Power Generation
and POWER PLANT ENGINEERING

For ALL Power Engineers • Steam, Electricity and All Other Power Engineering Services

COMPLETE CONTENTS

Regular Departments

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THE POWER INDUSTRY—

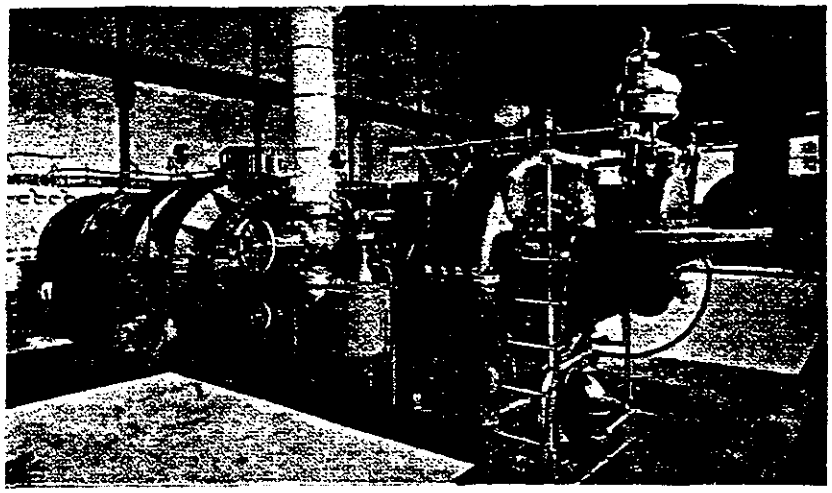
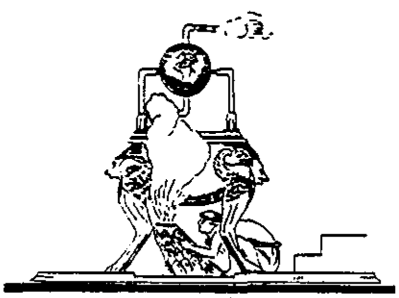


Fig. 1. A photograph of the first turbine for central station use in the United States. This was the 2000-kw Westinghouse unit installed in the plant of the Hartford Electric Light Co. in 1900. It was a 1200 rpm condensing turbine, far exceeding in capacity any unit previously built. This machine ran for eight years

AS THE WORLD MOVES into the second half of the twentieth century the advent of nuclear energy or atomic power as it is popularly known gives promise of changes so vast, so inconceivably beyond anything we can even imagine today that it would be foolish to try to predict what the power industry will be like in the year 2000. Make no mistake about this; do not be misled by economics or so-called engineering considerations by so-called experts today. The nucleus of the atom is not amenable to economics. As pointed out in a recent issue of *Nucleonics*, an accountant can't see an atom and if he could he probably wouldn't know what he was looking at. For this reason, all estimates of the probable cost of developing atomic energy are relatively worthless. Such estimates only show up the circumscribed kind of thinking which people—engineers as well as accountants—indulge it. As *Nucleonics* points out, "only a scientist can tame an atom, and almost no one can tame a scientist, except perhaps his wife. Trying to reduce such a situation to generally accepted accounting principles consistently applied is both elusive and illusory."



Hero's Turbine

In the use of nuclear energy we have a gain over present day fuels of three million to one. No matter what the engineering difficulties, no matter how diffused the supply of fissionable materials may be on earth, nuclear power will be put to use during the next half century. It is fortunate that nuclear energy can be used as a war weapon because the development of weapons, like the atom, is not subject to the laws of economics, and the intensive research that is going on under the weapon program is enormously accelerating the development of atomic power for peacetime use.

Fifty years ago, in the year 1900, the first turbine-generator for central station service went into operation in the plant of the Hartford Electric Light Co. A picture of this unit is shown on this page. It was a 2000-kw, 1200 rpm condensing turbine driving a d-c generator through reduction gears. As will be seen from the photograph, it was quite modern in appearance. Charles A. Parsons had developed the turbine in England and as soon as George Westinghouse heard of Parson's success he investigated and in 1895 Westinghouse obtained the exclusive American rights for the Parson's type steam turbine. After building several small units—one 400-kw unit—the Hartford unit was built in 1900.

First 500-Kw at Fisk

The General Electric Co., in the meantime developed a type of turbine based on the patents of Curtis. At first, the vertical type was exclusively the standard in this type of turbine. Outstanding among the names associated with the early days of the utility industry and the steam turbine is the name of Samuel Insull. Despite the later notoriety which surrounded this man when the lust for power and money overruled his earlier good judgment, Samuel Insull deserves considerable credit for his untiring efforts in the development of the utility industry. It was Insull's confidence in the advantage of the turbine that led him, in 1903 to install the first 5000-kw turbine generator at the old Fisk Street Station in Chicago. This was by far the largest turbine unit ever constructed and there was some apprehension concerning its feasibility. A picture of this unit is shown in Fig. 3. It was a vertical unit which operated successfully for many years. Then, it was moved back to the General Electric Co. works at Schenectady, where it was made, to stand as a monument to commemorate the beginning of the turbine industry.

There is a great difference between these early turbines, the one at Hartford, the 5000-kw unit at Fisk, and the modern 100,000 and 150,000-kw turbine generating units of today—between them lies the growth and development of practically the whole of the electric power industry as we know it today. Yet, if history is any criterion, we can expect far greater changes in the power industry in the next 50 years. This would probably be true even without atomic energy but with it, the changes are bound to be revolutionary. With the development of the breeder type of nuclear reactor the entire problem of fuel supply and transportation will vanish. Instead of having to transport hundreds of millions of tons of coal and

Past, Present, and Future

oil over long distances, it may become possible to deliver the nation's annual nuclear fuel supply in a single good size truck. At the present time, of course, noboby outside of the top members of the Atomic Energy Commission know how much fissionable material can be made with our present production facilities. Niels Bohr was attributed to have said that at the close of the war the Oak Ridge plant was making 6 lb of U-235 a day by the gaseous diffusion process. Since then we have considerably added to the capacity of the diffusion plant, and, of course, the Hanford facilities have also been extended.

Cost of Uranium

Even now, as reported by Dr. John R. Dunning at the meeting of the American Association for the Advancement of Science in New York on December 26, the cost of producing fissionable uranium is somewhere between $10,000 and $25,000 a pound. Averaging these two extremes would give us uranium at a cost equivalent to less than $10.00 per ton for coal. Many present-day steam stations, of course, pay only a little over $5.00 per ton for coal.

As Dr. Dunning said, "uranium fission converts only one part in a thousand of mass into energy, so we certainly have plenty of room for some faith in the future and some new ideas and discoveries.

During the first fifty years of the twentieth century, we have attained in this country the world's highest standard of living, due largely to our great and universal use of electricity. In 1949 the use of electrical energy by residential customers reached an all time high in the United States with an annual consumption of 1685 kilowatthours per customers. Only 10 years ago the average annual consumption per customer was 897 kilowatthours. At the end of the year 1949, there was installed in this country a total of 63,500,000 kw of generating capacity. This included plants of all business-managed companies as well as federal, municipal and REA plants.

The leadership of the United States in the production of electricity among the nations of the world is indicated in the accompanying table. With a total annual production of 336,808,000,000 kwh, the United States produces 44.4 per cent of the world's production. This figure is even more significant when we compare it with population. With less than 7 per cent of the world's population, the United States produces (this was in 1948) over 44 per cent of the world's electricity. This was about 5½ times as much electricity as Russia, the country generating the next greatest amount, was able to produce.

At the beginning of the century many generating plants used as much as ten pounds of coal per kilowatt hour and the best stations used around six pounds. (Edison's *Jumbo* units which required *only* 10 lb per kwh were a great improvement over earlier arc-lighting plants which used 30 lb of coal per kwh.) Today, the national average is 1.2 lb of coal per kwh and the most efficient plant requires less than ¾ of a pound of coal per kwh.

For the long term future, these gains will serve as the springboard to much greater progress. Future years will witness great development of the gas turbine. The gas turbine has been in process of development for some 25-years but only this year was the first gas turbine installed in a central station in this country. Of course, they have been used in Europe for well over ten years. The great advances in the art of metallurgy, however, have given renewed impetus to gas turbine development during the last four years and from now on, an increasing number of gas turbines will be installed for power production. The development of the coal-burning gas turbine is well

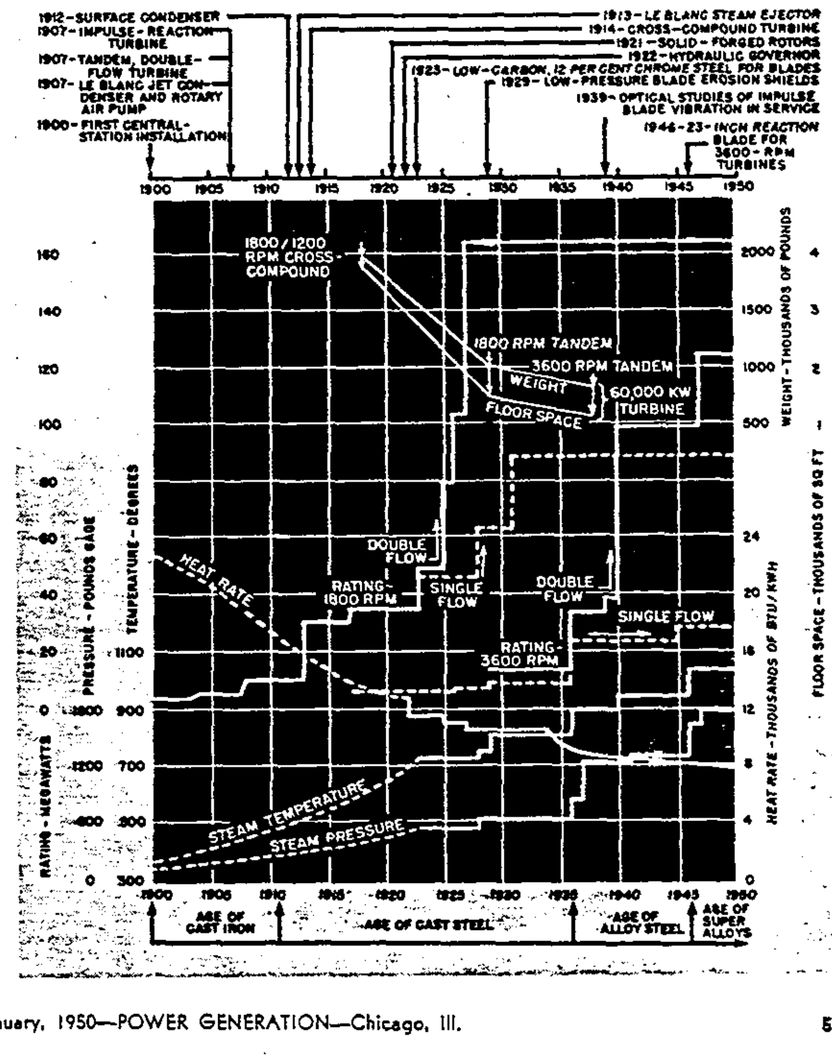


Fig. 2. Chart showing the development of the steam turbine and the influence of the development of *different metals* upon its growth. This chart was presented at the Westinghouse Electric Corp. Mid-century Review and Forecast Forum in Pittsburgh, November 10, 1949

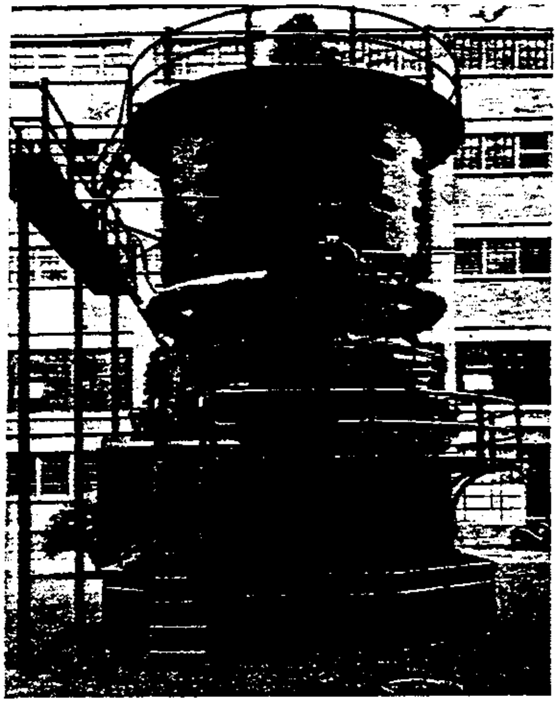


Fig. 3. The first 5000 kw steam turbine generating unit installed at the old Fisk Street Station in Chicago in 1902. This was the largest unit ever built at that time and Fisk Station was the first all steam-turbine electric generating plant built in this country. Curiously enough, Fisk Station today has installed in it the largest single-shaft steam turbine unit ever built. This unit is shown in Fig. 4

under way and when a fully practical and successful coal-burning gas turbine is achieved even our highly developed steam turbine will disappear, not completely perhaps but to a marked extent.

Like the gas turbine, the mercury and his assistant L. A. Sheldon and installed under the supervision of H. N. Hackett. The mercury cycle was developed by these pioneers to superimpose or *top* the then existing low-pressure 250 psig steam cycle. Today, even with the practical

WORLD PRODUCTION OF ELECTRICITY—1948

Country	Kilowatthours Produced	Per cent of World Production
United States	336,808,000,000*†	44.4
Russia	60,000,000,000‡	7.9
Canada	46,930,000,000*§	6.2
United Kingdom	46,536,000,000	6.1
Japan	33,624,000,000	4.4
Germany (United States, British, and French zones)	31,320,000,000	4.1
France	27,564,000,000*	3.7
Italy	22,692,000,000	3.0
Sweden	14,268,000,000*	1.9
Norway	12,444,000,000*	1.7
Estimated other countries, including Russian zone in Germany	125,814,000,000	16.6
Total	758,000,000,000	100.0

SOURCE: United Nations Statistical Bulletins, Sept. 1949.
NOTES: * Includes industrial plant production.
† EEI Statistical Bulletin No. 16.
‡ Business Week, Feb. 12, 1949.
§ Industrial plant figures for 1945.

turbine has been a long time in development. Development of the mercury turbine dates back some 30 years and during this time General Electric has spent upwards of 20 million dollars in its development. The first commercial mercury turbine went into operation in 1928 at the Hartford Electric Light Co. This first installation was designed by W. L. R. Emmet then consulting engineer of the General Electric Co.

maxima of pressure and temperature in steam generating equipment, the mercury cycle still can successfully top such units and increase the overall efficiency. The resulting economies, especially in the higher fuel cost areas, may be sufficient to pay off the additional investment in about three years.

In January 1949—just a year ago —a new mercury boiler and turbine was started in the South Meadow Station of the Hartford Elec Light Co. This replaces the old u referred to above. The new u consisting of a 15,0.. kw merc boiler and turbine, produces 33. kw net capacity from the merc turbine and steam produced in condenser-boiler. This unit is first of several post-war merc unit power plants to be placed service before very long.

Where the Mercury Turbine Fits

While high thermal efficiencies c be attained by the use of the hi pressure high-temperature ste cycle, the mercury turbine offers tractive features in that its h thermal efficiency can be attai with small plants—plants of 1500 and less. Thus, while it is possi with present day high temperat steam plants to attain very h thermal efficiencies in large static it is not economically feasible obtain these same efficiencies w small steam plants. It is here t the mercury type of plant off great promise.

Thus, both the gas turbine and mercury turbine can be expected find increasing application in fut decades. The task with the gas tu bine in the immediate future clearly, to develop it for long co tinuous operation with gas tempe tures beyond 1300 degrees and obtain information as quickly possible that will lead to constru tion of suitable units for tempe tures up to 1500 degrees. Such pr grams are being aggressively pu sued. Both the central station fi and industry generally have attra tive applications for the gas turbi that await its development. The is little doubt that such practic long-life machines will become reality and that machines of ope cycle form and in capacities up say, 10,000 kw will be built in few years. Closed cycles offer po

Faraday discovering the principle of electric generator sibilities of machines several times this rating.

Now, at mid-century, the gas turbine stands about where the *steam* turbine stood at the beginning of the century. The gas turbine inherits much experience *from* its cousin. Its further development, for all its obstacles should be rapid and what the next 50 years holds for the gas turbine, like atomic energy, makes interesting speculation.

Development of all three types of prime movers, the steam turbine, the gas turbine, and the mercury-vapor turbine will no doubt continue far into the second half of the twentieth century unless some new type of electric generator, such as, for example, a thermoelectric generator, should be developed. This is true regardless of whether or not nuclear energy comes into use on a large scale. At the present time the only practicable method of developing power from nuclear energy is by utilizing the thermal energy produced as a consequence of nuclear fission in a conventional type of prime mover such as a steam, gas, or mercury turbine. Nuclear energy is thermal energy and unless a way is found whereby this thermal energy can be converted directy into electrical energy, it will be necessary to use prime movers driving electrodynamic generators.

New Forms of Generators

As indicated in the section devoted to electrical engineering in the pages that follow, there is a possibility that a practical thermoelectric generator might be built—a generator that would absorb the heat from a coal or oil fired furnace, or a nuclear reactor, and convert it directly into electical energy. A new type of thermocouple, one made of silicon carbide and carbon has been developed which produces a very much higher electromotive force per degree difference in temperature and this thermocouple offers possibilities in that direction, though there may be reasons which will prevent the development of a practical generator of this kind. Some scheme of this kind would be of inestimable value in abstracting the heat from a nuclear reactor. It appears that the amount of energy that may be released in a nuclear reactor and, hence, the amount of power that may be produced, does not depend upon the size of the reactor as determined by nuclear considerations. Any amount of power from a few watts up to hundreds of thousands of kilowatts may be produced from any size pile provided the energy can be removed from it. In other words the problem in reactor design is mainly one of heat transfer. In the extreme case, the atomic bomb is a nuclear reactor and it is quite clear from even the small amount of information that has been released, that the mass of uranium or plutonium [illegible] is of the order of a sphere 3 to 6 in. in diameter.

The great advantage of atomic power over other forms of power lies in the extreme concentration of *the fuel.* In recent years there has been considerable discussion concerning the possibility of utilizing the radiant energy issuing from the sun directly by photosynthesis, or by some other method. True, all our power stems from the sun and each square mile of the earth's surface receives a relatively enormous amount of energy from the sun, but it seems unlikely that a practical method can be developed in the foreseeable future which would convert this radiant energy into useful power without the construction of vast structures covering large areas. Wind power is somewhat in the same category and, so far, the most feasible way of utilizing wind power is by the pumped storage method, that is by having windmills pump water from a low to a high level and then using the potential energy of the stored water in hydroelectric plants. This scheme, however, involves the building of great reservoirs and while other forms of energy are still relatively cheap this method is not likely to find extensive use.

At the present time coal and oil are abundant in many parts of the world and since these are concentrated forms of energy they will be drawn upon until the reserves have

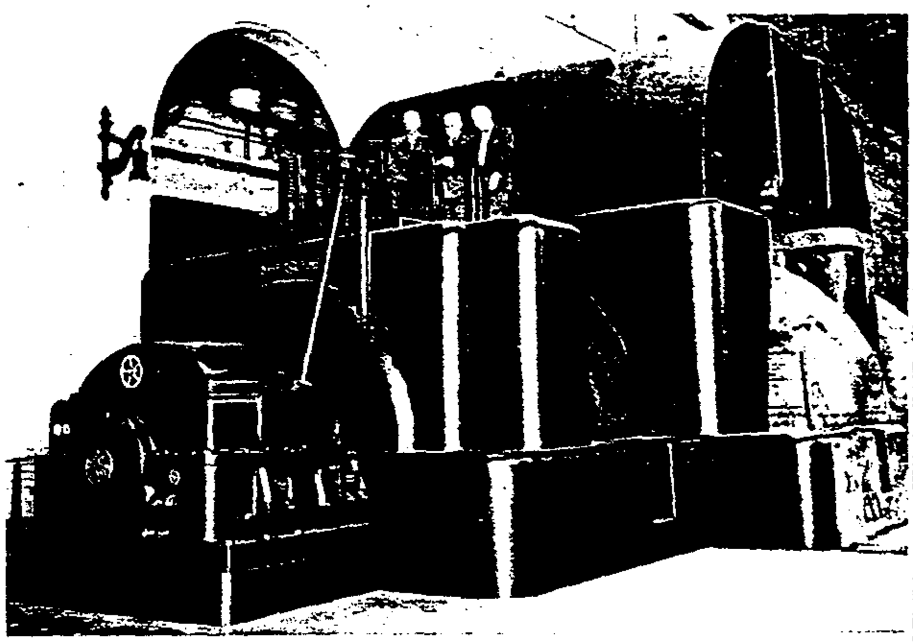


Fig. 4. The 150,000 kw turbo-generator placed in service at Fisk Station of the Commonwealth Edison Co. in Chicago in July 1949. *This is one of the largest generating units ever built. It is Unit No. 18 at Fisk and with its installation, Fisk Station attains a capacity of 473,000 kw, making it the largest of the ten generating stations of the Commonwealth Edison system*

nuclear energy offers an almost infinitely more concentrated form of fuel and therein lies its particular charm. A small reactor, no larger than a modern steam boiler may be able to deliver a thousand, perhaps a hundred thousand times as much energy.

Atomic energy, then, is the great new force of the second half of the twentieth century. It offers prospects of revolutionary changes far greater than those which the development of the steam turbine brought in the first half of the century. Our electric power systems no doubt will continue along the present lines of development; our electric transmission and distribution systems will grow and become more effective and efficient. Transmission voltages will increase on our long distance transmission systems, the underground transmission of electrical energy will be developed to a point where it may become possible to do away with overhead transmission as has been the case in telephone systems.

As to the use of electrical energy in this country fifty years from now, it would be foolish to even try to predict. About all we know now, is that in another ten years, by 1960, say, the installed electric generating capacity in the United States will be well over 100 million kilowatts and this assumes no use of atomic energy. After that, atomic energy will probably begin to have its effect.