GENERATION OF STEAM BY ELECTRICITY*

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THE purpose of this paper is to bring before the engineering profession the conversion of electric energy into heat energy by means of an improved and inexpensive apparatus, the electric steam-generator. To produce steam by electricity appears at first sight a reversal of common-sense, but this process has its economic *raison d'être* in the fact that it can utilise hydro-electric power that would otherwise be wasted. In times of business depression the engineer is forced to consider all kinds of improvements, such as increasing efficiency of production, elimination of waste in material, labour and power; and the electric steam-generator is a handy and simple means of contributing toward this end. There are more than 300 installations in Italy, Switzerland, Sweden and France, and a small number of generators has been in use for a short time in Canada and the United States.

The low cost of the electric steam-generator compared with that of other electrical plant for converting electricity into heat, and the comparative cheapness of the wiring and control apparatus necessary, are very favourable considerations. It can be shown that even when the load factor is comparatively high, *e.g.*, in pulp and paper factories, which purchase big blocks of power and consume it, mainly for pulp-grinding, during only six days of the week, it is economically feasible during the seventh day to turn the power into steam, which is always required either for heating or manufacturing.

In the electric steam-generator the electric current passes through a resistance either of metal or formed by the water to be evaporated, and all electric energy is converted into heat energy. One kilowatt-hour is equivalent to 3412 British Thermal Units; the total heat content of 1 lb. of steam at an absolute pressure of 150 lb. per sq. in. is 1193 B.Th.U.; assuming the temperature of the feed water to be 150° F., the total heat to be supplied will be 1193—(150—32) = 1075 B.Th.U. One kilowatt-hour will therefore produce 3412/1075 = 3.17 lb. of steam. The heat losses are very small.

During the past ten years generators have been made with capacities up to 1000 kw., and only within the last two years have sizes of 2000 kw. or more been constructed.

There are two main classes of electric steam-generators: (a) those in which the current passes through a combination of metallic resistors, and (b) those in which the water itself forms the resistance. In (a) the resistors in the form of wire and ribbon made of some high-

resistance alloy may be mounted in tubes similar to those of fire-tube boilers. The arrangement allows the use of alternating or direct current, as the heating elements do not come into direct contact with water; in all other cases in which the resistors are in contact with water and the current passes partly through metallic resistors and partly through water, only alternating current can be used because direct current would decompose the water.

Generators in class (b) are built on an entirely different principle. The electric current passes through steam-tight insulating bushings to a system of stationary electrodes partly submerged in water, the water to be evaporated serving as the electric resistance. The outstanding advantages of this type are its simplicity of construction, compactness, easy control, and very low cost per kilowatt capacity. Practically any water that is satisfactory for ordinary boilers is also suitable for the electric steam-generator. The resistance of water has a negative temperature co-efficient, *i.e.*, the resistance decreases as the temperature and pressure increase. The writer has made many tests to determine the relationship between resistance and temperature for various kinds of water, and has used apparatus specially constructed for currents up to 10 amperes and 6000 volts. at atmospheric pressure. Fig. 1 shows a set of curves giving the relation of temperature and resistance for raw water from

FIG. 1

the St. Maurice River and for condensate water mixed with about 25 per cent. of raw water from the same source

Using a logarithmic scale, the curves appear as straight lines, and in many other tests, of

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which the results are not shown in the diagram, it was found that these lines were all very nearly parallel. This would indicate that the same general law applies to all kinds of water. The curves have been verified above $100^{\circ}\text{C}.$ by tests on steam-generators under pressure.

Figure 2 shows a section of a 5000 kw. generator, consisting of a vertical cylindrical tank with an extension at the bottom. The

Electric Steam Generator
Three-phase single unit system

FIG. 2

upper part is flanged, and to it is bolted a dished cover which contains three openings for the porcelain bushings that insulate the three copper conductors leading to the electrodes.

The insulator bushing consists of three parts: two corrugated sleeves, one of which is outside and the other inside the tank, and a tube inside these sleeves, the whole being held together by the shoulder and nut of the conductor passing through. The arrangement shown in Fig. 2 is for 1300 amps., 2200 volts, 3-phase, 60 cycles, and for a working pressure of 165 lb. per sq. in.; the electric current passes through from both sides of the electrode to the inside and outside cylinders, and to a much smaller extent directly from electrode to electrode.

This type of generator requires but little floor space; the 5000 kw. generator with electric control apparatus can easily be placed in an area 10×12 ft., and the 18,000 kw. generator, equal to 1800 boiler horse-power, with all its

accessories, needs a floor space of about 15×22 ft., and a head-room of 25 ft. for ease in dismantling.

As the heat in the steam-generator is produced in the water, there are no parts subjected to a higher temperature than that of the steam; hence no dangerous stresses are produced by temperature differences. Another element of safety is that interruptions to feed-water supply can be easily met by shutting down the generator. The operation of the electric steam-generator is at least as safe as that of the coal-fired boiler.

PHOTOSYNTHESIS

The following is a short report of the discussion on Photosynthesis which took place at a joint meeting of Sections B (Chemistry) and K (Botany) at the recent meeting of the British Association in Hull. Prof. H. H. Dixon, President of Section K, presided over a large attendance.

In opening the discussion, Dr. F. F. Blackman said that he proposed to deal with the active system of photosynthesis and its organisation in the living cell, and bring together evidence which supported the thesis that here we had to do, not with a simple photochemical reaction, but with a complex system in which other components, that might be described provisionally as protoplasmic components, played an essential part.

The first point developed was that there were numerous lower plants which obtained all their carbon by the reduction of carbon dioxide in the dark without the intervention of radiation, and synthesised all their organic compounds from that source; instead of radiant energy, there was utilised the chemical energy of the oxidation of nitrogen, sulphur, and hydrogen, or their compounds. In those chemosynthetic organisms there was not a gain of energy, but only an exchange of oxidation potential: the gain to the organism was substance for growth. It might be asked whether this power was entirely absent in the higher plants, and what connexion the chemical machinery of it had with the chemistry of photo-reduction of carbon dioxide.

The second point was the fact, now thoroughly investigated, that the seedlings of many plants at a stage when they have developed chlorophyll to a full green colour might be quite incapable of reducing carbon dioxide in light, and gave out as much of that gas from respiration in light as in dark. Some other component or property lagged behind the chlorophyll in its development and the slow, steady rate of its development was the same in darkness or light.

A third point of interest was the efficiency of photosynthesis in the golden-leaved varieties of certain shrubs. Here the amount of chlorophyll might be as low as 4 per cent. of the normal green form, and yet under medium conditions the reduction of carbon dioxide might be as great as in green leaves. The fact had been established that the golden leaf needed more light than the green to carry out the same rate of reduction of carbon dioxide. It looked as if with these extreme variations of chlorophyll what counted was the cube root of the amount of chlorophyll present—a single dimension