overall value for the new motors, particularly since the reductions are not attained by sacrifice of performance or endurance capabilities.

Service Factor—Extra Load Capacity

The *present* standards for open general-purpose motors (Class A insulation, 40 degrees C rise by thermometer or 50 degrees C rise by resistance at rated load) provide for graduated service factors, higher for the smaller ratings, as follows:

Rating	*Service Factor*
1 hp and below	1.25
1.5 and 2 hp	1.20
3 hp and above	1.15

The indicated level of temperature rise at rated load permits the motor to carry an increased load without exceeding the thermal capabilities of its insulation. The percent increase in load is known as service factor.

The *revised* rating/frame assignments for open motors, with Class B insulation systems, are based on 1.15 service factor for all ratings. Adoption of 1.15 service factor across the board contributes to the facility of the rerate program and also recognizes current industry application trends. It should be noted that the present temperature rating standards do not specify the permissible temperature rise at the service factor load; the revised standards do.

Rating/frame assignments of totally enclosed motors for both the present and the revised standards are based on a service factor of 1.0.

Shaft Size

A special NEMA task committee thoroughly investigated the question of whether the shaft extension diameter of the new rerate motors should relate to the present shafts on a horsepower or on a frame-size basis. Even though the study established that the shaft diameters of the present "U" frames were entirely adequate to serve the increased loading imposed by the higher rerate horsepowers, it was ultimately decided that the new shaft diameters would be the same as the present for a given horsepower. Hence the need for the "T" designation for the new frames to distinguish them from the present.

A primary reason for retaining shaft diameters with horsepower was to minimize problems for the user in application of pulleys. Corollary results are retaining the same liberal safety factor in the new motor shafts as in the present ones and fostering a conservative application of bearings in the new motors. Present and new shaft extension dimensions are compared in Tables 2 and 3.

Torque Capability

Present breakdown and locked-rotor torque standards have some inconsistencies as a function of horsepower rating. Minor revisions made by NEMA retain the same general level as before but iron out the inconsistencies (Tables 4 and 5). The improved consistency is illustrated in Fig. 2. This revision applies to both present and rerate motors.

Insulation System—Higher Temperature but Longer Life

From the standpoint of industry standardization, the advance to Class B insulation was the major factor in assigning more rating to a given frame size. (Temperature standards are listed in Table 6.) Maximum-rated (service factor = 1.0) motors are permitted 80 degrees C rise by resistance at rated load with a Class B insulation system and 60 degrees C rise by resistance with Class A. (These values have been standards for many years and have not been altered by the rerate program.) The higher temperature rise for the Class B insulation system obviously allows more rating to be attained.

In the discussion of service factor, it was pointed out that the present temperature rating standards for Class-A-insulated, open, general-purpose motors embody a margin for service factor. That is, their full-load temperature rating is 50 degrees C rise by resistance, whereas 60 degrees C rise by resistance is permitted with Class-A-insulated motors having no service factor (which is another way of saying service factor = 1.0).

However, the present standards do not make any provision for service factor for insulation systems other than Class A. The new rerate motors with Class B insulation system will have 1.15 service factor for the open (or dripproof) general-purpose category. Thus, it was necessary to establish new

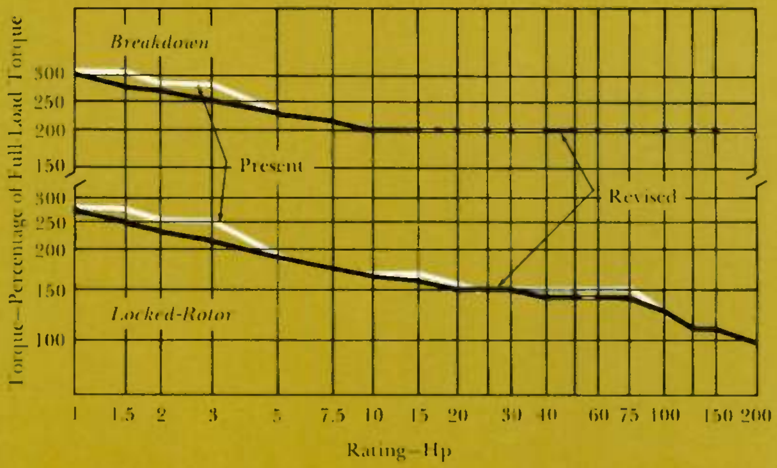

Table 4—Breakdown Torque for Polyphase Designs A and B Motors (Percentage of Full-Load Torque)

	3600 RPM		*1800 RPM*		*1200 RPM*		*900 RPM*	
Rating (hp)	*Present*	*Revised*	*Present*	*Revised*	*Present*	*Revised*	*Present*	*Revised*
0.5	—	—	—	—	—	—	250	225
0.75	—	—	—	—	275	275	250	220
1	—	—	300	300	275	265	250	215
1.5	275	250	300	280	275	250	250	210
2	250	240	275	270	250	240	225	210
3	250	230	275	250	250	230	225	205
5	225	215	225	225	225	215	225	205
7.5	215	200	215	215	215	205	215	200
10	200	200	200	200	200	200	200	200
15	200	200	200	200	200	200	200	200
20	200	200	200	200	200	200	200	200
25	200	200	200	200	200	200	200	200
30	200	200	200	200	200	200	200	200
40	200	200	200	200	200	200	200	200
50	200	200	200	200	200	200	200	200
60	200	200	200	200	200	200	200	200
75	200	200	200	200	200	200	200	200
100	200	200	200	200	200	200	200	200
125	200	200	200	200	200	200	200	200
150	200	200	200	200	200	200	200	200
200	200	200	200	200	200	200	200	200

Table 5—Locked-Rotor Torque for Polyphase Designs A and B Motors (Percentage of Full-Load Torque)

	3600 RPM		*1800 RPM*		*1200 RPM*		*900 RPM*	
Rating (hp)	*Present*	*Revised*	*Present*	*Revised*	*Present*	*Revised*	*Present*	*Revised*
0.5	—	—	—	—	—	—	150	140
0.75	—	—	—	—	175	175	150	135
1	—	—	275	275	175	170	150	135
1.5	175	175	265	250	175	165	150	130
2	175	170	250	235	175	160	150	130
3	175	160	250	215	175	155	150	130
5	150	150	185	185	160	150	130	130
7.5	150	140	175	175	150	150	125	125
10	150	135	175	165	150	150	125	125
15	150	130	165	160	140	140	125	125
20	150	130	150	150	135	135	125	125
25	150	130	150	150	135	135	125	125
30	150	130	150	150	135	135	125	125
40	135	125	150	140	135	135	125	125
50	125	120	150	140	135	135	125	125
60	125	120	150	140	135	135	125	125
75	110	105	150	140	135	135	125	125
100	110	105	125	125	125	125	125	125
125	100	100	110	110	125	125	125	120
150	100	100	110	110	125	120	125	120
200	100	100	100	100	125	120	125	120

2—Torque standards have been made more consistent by NEMA, along with its revision of rating standards. These curves are plotted from the data for 1800-rpm motors in Tables 4 and 5.

temperature rating standards for these motors. An intensive review of the total question was undertaken by NEMA, and it was agreed that the temperature rating standards for the new, open, general-purpose motors be set to provide insulation life expectancy equal to or longer than that of the present motors. A detailed explanation was given in a previous article.[1] Briefly, the revised standards establish the maximum temperature rise at the service-factor load; this in turn affords a more conservative temperature rating at full load than resulted from present standards. The net result is shown in Fig. 3.

Insulation-system life expectancy for new rerate enclosed motors is the same as for present enclosed motors.

Although no standard rating/frame assignments to date are premised on a Class F insulation system, NEMA did update the Class F temperature standard simultaneously with Class B. This updated Class F standard provides about the same increased insulation life expectancy over the Class-A-insulated motor as does Class B. Details on Class B and F temperature rating standards were given in the previous article.

Frame Surface Temperatures

With higher temperature rise, the new rerate motors necessarily tend to have higher surface temperatures. Approximate frame surface temperatures for the three primary enclosure types with various insulation systems are plotted in Fig. 4. Note that dripproof and ribbed totally enclosed fan-cooled (TEFC) motors with Class B insulation have lower frame surface temperatures than the totally enclosed nonventilated (TENV) motor with Class A insulation. The TENV Class-A-insulated motor has been used successfully in a wide variety of applications; hence, with respect to surface temperature, rerate dripproof and TEFC motors should be equal to or more acceptable than the present Class A TENV. Judging a motor's temperature by placing a hand on its surface has caused much confusion for many years and should definitely be considered obsolete.

The data in Fig. 4 were taken from test results on motors having mechanical construction and ventilation systems typical of present motors. Improved ventilation procedures that probably will be generally incorporated in rerate motors will tend to decrease surface temperatures below the levels indicated in the figure.

Flange Brackets

Standard mounting flanges, for mounting driven apparatus on the motor or end-mounting the motor on a machine, are an important area of secondary standards. Three types of mountings have been standardized by NEMA: C-flange, D-flange, and P-base.

Considerable thought and effort have been expended on modification of these standards to serve the new rerate motors, and agreement has been reached on dimensions for all sizes of rerate C- and D-flanges and for the three smallest sizes of P-base. Present and revised standards are compared in Table 7.

Locked-Rotor Current

Revision of the locked-rotor current standard has been under study for some time. Like the torque-rating standard discussed previously, it is directly associated with the present rerate program only in that it was issued at the same time. The old and new locked-rotor currents are compared in Table 8.

The standard for locked-rotor currents was revised to incorporate the higher values for polyphase motors included in *EEI-NEMA Joint Report on Recommended Motor Starting Currents.* As the table shows, the increase in permissible locked-rotor current is significant only in the very smallest motor ratings

Table 6—Temperature Standards for Basic Insulation Classes (Degrees C)

	Class A		*Class B*		*Class F*		*Class H*	
	Present	*Revised*	*Present*	*Revised*	*Present*	*Revised*	*Present*	*Revised*
Dripproof and TEFC Motors with Service Factor of 1.0								
Ambient Temperature	40	40	40	40	40	40	40	40
Rise by Resistance (100% load)	60	60	80	80	105	105	125	125
Hot-Spot Allowance	5	5	10	10	10	10	15	15
Hot-Spot Temperature	105	105	130	130	155	155	180	180
Dripproof Motors with Service Factor of 1.15								
Ambient Temperature	40	—	—	40	—	40	—	—
Rise by Resistance (100% load)	50	—	—	—	—	—	—	—
Rise by Resistance (115% load)	—	—	—	90	—	115	—	—
Hot-Spot Allowance	5	—	—	10	—	10	—	—
Hot-Spot Temperature	95	—	—	140	—	165	—	—

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[1] Woll, R. F., "High-Temperature Insulation in AC Motors," *Westinghouse ENGINEER*, March 1964, pp. 50-53.

(which impose no notable burden on distribution systems in any event), and there has been no change for ratings 20 hp and larger.

Voltage Ratings

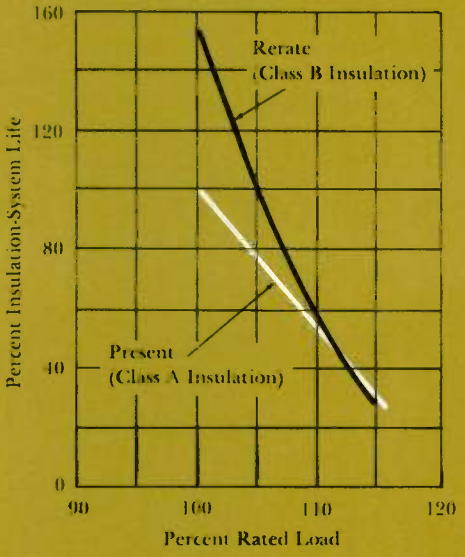
For many years, the standard three-phase utilization voltage has been set as 220 or 440 volts for small integral-horsepower motors in the range of ratings generally covered by the NEMA standards (through 200 hp). This standard was premised on the assumption that the secondary voltage of distribution transformers was 240 or 480 volts, and that the voltage drop in normal distribution circuits was such that the nominal voltage at point of utilization closely approached the 220 or 440 value. In recent years, however, two factors have altered the situation: distribution voltage has crept upward because of increased transmission voltage with insufficient adjustment of transformation; and distribution circuits have been stiffened so that voltage drop between distribution transformer secondary and point of utilization is less.

Utilization voltage surveys conducted by several groups have shown that 230 or 460 volts is far more frequently encountered at the motor terminals than 220 or 440 volts. In recognition of this fact, NEMA has changed the normal motor voltage rating to 230/460 volts as a Suggested Standard for Future Design. The changeover from 220/440 to 230/460 will be gradual and will extend over a long period of time. The revised NEMA values for breakdown and locked-rotor torque listed in Tables 4 and 5 will apply to 230/460-volt motors as well. The new values of locked-rotor current (Table 8) will also apply at 230 volts.

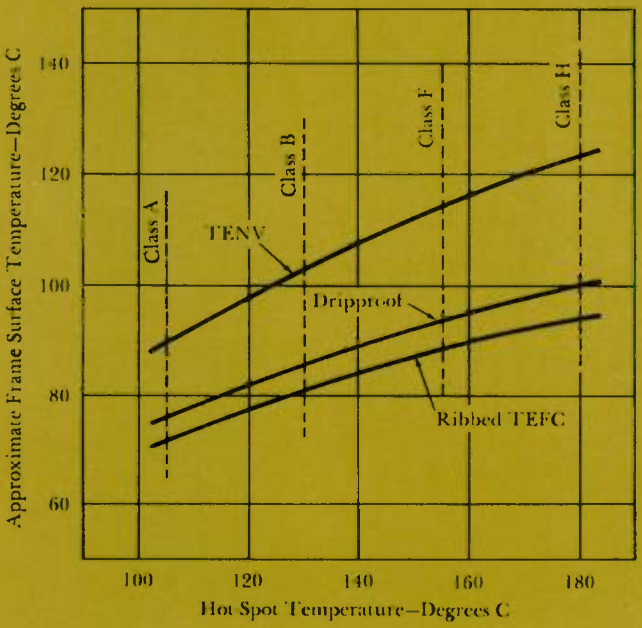
Unfortunately, the voltage changeover could lead to marginal torque capability in applications where users are utilizing the full torque capacity of motors. For example, a motor designed for 220/440 volts but operated at 230 or 460 volts will have, on the average, about 9 percent greater breakdown and locked-rotor torque than a motor designed for and operated at 230 or 460 volts. Therefore, those users who are utilizing the full torque capability of motors are advised to check their applications with their motor supplier. In view of the relatively high values of breakdown and locked-rotor torque (in terms of percentage of full-load torque) provided by the NEMA standards, marginal torque capability resulting from the change in voltage rating standard should seldom be a problem. From an overall standpoint, including reduced power consumption at rated load and, especially, at lighter loads, the change to 230/460 standard voltage rating is beneficial and necessary.

Conclusion

The present ac motor rerate program truly means progress and better value for all because it takes advantage of the latest advances in materials, design, and manufacturing. How these advances are applied in Westinghouse motors built to the new standards will be described in a subsequent article.



3—Relative insulation-system life expectancies for standard open motors with Class A insulation and with Class B. The new rerate motors have much longer insulation life in the loading range commonly encountered; for example, 50 percent more life at 100 percent load.



4—Approximate frame surface temperatures for motors operating in 40-degree-C ambient and having winding rise by resistance at maximum value allowed for enclosure and insulation-system class. Improved ventilation designs probably will reduce surface temperature of the rerate Class-B-insulated motors below these values.

Table 7—Basic Flange Dimensions for Present ("U"-Frame) and New ("T"-Frame) Motors (Inches)

C-Flange Mounting

	AJ (bolt-circle diameter for mounting holes in flange)		*AK (diameter of flange mounting fit)*		*BD (maximum outer diameter of flange)*		*BF (number and size of mounting holes in flange)*		*BA-BC (center line of rear foot hole to mounting face of flange)*	
Frame Size	*Present*	*New*	*Present*	*New*	*Present*	*New*	*Present*	*New*	*Present*	*New*
140C	——	5.875	——	4.50	——	6.50*	——	4, 3/8–16	——	2.875
180C	5.875	7.25	4.50	8.50	6.50*	9.0	4, 3/8–16	4, 1/2–13	2.875	3.625
210C	7.25	7.25	8.50	8.50	9.0	9.0	4, 1/2–13	4, 1/2–13	3.75	4.50
250C	7.25	7.25	8.50	8.50	10.0	10.0	4, 1/2–13	4, 1/2–13	4.50	5.0
280C	9.0	9.0	10.50	10.50	11.25	11.25	4, 1/2–13	4, 1/2–13	5.0	5.0
320C	11.0	11.0	12.50	12.50	14.0	14.0	4, 5/8–11	4, 5/8–11	5.50	5.50
360C	11.0	11.0	12.50	12.50	14.0	14.0	8, 5/8–11	8, 5/8–11	6.125	6.125
400C	11.0	11.0	12.50	12.50	15.50	15.50	8, 5/8–11	8, 5/8–11	6.875	6.875
440C	14.0	14.0	16.0	16.0	18.0	18.0	8, 5/8–11	8, 5/8–11	7.75	7.75
500C	14.50	——	16.50	——	18.0	——	4, 5/8–11	——	8.75	——

D-Flange Mounting

	AJ (bolt-circle diameter for mounting holes in flange)		*AK (diameter of flange mounting fit)*		*BD (maximum outer diameter of flange)*		*BF (number and diameter of mounting holes in flange)*		*BA-BC (center line of rear foot hole to mounting face of flange)*	
Frame Size	*Present*	*New*	*Present*	*New*	*Present*	*New*	*Present*	*New*	*Present*	*New*
140D	——	10.0	——	9.0	——	11.0	——	4, 17/32	——	2.75
180D	10.0	10.0	9.0	9.0	11.0	11.0	4, 17/32	4, 17/32	2.75	3.50
210D	10.0	10.0	9.0	9.0	11.0	11.0	4, 17/32	4, 17/32	3.50	4.25
250D	12.50	12.50	11.0	11.0	14.0	14.0	4, 13/16	4, 13/16	4.25	4.75
280D	12.50	12.50	11.0	11.0	14.0	14.0	4, 13/16	4, 13/16	4.75	4.75
320D	16.0	16.0	14.0	14.0	18.0	18.0	4, 13/16	4, 13/16	5.25	5.25
360D	16.0	16.0	14.0	14.0	18.0	18.0	4, 13/16	4, 13/16	5.875	5.875
400D	20.0	20.0	18.0	18.0	22.0	22.0	8, 13/16	8, 13/16	6.625	6.625
440D	20.0	20.0	18.0	18.0	22.0	22.0	8, 13/16	8, 13/16	7.50	7.50
500D	22.0	——	18.0	——	25.0	——	8, 13/16	——	8.50	——

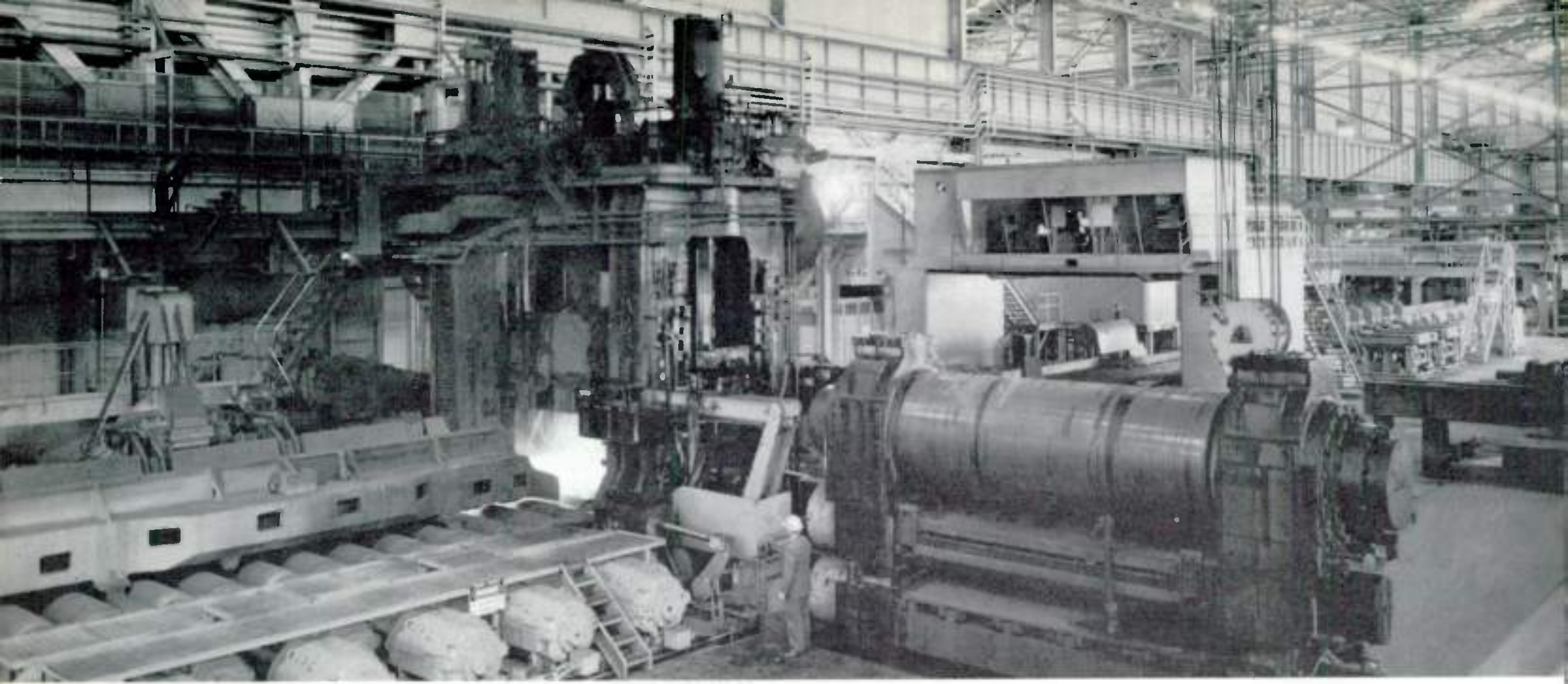
P-Base Mounting

	AJ (bolt-circle diameter for mounting holes in base)		*AK (diameter of base mounting fit)*		*BD (maximum outer diameter of base)*		*BF (number and diameter of mounting holes in base)*	
Frame Size	*Present*	*New*	*Present*	*New*	*Present*	*New*	*Present*	*New*
140P	——	9 1/8	——	8 1/4	—	10	——	4, 7/16
180P	9 1/8	9 1/8	8 1/4	8 1/4	10	10	4, 7/16	4, 7/16
210P	9 1/8	9 1/8	8 1/4	8 1/4	10	10	4, 7/16	4, 7/16

* These are nominal, not maximum, dimensions.

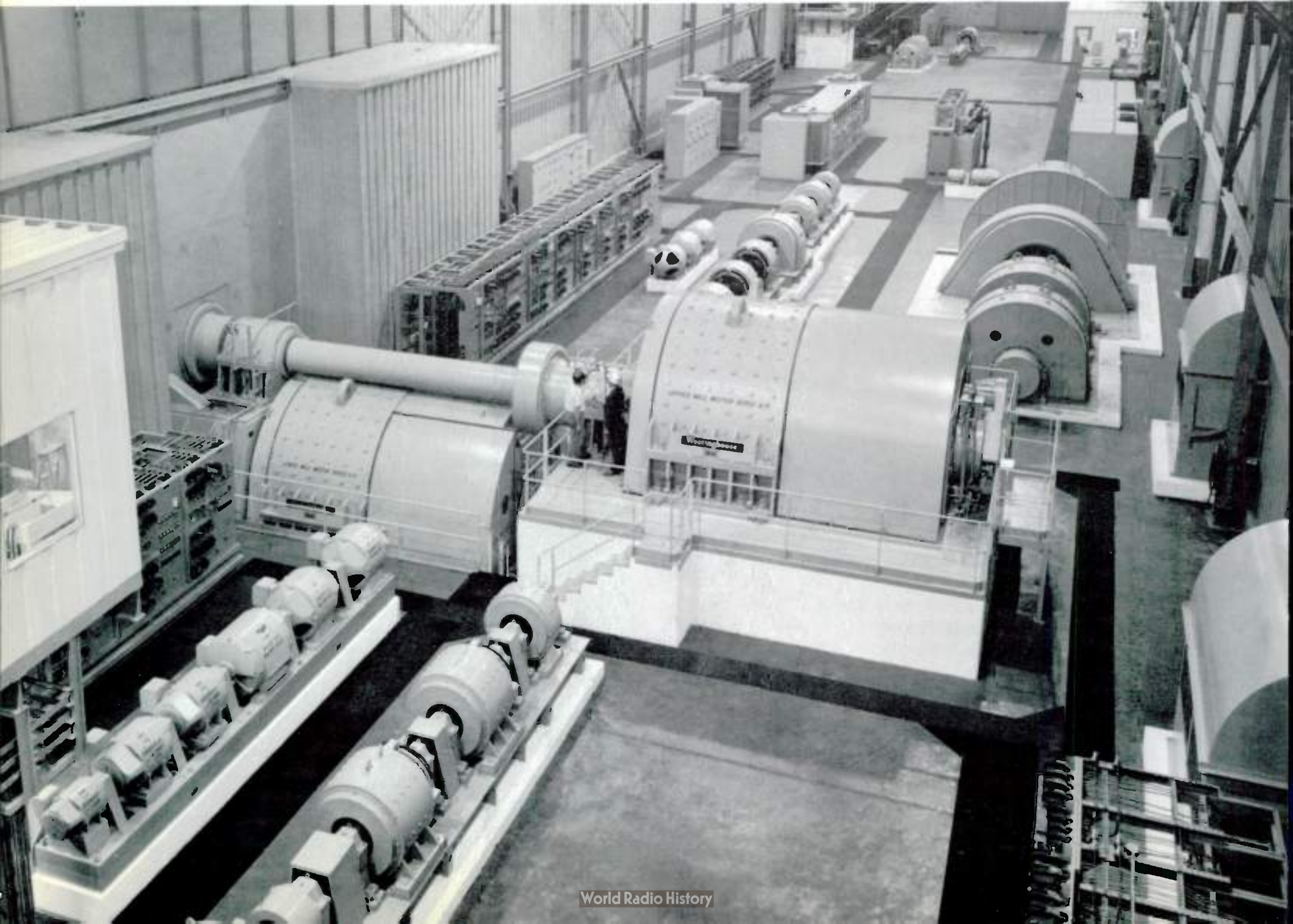
Table 8—Locked-Rotor Current for Three-Phase, 220-Volt, 60-Cycle, Designs B, C, and D Motors (Amperes)

Rating (hp)	*Old*	*New*
0.5	12	30
0.75	18	30
1	24	30
1.5	35	40
2	45	50
3	60	64
5	90	92
7.5	120	127
10	150	162
15	220	232
20 and larger	Unchanged	Unchanged



1—Combination reversing mill rolling an ingot to a slab with the two-high roll assembly *(above)*. These rolls can be withdrawn and the four-high assembly in the foreground moved into the mill for rolling slabs to plate. Total length of mill line is 707 feet 8 inches.

2—Rolls are driven by a 12,000-hp drive developing up to 4,340,000 lb-ft maximum peak torque *(below)*. Adjustable-voltage power for this twin-motor drive is supplied by the 10,000-kw flywheel m-g set in right background. Smaller m-g sets in foreground power the screwdowns, manipulators, and tables, and the slab shear drive is seen in the far background. Air-conditioned room at left houses the computer and the digital positioning controls.



On-Line Computer Controls Giant Rolling Mill

by Alonzo F. Kenyon

A reversing combination mill produces slabs and blooms from ingots, or plate from slabs, under automatic control. The control system minimizes the number of passes required, produces rolled pieces of the desired dimensions, and protects the equipment against overloading.

The new combination reversing mill at the Houston (Texas) Works of the Armco Steel Corporation is one of the largest and most heavily powered primary rolling mills in the industry, and it operates automatically under the control of a Westinghouse Prodac on-line process-control computer. The mill is arranged to operate alternatively as a two-high bloom-slab mill to roll ingots to blooms or slabs or as a four-high plate mill to roll reheated slabs to plate (Fig. 1). The large size of the mill makes for high production and enables it to roll large ingots into wide slabs and plates, and the convertible feature provides an efficient installation by allowing double use of much of the equipment.

Two entirely separate computer programs have been developed, and the appropriate program is read into the computer memory each time the mill mechanical setup is made for bloom-slab rolling or for plate rolling. The control system includes the high-speed digital computer, peripheral accessory equipment, feedback sensing devices, input card reader, output typewriter, output card and tape punches, visual digital readouts, and operator control stations. The system provides the following principal functions:

1) Calculates the optimum mill rolling schedule for reducing the starting ingot or slab to the specified finished slab or plate. It draws the necessary information from a permanently stored program (which defines rolling rules and equipment and product characteristics) and from minimum punched-card input (which describes starting material, specifies desired rolled product, and gives special rolling instructions).

2) Operates the mill automatically according to this rolling schedule computed on-line.

3) Updates the stored program rules and modifies the initially computed schedule settings with process and product feedback information during plate rolling. This updating compensates for variations in steel analysis, slab temperature, mill deflection, and other factors and thereby finishes the product more nearly on-gauge; it also protects the mechanical and electrical equipment from overloading.

4) Tracks each piece as it progresses through the mill line, provides appropriate visual readouts in each operator's control station, and produces punched-card, punched-tape, and typed-sheet logs of selected process and product data for each finished slab or plate.

In the two-high roll arrangement, upper and lower grooved rolls of 46-inch nominal diameter reduce ingots to large blooms or slabs. The rolls are 120 inches long in the body. They have a 72¾-inch central "bullhead" area, a 16-inch groove at the left of the bullhead, and 10⅛-inch and 5¼-inch grooves at the right. To roll reheated slabs into wide plate, the bloom-slab rolls are removed and replaced with a four-high complement of rolls. The middle working rolls are of 39-inch nominal diameter, top and bottom backing rolls of 60-inch nominal diameter, and all of 160-inch body length.

For either mill setup, the working rolls are independently driven by two reversing motors rated 6000 hp, 700 volts dc, 40/80 rpm (Fig. 2). Motors and generators are excited from individual quick-response forcing exciters that, in turn, are excited and regulated by thyristor regulators for fast reversal, generator voltage regulation, motor speed regulation, current limit protection, and load balance. The mill can be reversed from 40 rpm base speed forward to 40 rpm base speed reverse in 1.5 seconds, and from 80 rpm maximum speed forward to 80 rpm maximum speed reverse in 4.0 seconds.

The mill screwdown, which adjusts the opening between rolls to determine slab or plate thickness from each pass, has a high-speed drive for bloom-slab rolling and a low-speed drive for plate rolling. The latter can make screwdown movements in 0.002-inch setting increments and can position to within 0.002-inch bandwidth accuracy on all passes.

Sideguards guide metal into and out of the mill rolls. The front and back left sideguards are connected so they operate together, and the front and back right sideguards are similarly connected. When operating in the bloom-slab mode, left and right sideguards are controlled independently to move the ingot across the table, manipulate it, and align it at the bullhead or at one of the groove passes. When operating in the plate-mill mode, left and right sideguards are controlled together and regulated to keep them centered on the mill. Manipulator fingers in front and back right sideguards enable the operator to manipulate the ingot at the front or back of the mill during bloom-slab mill operation.

Roll tables deliver metal to the mill and carry away the product. The rolls for the tables near the mill are driven by adjustable-voltage systems so their speeds can be matched to the main mill speed. An entry-side turn table consists of ten alternate oppositely tapered rolls. When all of the rolls are operated in the same direction, the slab or plate is moved toward or away from the mill. When alternate rolls are rotated in opposite directions, the piece is "spin-turned" so it can be cross-rolled.

Nine operator control stations are located along the mill line. The main station, or "pulpit," is located over the approach table (Fig. 1). It includes switching and indicating devices for making the initial setup, controls to advance the automatic sequence and to intervene with manual control when necessary, meters to show the performance of the main drive, a punched-card reader to read the stored setup program into the computer memory and to read individual data for

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each ingot or slab, indicators to show screwdown setting, visual digital readouts, and television screens to show the ingot or slab approaching the mill and the finished slab or plate beyond the mill. The pulpit is arranged for one-man operation.

Ingot-to-Slab Rolling

Ingots are brought to the mill soaking pits usually within one and a half to two hours after having been poured. They have cooled on the outside but are hotter or even molten inside, so they must be "soaked" (reheated to uniform temperature) before they can be rolled. A heated ingot ready for rolling is drawn from the pit and taken to the receiving roll table by an ingot buggy. An operator at the pits informs the process foreman of the next heat to be rolled so that input cards will be available in sequence to read into the computer as the ingots are delivered to the line. A scale in the table line weighs each ingot, and the computer records the weight for the production record.

Ingots range in size from 23 by 45 inches (15,000 pounds) to 39 by 74 inches (72,000 pounds). They are delivered to the mill on edge. The usual heavy-slab rolling schedule consists of two bullhead edge passes to break off scale and square the ingot, six or eight flat passes, two bullhead edge passes, six or eight flat passes, one or two 16-inch groove edge passes, and one to three final flat passes. For rolling to thinner slabs, more passes are required and the ingot is turned up for edging in the 10⅛- or 5¼-inch groove. Occasional ingots have to be reduced to much narrower slabs, and some have to be rolled to blooms of 15 by 20 or 15 by 24 inches; additional sequences of alternate edge and flat passes are necessary to accomplish this large width reduction.

A shear crops the rolled slab's irregular head and tail end to sound steel, and the slab may also be sheared into two to ten pieces. (The shear can cut hot low-carbon steel up to 14 inches thick by 60 inches wide.) An air-operated marking stamper marks each sheared slab with die wheels positioned by remote control from the stamping and weighing control station, and a scale then weighs each sheared slab.

Slab-to-Plate Rolling

The four-high mill is served by one continuous slab-reheating furnace with a capacity of about 150 tons per hour, and space permits the future installation of a second furnace if needed. Slabs may range from 4 by 40 by 78 inches (3500 pounds) to 14 by 68 by 120 inches (32,000 pounds). Finished plate may range from 7/16 to 3 inches thick, 60 to 150 inches wide, and 300 to 800 inches long. Since practically all plate product is wider than the 68-inch maximum slab width, the slab is usually turned at some point in the rolling schedule and cross-rolled to spread it to the desired width.

Automatic Control of Bloom-Slab Mill

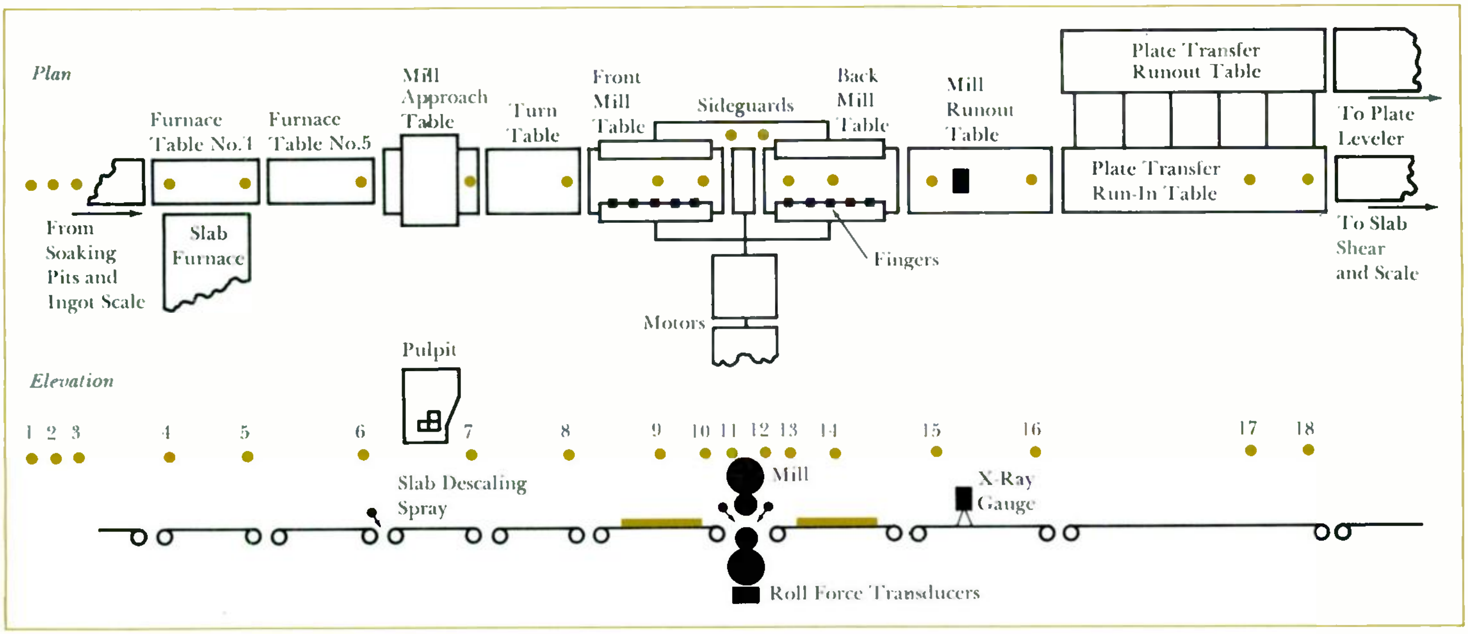
The on-line computer automatically controls mill operation to reduce the starting ingot to the specified finished slab. This automatic control extends from the ingot receiving table to the transfer run-in table (Fig. 3). An ingot-schedule punched card contains all the input information required for the computer to calculate a suitable rolling schedule, control the tables and mill automatically, and instruct the shear operator to cut the rolled slab into the desired lengths and number of pieces. Information on the card includes heat number, ingot number, chemistry of the heat, operating practice to be followed, scheduled ingot size and weight, scheduled slab size, and shear instructions. From this input, the computer calculates the schedule of screwdown settings, determines the movements and positions of the sideguards and fingers to manipulate and align the ingot between flat and edge passes, and develops the logical sequence of operations for the complete rolling schedule.

The schedule of screwdown settings is computed on the basis of specified limits of draft (cross-section area reduction) and percent draft for different alloy grades. A roundoff subroutine distributes the work among the passes in a series so as to end with specified dimensions at predetermined points (for example, thickness required to enter the groove edge passes, final width, and final thickness).

Operating Sequence—Eighteen hot-metal detectors sequence the operations and track each piece through the mill line. When the first one (HMD-1) detects an ingot on the buggy at the first furnace table, it starts the buggy roll table and receiving table to advance the ingot to the weighing scale. HMD-2 and -3 stop the ingot buggy roll table, return the buggy, and initiate the weighing cycle. The scale reading is recorded in the computer as actual ingot weight. The ingot is then advanced toward the mill by running the furnace tables. HMD-4, -5, and -6 monitor the movement of the ingot to the mill and sequence the table operations. If the mill has not finished rolling the preceding ingot, HMD-5 and -6 slow or stop the tables. During the last pass on the preceding ingot, the mill approach table and the turn table deliver the new ingot to the front mill table.

HMD-7 to -15 and the roll force transducers supply program-initiation signals to sequence the computer for the rolling operation. The control sequence includes several stages of operation. The *schedule advance* stage supplies input data for the incoming ingot that initiates the rolling schedule calculation. When the settings for the first passes have been completed, the sequence advances to the *new ingot* stage, which sets the manipulator sideguards and screwdown for the first pass. The *forward-pass-set* stage provides setup information for rolling a forward (odd-numbered) pass. Position references for the screwdown and manipulators are set, and the movements to the set positions are initiated. Main-drive entering and running speeds are selected, and when the positioning drives are within the anticipatory range the sequence advances to the next stage.

The *edge-pass* stage initiates movement of the ingot into the mill by setting the main drive on the entering speed, setting entry-table speed-draft compensation, and placing front and back tables on mill follow so they are speed-referenced from a pilot generator on the main drive motor. When the roll



3—Central area of mill line showing arrangement of mill and supporting facilities. Slabs and ingots are passed back and forth through the mill until they are of the desired dimensions. Numbered dots represent hot-metal detectors that sequence operations and track work pieces through the line.

force transducer indicates that the ingot is in the mill, the main mill is accelerated to running speed. At the end of the pass, the loss of signal from the roll force transducer advances the sequence to the *pass-advance* stage, which increases the pass number by one and selects the logic flags and position settings for the next pass. If the pass to be rolled is odd, the sequence advances to the forward-pass-set stage; if it is even, the sequence advances to the reverse-pass-set stage; if the last pass rolled was the final pass, the sequence advances to the schedule-advance stage.

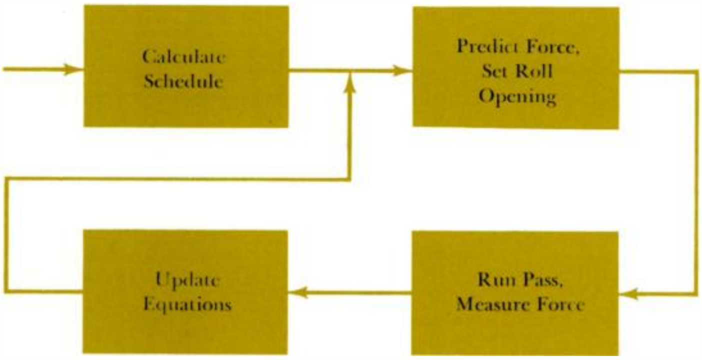
The *reverse-pass-set* stage initiates mill setup for rolling a reverse (even-numbered) pass; it includes the same functions as the forward-pass-set stage. The *flat-pass* stage includes the same functions as the edge-pass stage except that the piece is to be worked in the flat position. The *front-manipulation* stage controls the manipulator sideguards and front manipulator fingers to make a manipulation turn on the entry side of the mill following an even-numbered pass. The *back-manipulation* stage controls the manipulator sideguards and back manipulator fingers to make a manipulation turn on the delivery side of the mill following an odd-numbered pass.

Manipulation—Turning the ingot from the upright "edge-pass" position to the horizontal "flat-pass" position, or the reverse, requires complex coordinated movements of the left and right manipulator sideguards and the manipulator fingers in the right sideguard. Although turns are difficult to execute reliably because of many variables that cannot always be predicted, automatic manipulation is entirely feasible and has been made to work on this mill. About 95 percent of all turns are made automatically, and, on the remaining 5 percent, a simple manual intervention overcomes the abnormal condition and allows the operation to proceed without delay. The computer program is being improved to accomplish the manipulations even more reliably and consistently.

Delivery Sequence—After the last flat finish pass, the rolled slab is advanced automatically to the plate transfer run-in table, where it is stopped by HMD-17 and -18. From this point on, movements of the slab on the tables and operations of the slab shear, stamper, scale, piler, and slab transfer are manually controlled by operators. However, the computer continues to track the slab and to develop final data for the production log.

Slab-Processing Sequence—The computer controls visual digital displays at the shear operator's station that indicate the schedule number applying to the rolled slab, the hot length of the cut to be made, the number of cuts of that length, and the cut number. The operator controls the shear gauge and the shear manually. As cuts are made, the cut number display increases, always indicating the next cut to be made.

At the operator's station for the slab stamper and weighing scale, the computer controls visual digital displays indicating schedule number, heat number, ingot number, and cut slab number. These displays are set automatically when the shear displays are initiated. The computer checks the manual setup of the stamper against the identification designated by the computer for that slab and initiates the stamper marking



4—Roll force feedback is used to update the initially computed plate-rolling schedule, which is based on assumed hardness of slab.

cycle only if the identifications agree. The operator initiates the slab weighing cycle, and the computer records the cut-slab weight as part of the production log.

Mill Production Data—Production data first is punched on a paper tape and then typed on a mill production record. It includes identification, dimensions, and actual weight of each starting ingot; scheduled and actual weight and dimensions of each sheared slab; ratio of total sheared slab weight to starting ingot weight to indicate yield; and starting and finish time. The computer also operates an on-line card punch to produce a slab inventory card for each sheared slab. This card shows heat number, ingot number, and cut number (corresponding to the stamped marking on the slab); actual cold dimensions; and actual weight.

Automatic Control of Plate Mill

On-line computer control of the four-high mill operation is generally similar to that for the two-high operation. The processing of each plate is automatically controlled and sequenced from the time a slab is pushed from the slab reheating furnace onto the furnace table until the finished rolled plate is delivered to the transfer run-in table, with the exception that the operator controls the turn table manually for cross-rolling. When a turn is required, the computer stops the piece on the turn table and signals the operator to make the turn. When the turn has been made, the operator pushes an "Auto Reset" button and the computer resumes automatic operation.

A plate schedule card contains the input information necessary for the computer to calculate a rolling schedule and to sequence the mill operations automatically to roll a slab to a finished plate. (The slab inventory card produced by the computer when the slab was rolled from an ingot and sheared to length is used to produce this card.) A spread code on the card tells the computer the general procedure for rolling the plate (that is, whether only one 90-degree turn is to be made so the slab length will become the plate width, or if two turns are required so the finished plate axis will be the same as the starting slab axis).

Schedule Calculation—The rolling schedule calculations determine the number of passes, the points in the schedule at which the piece is to be turned for cross rolling, the screwdown and other settings for each pass, and other references to properly produce the desired finished plate. The most common rolling sequence brings the slab onto the front mill table, centers and aligns it with the manipulator sideguards, and makes two passes to reduce the thickness about 10 percent and establish an accurate thickness on which the cross-rolling passes are based. The operator then turns the piece 90 degrees and spreads it until its length is the ordered finished plate width. The piece is again turned 90 degrees and finish-rolled to the required thickness and length.

Model equations stored in the computer memory are used to predict the roll separating force, mill spring, and screwdown setting for each pass on the basis of the assumed hardness of the steel. The alloy number on the plate schedule card tells the computer which of nine sets of constants to use in making the initial schedule calculations to take care of variations in the resistance to deformation due to the alloy composition (or temperature) of the material.

On-Line Schedule Updating—Feedback information is used to update the control (Fig. 4). The first step is an initial schedule calculation with the model equation constants selected for the assumed hardness of the piece. The roll separating force is predicted for each pass, and the screwdown is set to compensate for the mill stretch. When the pass is made, the measured roll force is compared with the predicted roll force; this feedback information is used to update the model equations for the remaining passes and compensate for deviation of the actual material hardness from the assumed hardness used in the initial schedule calculation. During the setup for the next pass, the separating force is always predicted with the updated equations, and the screwdown setting includes compensation for mill stretch corresponding to the updated prediction of roll force.

The results of such schedule updating during the last six passes on two successive ⅜-inch plates are shown in the table. The first plate was "hot," approximately 15 percent softer than assumed by the alloy number specified, and the second plate was "cold," approximately 15 percent harder than assumed. "Actual gauge" is the calculated loaded roll opening corresponding to the measured roll separating force and the indicated screwdown position. The last two columns show the actual measured roll force and the ratio of this force to the initially predicted force. Because of the fairly large variation in roll force, the screwdown settings required to produce the same plate thickness are quite different.

Thus, the problem of producing finished plates of uniform thickness from slabs of varying hardness is solved by measuring hardness (due to alloy composition, temperature, or other condition) as each pass is rolled and using this feedback information on the next pass to predict the required roll force and screwdown setting. The technique also allows the computer to process pieces that are widely different from the

Automatic Updating of Rolling Schedule to Roll 3/8-Inch Plate From Off-Temperature Slabs

	Pass Number	*Desired Gauge*	*Actual Gauge*	*Screw Settings*	*Actual Roll Force (10^6 lb)*	*Ratio Actual/Predicted Roll Force*
"Hot" Piece	13	0.667	0.666	0.552	3.04	0.85
	14	0.577	0.576	0.464	3.01	0.87
	15	0.506	0.503	0.394	2.93	0.90
	16	0.452	0.453	0.347	2.81	0.88
	17	0.413	0.411	0.308	2.75	0.90
	18	0.387	0.385	0.288	2.54	0.86
"Cold" Piece	13	0.667	0.663	0.503	4.25	1.20
	14	0.577	0.569	0.427	3.78	1.17
	15	0.506	0.511	0.376	3.56	1.09
	16	0.452	0.450	0.304	3.92	1.19
	17	0.413	0.412	0.275	3.63	1.18
	18	0.387	0.385	0.255	3.46	1.15

material described by the model equations stored in the computer memory.

For instance, a very hard slab of high nickel-chromium alloy was rolled with carbon-steel model equations. Although measured roll forces were as much as 50 percent higher than the initially predicted forces, the computer did such a good job of recalculating screwdown settings that the finished plate was practically on-gauge. When data is collected for this hard alloy, model equation constants will be developed and stored in the computer. In the meantime, coarse adjustment of the constants can be made to enable the computer to calculate an acceptable initial schedule for unusual alloy steels, and the on-line updating does the rest.

The operator would have a difficult job trying to control the mill manually for the conditions shown in the table. The cold piece probably would be over-gauge at the end of the series of manually selected passes, so the operator would make two or more additional passes. These additional passes, uncoordinated changes from the usual schedule, might ruin the shape and flatness of the plate and certainly would reduce mill production.

An X-ray thickness gauge about 45 feet downstream from the mill measures finished plate thickness. This actual thickness measurement serves as a check on calculated thickness derived from the measured roll force and screwdown position; it also provides a means for automatic recalibration of the screwdown position reference to compensate for roll and bearing wear, changes in mill-housing and roll temperature, and any other slow drift in the system of thickness measurement by roll force and screw position. Once the screw position is accurately referenced, only occasional calibration adjustment is required.

A length-measurement system measures the attained length during broadside spreading passes and provides a feedback signal to the computer to check for errors in length (width) that might be caused by deviations in starting slab dimensions. However, the dimensions and weights of the slabs produced under computer control have been so consistently accurate that this length measurement has been found unnecessary except as a check of the weight lost by removing defects.

The same data-logging equipment used for the two-high mill operation produces punched-tape and typed production records. In the future, it may punch a plate inventory card showing heat number, ingot number, slab number, chemistry code, rolling practice, starting slab weight and dimensions, scheduled rolled plate dimensions, actual rolled plate thickness and width, and starting and finishing times.

Results and Conclusion

Computer-controlled automatic operation of this combination mill has proved successful. Taking into account initial heating-capacity limitations and the wide diversity of schedules rolled, production rates have been satisfactory. Since the mill is automatically controlled, actual product output closely approaches scheduled output; such performance greatly eases the problems of mill providing, production planning, and delivery.

Reliability of the automatic control system has been excellent. The computer and its peripheral equipment have been available for mill control more than 99 percent of the operating time.

The main mill operator's pulpit is arranged only for one-man operation, so the mill must operate under the computer-controlled automatic mode with only minor operator intervention. The mill does, in fact, operate in both the two-high and four-high modes with more than 95 percent completely automatic sequencing. Manual intervention is required principally to overcome unpredictable abnormal behavior of the slab being rolled and to assist the programmed sequence during manipulation and during entry of a slab into the 16-inch groove edge pass. The automatic control system is being improved constantly by changing the computer program and control subsystems as operating experience is gained. These refinements are expected to reduce the necessity for manual intervention significantly below the present approximate five percent.

Modern Electrical Testing Laboratory

by H. J. Reichwein

A new test facility provides for the testing of components at precisely controlled currents up to 100,000 amperes.

The increasing use of electrical energy in industrial plants and commercial buildings has created a need to provide increasing amounts of electricity with more compact distribution equipment. In addition, users sometimes want to locate transformers served by high-voltage circuits as close as possible to the point of energy use. Although space can be saved by such an arrangement, the result is higher available short-circuit currents since these currents increase as the distance between transformer and point of use is decreased.

To meet the need for reliable and thoroughly tested products under operating and short-circuit conditions, a new test laboratory has been opened by the Westinghouse Standard Control Division at Beaver, Pennsylvania. It is the first laboratory in the nation specifically designed to test low-voltage breakers at currents up to 100,000 amperes. It also is used to test manual and magnetic motor starters, fused and unfused safety switches, and bus duct. Test currents can be adjusted in fine increments over the full range from 500 to 100,000 amperes.

Uses of the Laboratory

Product Design Verification—Through elaborate tests, engineers determine design limitations and acceptable safety margins beyond regular operational requirements. They also evaluate new materials and technological concepts. These tests are needed because many factors cannot be calculated; actual performance under short-circuit conditions can be determined only by test. Among these factors are the ability of particular contact configurations and materials to withstand electrical damage on closing and opening under fault conditions; ability of mechanical parts to withstand the electromagnetic forces and high pressures associated with high currents and electric arcs; interrupting capability of circuit breakers, switches, and starters; and ability of components to withstand a specified current flow for a specified time.

Continuing Product Improvement—The new laboratory provides for testing of all products under field operating conditions. If the resulting information suggests design improvements, they are quickly made; if it leads to new technological concepts, the concepts are explored and developed if further verification tests prove them sound.

Underwriters Laboratories Qualification—All qualification tests for circuit breakers, switches, bus duct, and control devices are performed according to the specifications of Underwriters Laboratories, Inc.

NEMA Requirements—All tests also are performed in accordance with the National Electrical Manufacturers Association specifications for molded-case circuit breakers, for bus-duct short-circuit and current-carrying capabilities, and for continuous and high-energy values for industrial control equipment and safety switches.

Reliability Tests—Product reliability testing includes standard performance tests, such as calibration and overload, and tests of maximum interrupting and current-carrying capacity. Design engineers use the data obtained, with data from life tests and other operational tests, to evaluate failure rates and thereby determine whether modifications are needed.

Customer Use—Any manufacturer of control panels, panelboards, and similar devices can arrange to test his assembled product in the laboratory, with his engineers working side by side with Standard Control Division engineers. All test data will be retained by the customer.

Electrical System

Test voltages available conform to Underwriters Laboratories specifications and are representative of the distribution voltages in common use: 120, 240, 480, 600, and 277/480 volts ac. In addition, a test voltage of 480/831 volts ac is available for special application testing.

Short-circuit currents are available in 2500-ampere increments up to 25,000 amperes, in 5000-ampere increments from 25,000 to 50,000 amperes, and then at 60,000, 75,000 and 100,000 amperes. The currents are average rms symmetrical and are available for both single-phase and three-phase short-circuit tests. Power factors are 45 to 50 percent at 10,000 amperes and less, 25 to 30 percent from 12,500 to 20,000 amperes, and 15 to 20 percent from 22,500 to 100,000 amperes.

By far the most difficult electrical design problem was that of providing a system that would deliver up to 100,000 symmetrical amperes at 240 volts with power-factor control at all current values. The system that achieves this capability was designed jointly by engineers of the Standard Control Division, the Industrial Systems Division, and the Works Engineering Department of Headquarters Manufacturing.

The laboratory is served by a high-voltage line rated 1,300,000 kva at 69 kv (No. 1 in the illustration). The 69-kv air-break disconnect switch (2) is a three-pole 600-ampere (momentary 40,000-ampere) unit, motor-driven for remote operation from the control room. A manual operating system is provided for emergency use. A three-pole SF_6 gas circuit breaker (3) rated 1200 amperes at 69 kv is used as the main breaker for disconnecting the laboratory from the line and as a backup breaker when more than 50,000 amperes are used.

The 7500-kva 69-kv transformer (4) is similar to those used for arc furnaces. Its primary winding is delta-connected, with taps operated manually from outside the tank. Secondary windings are wye-connected and supply five secondary voltages by electrically operated no-load tap-changer control.

An isolated-phase bus structure forms the secondary circuit from the transformer to the device under test (5). It was chosen for its low impedance and elimination of short-circuit magnetic forces, characteristics achieved by mounting each

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bus conductor in the center of a nonmagnetic metal casing and spacing the casings as far apart as possible. The concentric magnetic field between conductor and casing wall is balanced, eliminating transverse short-circuit forces on the insulators. The current in the casing virtually eliminates all external magnetic fields and thereby also eliminates magnetic forces between conductors in adjacent casings.

A 4000-ampere electrically operated air circuit breaker (6) is used as a backup breaker for short-circuit currents below 50,000 amperes. The electrically controlled and pneumatically operated closing switch (7) consists of three identical high-speed units, one in each phase of the low-voltage bus system. It is used to apply short-circuit currents of 50,000 amperes and more to the device on test.

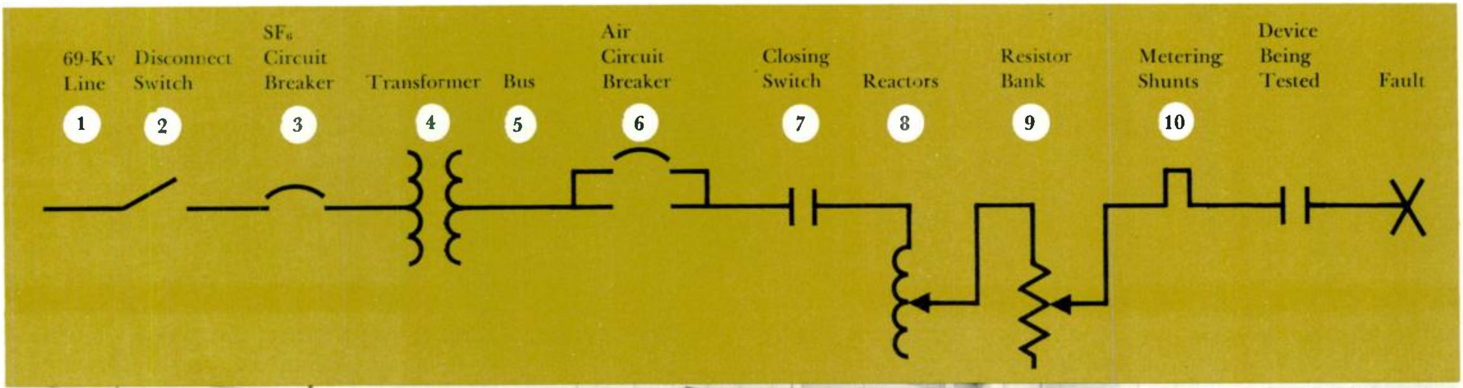
Two dry-type air-core reactors (8) and a resistor bank (9) in each phase help control current. Knife-blade switches and links connect the 13 resistor units in each bank in series, parallel, or any combination. A noninductive shunt (10) is included in each phase for metering purposes.

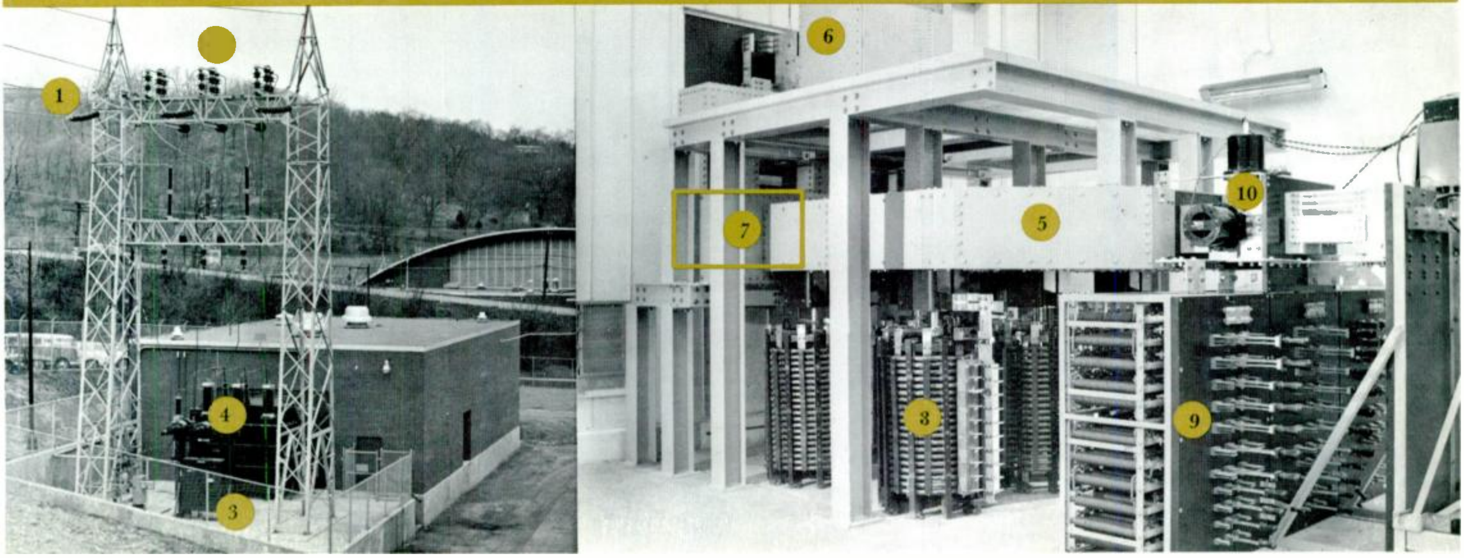
Electrical interlocks assure safe and reliable system operation. The power system is controlled from a console in the control room; as each element is energized, its symbol in the illuminated diagram above the observation window changes from green to red. A rotating cam switch is provided for automatic sequence control of tests and for automatic recording of test data.

Conclusion

This high-power laboratory is a design and test tool that enables Standard Control Division engineers to provide equipment tailored to today's and tomorrow's needs. It helps them design, build, and test equipment that will serve ever-increasing electrical requirements reliably, safely, and economically.

Westinghouse ENGINEER
November 1965





New laboratory is the first in the nation specifically designed to supply test currents up to 100,000 amperes. Numbers on the photographs identify the components illustrated in the single-line diagram. Devices to be tested are mounted on the panel at far right in the second photograph.

Steelmaking Arc Furnaces Supervised by Computer

Two large arc furnaces being installed at the Alton, Illinois, plant of the Laclede Steel Company will melt steel under the control of a Prodac 50 computing control system. The advanced control system will dispatch electric power to the furnaces in the most efficient manner.

Each furnace will operate at approximately 50,000 kilowatts to melt steel at temperatures between 2800 and 3000 degrees F. The furnaces, among the largest in the world, each measure 24 feet in diameter and 16 feet in height; capacity is 200 tons. They will receive power from a new substation capable of transmitting approximately 200,000 kva. Melting capacity of each furnace will be more than 50 net tons an hour.

Oxygen Regenerating System Based on Fuel-Cell Principles

The oxygen requirements of personnel in relatively short manned space missions are met by carrying compressed or liquified oxygen along. However, as missions become longer, the large amount of oxygen required makes it desirable to regenerate used oxygen. A man obtains about two pounds of oxygen a day from the air he breathes and another half pound from his food; the body converts about 90 percent of this oxygen into carbon dioxide and water. An experimental oxygen generator that can extract oxygen from these two compounds has been developed as a possible component of life-support systems in space.

Essentially, oxygen is generated by operating a battery of solid-electrolyte fuel cells in reverse. Fuel cells normally generate electricity by chemically reacting a fuel, such as hydrogen, with oxygen. To reverse the process, electric power and combustion products are introduced into the cells to generate pure oxygen. Carbon dioxide, water, or a mixture of both is a suitable combustion product to start with.

The solid electrolyte used in the fuel cell is a ceramic material composed mainly of zirconia. When red hot, it has the unusual property of permitting oxygen ions to migrate through it easily; no other gases present in the cell can penetrate it, nor can electrons flow through.

At the operating temperature of the cell (about 1800 degrees F), both carbon dioxide and water vapor decompose and release oxygen ions at the cell's cathode. These ions move through the electrolyte to the anode, where they lose their electrons and become molecules of oxygen. Hydrogen and carbon are by-products.

The individual cells are small hollow cylinders that fit together to form pipes. Several such pipes make up the fuel-cell battery. (See photograph, outside back cover.) Carbon dioxide and water vapor flow inside the pipes, and oxygen is collected from the outside. Metal plating inside and out forms the positive and negative terminals to which the electric power is fed.

Studies made at the Westinghouse Research Laboratories, where the oxygen generator was developed, indicate that a complete system capable of supplying the needs of four men (fuel cells, controls, insulation, and auxiliary equipment) would weigh from 60 to 75 pounds. It would occupy about three cubic feet and require about 900 to 1100 watts of power.

Hot Strip Mill with Static Main Power Supplies

A continuous hot strip mill to be installed at the Middletown, Ohio, works of Armco Steel Corporation will be the largest and most modern of its kind in the nation. The main drives of its finishing-mill section will be supplied by static thyristor power supplies—totaling 58,400 kw of power output—instead of motor-generator sets. Thyristor power supplies will also be employed for the screwdowns and dc auxiliary drives.

The mill will be capable of producing steel strip from slabs up to 33 feet long, 75 inches wide, 10 inches thick, and weighing 82,500 pounds. It will roll the strip through 13 stands at speeds ranging from 1700 to 4000 feet per minute. At the delivery end, thickness of the strip will range from 0.05 to 0.50 inch. The main drive motors total 132,250 horsepower.

Systems design and coordination of the project is being performed by the Westinghouse Industrial Systems Division. The mill is scheduled to go into operation in mid-1967.

Improved Sampling Technique for Mass Spectrography

Mass spectrography has long been a useful tool in chemical analysis. In it, a sample is vaporized and ionized, and the ions are passed through a magnetic field that puts them into circular orbits. The heavier ions are flung outward farther than the lighter ones and so strike at different points on a photographic film. The result is a series of lines on the developed film, and the positions and darkness of these lines show what atoms are present and how abundant they are.

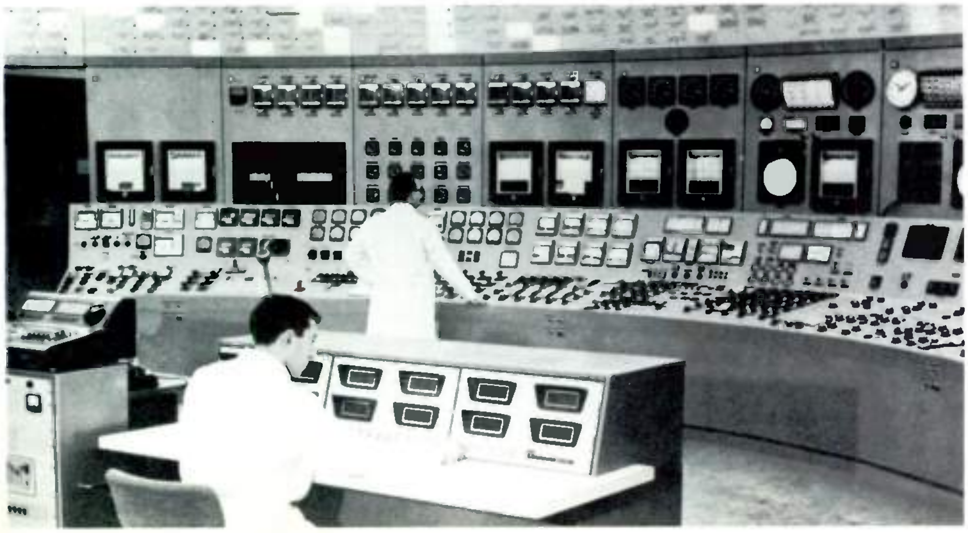
A new sampling technique greatly enhances the usefulness of mass spectrography for such areas as thin-film research, surface chemistry, and biochemistry because it does not penetrate deeply and does not subject the sample to excessive heat. The material to be analyzed rests on a spinning plate, placed less than a thousandth of an inch from a gold-tipped electrode charged with 50,000 volts of electricity at a rate of 800,000 times a second. Tiny sparks, each about a millionth of a second in duration, skip from the electrode to the specimen, and each spark digs a crater about 20 millionths of an inch in diameter and half as deep. (See photograph, top right.)

Because the craters are so shallow, sampling does not penetrate into the substrate material to contaminate surface films being analyzed. Such films are found, for example, in semiconductor electronic devices. Microtomed biological specimens and biological smears also are essentially thin films; so are many of the compounds of interest in surface chemistry, such as corrosion products.

For organic molecules, the new technique is a distinct improvement over previous sampling methods for yet another reason. The usual process of sparking

Sampling technique *(above)* for mass spectrography employs tiny sparks to vaporize similarly tiny samples from a specimen, forming the craters seen in this photomicrograph. The specimen is spun rapidly during sparking, so each sample comes from a fresh location.

Enrico Fermi nuclear power station *(below)* is monitored by an on-line computer system.



these materials at one point causes chemical changes through overheating, so the sample of vaporized material may not be typical of the actual substance. In the new system, spinning the specimen constantly brings clean undegraded material into the spark. Also, the sample is vaporized in less than a millionth of a second, which further lessens the chance of overheating.

Workers at the Westinghouse Research Laboratories, where the technique was developed, have used the new technique and apparatus to analyze both simple and complex organic molecules. One of the complicated molecules studied is deoxyribonucleic acid (DNA), a giant molecule that contains several hundred thousand atoms.

Computer System Serves Enrico Fermi Station

Automatic data-logging and computation are now being performed on-line by a computer system at the Enrico Fermi nuclear power station of the Societa Elettronucleare Italiana (SELNI) in Italy. The power station has a Westinghouse pressurized-water reactor and two turbine-generator units that, together, supply 270 mw of electric power. Its monitoring system consists of a Prodac 510 computer (with an 8196-word core memory and a 65,536-word drum memory), operator's, programmer's and typewriter consoles, and input-output peripheral equipment. (See photograph, bottom left.)

The system automatically collects and reduces data on reactor neutron flux. With this data, it computes such nuclear parameters as pointwise assembly power, flux-tilt ratios, hot-channel factors, and departure from nuclear boiling ratios. Before the advent of on-line monitoring, these computations had to be made by large scientific computers after the fact, with data collected manually.

The computer system also provides normal scanning, logging, and alarming functions. Reviews of reactor scrams and transient conditions are initiated automatically by the closure of external contacts or manually from the operator's console. Sequence-of-events recording is initiated by closure of one or more of 12 interrupts. Moreover, the computer system determines and displays nuclear parameters, reactor temperature data, total reactor thermal power, gross efficiency, and other quantities.

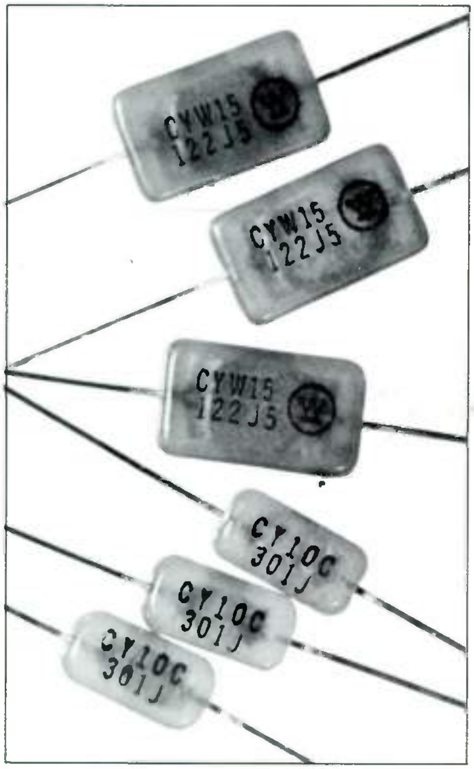
A symbolic assembler program was furnished with the computer system to facilitate program development in the field. Before the station was completed, the computer was used for hot functional tests of the primary plant.

Products for Industry

Glass-dielectric electronic capacitors are for military and industrial circuits requiring high stability and low drift or losses (photo, top right). Military line, type CY, covers capacitance range of 0.5 through 300 picofarads with voltage ratings of 300 and 500 at 125 degrees C. Industrial line, type CYW, covers range of 0.5 through 1200 picofarads with voltage ratings of 100 and 500 at 125 degrees C. Glass case and dielectric are fused to form homogeneous mass around and between aluminum electrodes and leads. *Westinghouse Electronic Capacitor Department, Box 130, Irwin, Pa. 15642.*

Type 252 line of instruments introduces taut-band suspension to the switchboard edgewise type (photo). Taut-band suspension makes instruments virtually immune to damage from shock or vibration, and its inherent freedom from friction gives near-perfect repeatability and high sensitivity. Instruments can be used horizontally or vertically; only the dial cards need be changed to convert. *Westinghouse Relay-Instrument Division, Plane and Orange Streets, Newark, N.J. 07101.*

Acoustic flowmeter, Model LE, uses acoustic pulses to measure liquid velocity and volume flow rate within ± one percent of full-scale accuracy. It is supplied with either digital or analog output circuitry. For measurement where the liquid moves in more than one direction, a two-plane version is available. *Underseas Division, Westinghouse Defense and Space Center, Box 3061, Baltimore, Md. 21203.*



New Literature

Ocean Bottom Scanning Sonar is an illustrated booklet describing principles, design, and applications of a high-resolution, side-looking acoustical system that provides detailed pictures of the ocean bottom. Copies available from Marketing Department, Underseas Division, Westinghouse Defense and Space Center, P.O. Box 1797, Baltimore, Md. 21227.

Westinghouse Engineering Service, B-9144, describes the Company's capabilities in solution of many problems associated with today's complex electric utility systems. The booklet includes sections on generation engineering (load forecasting, reserve planning and costing, unit commitment, and dynamic stability studies), transmission engineering (engineering analysis, computation, and field testing), and distribution engineering (planning, designing, and evaluating systems). Copies available from Westinghouse Electric Corporation, P.O. Box 868, Pittsburgh, Pa. 15230.

Technical Service Laboratories, B-9141, describes the Westinghouse Atomic Power Division's analytical services, post-irradiation facilities, and industrial hygiene and safety services. Copies available from Westinghouse Atomic Power Division, Waltz Mill Site, Box 158, Madison, Pa. 15663.

K-DAR Local Back-Up Relaying, RPL 65-3, is an 18-page booklet that reviews local back-up principles and shows how they can be applied to K-DAR line relaying for fast and selective tripping in spite of failure in primary protection system. Copies available from Westinghouse Relay-Instrument Division, Plane and Orange Streets, Newark, N.J. 07101.

How to Write Better and Faster is a book written by Terry Smith, a senior engineering writer in the Surface Division, Westinghouse Defense and Space Center, Baltimore, for people who are called on to write but who are not professional writers. It covers many aspects of the subject, from prewriting planning to printing. Published by Thomas Y. Crowell Company, 201 Park Avenue South, New York, N.Y. 10003. Publisher's list price is $4.95.

About the Authors

While much attention has been focused on the water shortage in New York City, the problem of producing pure water—both for drinking purposes and for industrial processes—is worldwide. Nothing brought this home to us clearer than working with **Roy E. Gaunt** on his articles on water purification in this issue. Possibly the manuscript logged more air miles, while Gaunt was on his way to conferences with companies and government officials, than many people accumulate in a lifetime.

Gaunt's career with Westinghouse began in 1950, shortly after his graduation from the University of Michigan, where he earned his BS degree in Marine Engineering and Naval Architecture. After completing the Graduate Student Course at Westinghouse, he served in various engineering positions both at headquarters and in the field. In 1959 he was appointed sales manager of the Heat Transfer Department, where he began to pile up experience with the type of equipment involved in the flash evaporation process. In 1964, he became marketing manager of that department. Later in 1964, he was appointed manager of the newly formed Water Province Department, the position he now holds.

William G. Rogal's career to date seems to indicate that a good engineer is a good engineer regardless of what project you hand him; he may also be proof that an engineer these days may often be called upon to stray from engineering to marketing to manufacturing and back again.

Rogal graduated from Purdue University in 1952 with a BSME, and shortly thereafter joined another company, where he underwent a training program on diesel engines. From 1954 to 1956, he did his stint in the Army, then rejoined his previous company.

This time he was assigned to the research and development division as an assistant project engineer, where he worked on a coal-fired gas-turbine locomotive, and then on a forced-draft engine cooling system.

In 1959, he joined another company and became a project engineer on a gas-turbine engine development for trucks, and other gas-turbine vehicle studies. Next came work on farm tractor transmissions.

In 1963, he shifted to another company and became an application engineer for high temperature heat transfer products, during which period he also was marketing and manufacturing product supervisor for a product in this category.

In 1964, he joined the Water Province Department, where he is a negotiations engineer concerned with water processing problems, including the flash evaporator method that he writes about in this issue.

Alonzo F. Kenyon has been designing drive systems and controls for the metals industries for more than 40 years, and he has played a leading role in the great advance in metalworking technology that has occurred in that time. For example, he saw the first mill for cold reduction of tinplate put into operation in 1928 to roll steel at 350 feet a minute; today, he engineers drives and controls for mills that cold-roll steel at 7500 feet a minute. Kenyon has contributed to the development of modern drive systems for all types of rolling mill, including card-programmed control systems, on-line computer control systems, and automatic gauge control. During the 1940's, he helped develop an automatic washing system to adapt electronic air cleaners for heavy industrial ventilation systems.

Kenyon graduated from Iowa State University in 1922 with a BS in electrical engineering and joined Westinghouse on the graduate student course. His first assignment, to the steel-mill section of the then General Engineering Department, was the right one; he has been continuously engaged ever since in the application of electrical drives and controls to all types of steel and nonferrous rolling mills throughout the world. Kenyon was awarded a professional electrical engineering degree by Iowa State in 1947. An active member of IEEE and AISE, he has presented about 25 technical papers and has had nearly 50 articles published. He holds 18 patents, most of them dealing with drive systems for rolling mills.

H. J. Reichwein graduated from Mannheim College in Germany in 1949 with a degree in mechanical engineering and business administration. He has also taken academic work at the Naval Academy of Germany and at the Universities of Toronto and London (Canada). He served as an industrial engineer with Siemens and Halske in Germany and then went to Flexonics Corporation of Canada as a plant engineer. Reichwein joined Westinghouse in 1963 as engineering manager of the Standard Control Division.

R. F. Woll has had primary design responsibility for new ac motor lines developed by the Motor and Gearing Division for the past 20 years, including the new Life-Line T line that is based on the revised NEMA standards discussed in this issue. He earned his BS in electrical engineering at the University of Pittsburgh in 1937 and joined the Westinghouse motor division, then in East Pittsburgh, as a tester. In 1939 he became an ac motor designer in the industrial motor engineering department and has been primarily concerned with design and development of ac motors ever since.

Woll moved to Buffalo when the Motor and Gearing Division was established there. He is now a Fellow Design Engineer in Medium AC Motor Development.

Oxygen Generator

This experimental oxygen generator is essentially a fuel-cell battery operated in reverse. Because it can regenerate oxygen from carbon dioxide and water, it is a possible component of future life-support systems for space vehicles. (See article on page 190.)