INDUSTRIAL RECIPROCITY IN THE SUPPLY OF POWER AND HEAT.

By Roy J. Bennie.

During the Great War many countries, which were formerly dependent upon the belligerent nations for the supply of their manufactured products, were forced to establish industries of their own; and at the same time vast additions were made to the manufacturing plant of the nations at war in connection with the supply of munitions. Consequently, at the termination of hostilities, there was a plethora of industrial plant, which induced keen competition, stimulating invention, particularly in those branches of engineering that led to improvement in the economy of industries. The greatest advance in this direction followed the adoption of a policy to secure closer co-operation between separate undertakings, and many great combinations have arisen by the pooling of the brains and resources of units producing the same class of article, thus reducing the capital, administrative and selling charges.

But by far the greatest advance in efficiency has followed the merging of those industries which form steps in the building of the final product. For instance, a modern steel works generally includes all those processes necessary to convert the raw products of iron ore, coal, limestone, etc., to the finished rolled sections; that is, they include the by-product coke ovens, blast furnaces, open hearth furnaces or convertors, and rolling mills. Apart from the saving in transport costs, the economy of combinations of this type depends upon the ability of one department to utilise the by-products of another. In the above example the by-products are surplus power and heat, and the intrinsic heat of the products themselves. Prior to the war these plants were usually independent, and that involved great waste of capital, labour, and fuel.

In order to apply these economic principles in countries with established industries, many of their old installations had to be jettisoned, for they had to root up plant and buildings. This entailed heavy capital loss; for, although these assets may have been "written off," their replacement necessitated drawing on capital reserves which might otherwise have been devoted to other purposes. To a certain extent Australia has been preserved from this loss; for most of her larger factories are of recent date, and have been planned with a knowledge of modern economies. Our two great steel works are excellent examples of this.
But much improvement in the economy of industry can be secured without the necessity for either of the above classes of fusion. This is receiving particular study on the Continent, where great savings of fuel and power are being attained by separate industries pooling their heat and power resources, without any financial liaison at all.

Wherever two or more factories in the same neighbourhood find that the interconnection of their electric generators, or their steam mains, would improve the total load-factor, they proceed to make a careful estimate of the economies that would ensue. If these are sufficiently promising, simple contracts are drawn up between the parties, who agree to give and take power or steam as required. A more steady load is thus secured on the boilers and generators of the more efficient plants, and it is possible to cease running the least efficient for part or whole of the time. Sometimes it is producer gas, water gas, or coke oven gas that is so distributed; or it may be found that a factory with a large boiler equipment furnishing steam for its heating process can, by interposing a back pressure turbine, supply power to a neighbouring machine shop. For example, the power output of an American plant was increased in this manner from 5500 kilowatts to 25,500 kilowatts, the surplus being fed into the mains of a public electric supply authority. The extra amount of fuel consumed to supply this surplus power was only one-third of what it would have been if the power had been generated at a conventional electric power station. It is generally found that while one factory requires much steam, another requires much power; and the most economical way to satisfy both these wants is for one to take the steam exhausted from the back-pressure engines or turbines which supply power to the other. The economies of this procedure were fully demonstrated in a former address, where it was shown that the supply of heat to industry requires the consumption of many times the amount of fuel consumed purely for power generation.

It is often found that an industry—such as ceramics or cement manufacture—has an unavoidable surplus of waste heat from the kilns, which may be available for power generation or for transmission as steam. From the nature of the industry little of this power could be absorbed in the industry itself. Hence, heterogeneous co-operation may lead to large economies.

The financial adjustments between the parties require only the exercise of ordinary common sense and moderation. The participants may be manufacturing entirely different products.

*"The Higher Emerging Relations of Power, Heat, and Chemistry."
Proceedings, Victorian Institute of Engineers, 26th March, 1930.
This procedure may be considered as a temporary measure, ultimately to be followed by the erection of a central power- and-heat generating station, which would be designed to supply the needs of the participating industries of the neighbourhood. The cost of the power and heat would be reduced, because they are complementary, and because they would be produced by a large central station with improved load factor, lower fuel handling costs, lower rentals for railway sidings or wharfs, and reduced running charges. This course entails the establishment of either a joint owned station or else of one erected by entirely independent capital, and operating in either case under mutual guarantees.

A local example of joint ownership is the New South Wales Electric Power Pty. Ltd.—an undertaking owned by three mining companies at Broken Hill—which is erecting a 30,000 horse power diesel engine electric power plant, and will supply power, compressed air and possibly water gas primarily to the mines of the associated companies. Similar co-operative organisations are now to be found on most big mining fields.

One of the most interesting examples of the pooling of heat and power requirements of separate interests is that of the Deepwater Station on the Delaware River, which supplies power and steam to the chemical works of the E. I. Du Pont de Nemours Company, and also power to two large electric supply undertakings. The generating plant consists of three 12,500 kilowatt high pressure turbines consuming steam from six boilers working at 1350 lbs. gauge pressure and 725 degrees F. Two of these turbines exhaust to low pressure turbines, giving each with its high pressure stage a total of 58,000 kilowatts. One of the electric supply companies requires 400 million units and the other 600 millions annually, the total equaling twice the annual demand of this State of Victoria. The chemical factory requires 12,500 k.w. generated by the third high pressure turbine, and also its exhaust steam, which, through evaporators, generates upwards of 400,000 lbs. of steam per hour at 180 lbs. pressure. Chemical works usually have good load factors, and their co-operation with central supply stations reduces the running charges of the whole plant. This station was erected, and is being run according to a working agreement possessing several interesting features. Two boilers each are at the disposal of each undertaking, and the chemical factory is entitled to the full electric output of its back-pressure turbo-generator, and all of its exhaust steam for heating processes in the factory. The electric undertakings may purchase spare power from the above generator, and must supply any additional power required by the factory at an agreed price. They
agree also to take or to supply, if possible, each other’s surplus or deficit of power at a figure representing only the running cost. In short, the whole agreement is intended to encourage the maintenance of a high load factor. Two features of this compact merit special notice: the first is the prudent spirit of discerning co-operation between undertakings of an entirely different nature; and the second is the transmission of large quantities of secondhand steam from a central power station, thus lowering the unit costs of both power and heat.

The participants in the above examples are very large undertakings. But magnitude is not essential to the adoption of such measures. Even in the smaller towns there are central stations, particularly in Germany, which supply power and steam, also, in places, producer gas, to neighbouring factories. For instance, in Brandenburg, at the town of Forst, with a population roughly equal to that of Geelong, a central station, supplying electricity to the town, also transmits exhaust steam partly to warm city buildings, but mostly to textile and dyeing works distant roughly two miles from the power station. At the capital of Mecklenburg-Schwerin, with a population of 49,000, there is a diesel engine driven central power station from which the warm jacket water, further heated by the exhaust gases, is pumped throughout the city where it is used for warming the buildings. Innumerable examples of dual function central stations might be cited from the Continent, where it is now a policy that, whenever designing a power station, consideration should be given to the economic possibility of distributing exhaust steam from the back-pressure turbines. Germany alone uses annually 150 million tons of process steam, which is a by-product of prime movers generating 15,000 million electrical units, or over 36 times the annual production of energy publicly generated in the State of Victoria. If raw steam only had been used there would have been an additional annual consumption of black coal of no less than nine million tons. The extent to which these economies might be secured would be limited were there no co-operation between factory and factory; but the existence of such cordial relations among industries on the Continent is responsible for the very rapid opening of new avenues of economy.

In the past the chief difficulty in the extensive use of exhaust steam from power generators for heating purposes has been its relatively low pressure, and the lack of synchronism of the heat and power demands. The former difficulty has been overcome by the introduction of modern high pressure boilers, which enable sufficient power to be economically extracted prior to the steam being exhausted to the distributing mains. For instance, at the Billingham works of the Imperial
Chemical Industries Ltd., the boiler pressure is 800 lbs. gauge, and the steam, after passing through the turbines, is used for heating the vats, stills, and other vessels of the factory. Similarly, at the new extension of the Yallourn briquette factory, steam will be delivered at 550 lbs. pressure to the two 10,000 k.w. back-pressure turbo-generators, the exhaust steam from which is to be used for drying the coal.

The lack of synchronism of the demands for power and heat may be counteracted by the use of heat storage systems, and in places by pumped water power storage systems. Steam storages are also used for balancing the load on modern high pressure boilers, which, having no elasticity, cannot be regulated for rapidly fluctuating demands. The steam is passed from the boiler into water in large insulated pressure tanks where it is condensed; it is subsequently released when an increased demand for steam causes the pressure to drop. Special turbines have been designed to work with the steam from these accumulators; automatic governing mechanism regroups the nozzles and stages to compensate for the gradual fall in pressure. The efficiency of these turbines is not necessarily very inferior to that of turbines working on a constant initial pressure of saturated steam; for a small extension of the lower range of a heat cycle has far more influence on thermal efficiency than a very considerable rise in initial pressure. An interesting example of the use of a heat storage system is one where a super-power station outside Berlin transmits steam through an underground insulated steam main nearly 4½ miles long to a storage station in the city equipped with tanks capable of holding enough steam to generate 67,000 electrical units, or more than enough to run the metropolitan railways of Melbourne during one hour of peak period. In the best practice, storage systems of this type may have an efficiency as high as 80 per cent.

Another method of compensating for the lack of synchronism of the fluctuating demands for power and steam is to use a "bleeder" steam turbine, which in principle is a high pressure turbine of large capacity discharging steam, partly to process-steam mains and partly to a low pressure condensing turbine. The whole is equipped with special governing mechanism whereby the pressure on the process steam main is kept constant, no matter how the demand for steam or for power may vary. The fluctuating demand on the boilers may be compensated for by the use of the accumulators above described, or in more recent practice by so-called "feed-water storage" systems. Here the water is circulated by a centrifugal pump between the small water-capacity high pressure boiler and insulated
storage tanks kept at the same pressure as the boiler. As the steam demand increases, the feed-water is automatically cut off, and the water from the storage vessels, coursing through the boiler, gives up its stored steam while the pressure slowly drops. The efficacy of this system is evident in the experience from a mine in Germany which formerly required two Sterling type boilers, each of 3767 square feet, and ten or twelve Cornish boilers, each of 6504 square feet heating surface; the Cornish boilers were replaced by one additional Sterling type boiler of the same heating surface as one of the Cornish boilers, merely by the addition of storage vessels having aggregate capacity 5827 cubic feet with a centrifugal pump to circulate the water. The total heating surface of the plant was reduced to one-sixth of its previous value.

In cold climates it is becoming quite common for central power stations to transmit exhaust steam, or even raw steam, through street mains for heating buildings. In New York, the mains extend as far as three miles from the stations, some of which do not generate power at all. The cost even of raw steam is said to be less than it would be if generated in boilers placed in the basements of the buildings themselves. In Paris, which is not a city of high buildings, it is claimed that over four times as much steam is required for heating as for generating the power consumed in the same district. The transmission of steam in an Australian city probably would not be economical if confined to the heating of buildings, although it is possible that the conversion of an old power station to this use might be warranted as a temporary measure.

Regarding the general introduction of power-heat stations, there is no reason why the industrial demand for heat should be less regular than that for power, and in any case heat storage systems can compensate for such fluctuations, which over the whole system can never be as great in proportion as they are in an individual factory. The thermal efficiency is high, the losses being generally about 15 per cent. of the heat in transit. The economics of the question have been thoroughly investigated in Europe. One authority considers that in built-up industrial areas it would be most economical to locate these power and heat stations in zones of approximately three miles radius. This suggests the principle that the nearer together the associated factories are placed, the easier will be the formulation of a workable scheme; and foresight may be exercised in the selection of sites for factories with a view to the ultimate nucleation of their heat and power plants.

It is generally conceded that, except in very large factories, the private generation of electricity is not as economical as its
purchase from those public power stations whose costs are determined by competition among themselves; but that where heat as well as power is required, it is cheaper to generate them both in the factory than to purchase the power and locally produce the heat. The advent of the central station, however, supplying power, steam, and at times industrial gases, is inclining the economic balance in favour of the central station in all cases. Of course, every proposal must be subjected to the most careful and critical examinations; but there is no physical or economical impediment to the principle of the multiple-function central station. Indeed, this is borne out by its increasing adoption in older countries.

The conservation of the chemical resources of the coal has been already reviewed in the address previously referred to; and it is sufficient here to indicate that with the advent of the multiple-function central station the trend of modern development is towards the establishment of great gasworks at the pit head, or sea port, to recover the valued by-products of the coal, with the transmission of the gas therefrom to the cities where it will be used partly for direct industrial and domestic heating, and the rest for power generation in public supply stations located in the industrial areas, from which back-pressure steam will be drawn for use in surrounding factories. The balance of the fuel—coke, coal slack, and non-coking coals—will be consumed in central stations located alongside the works at the pit head or sea port, and linked by transmission lines with the central power and heat stations dispersed throughout the industrial zones.

The extent to which this policy will be followed depends in each case upon the circumstances of the locality concerned; and it is the purpose of the foregoing review merely to outline the conditions favourable to the establishment of these central stations having multiple functions. Many of them are now in operation elsewhere, and further and larger schemes are contemplated. Their successful accomplishment requires only the exercise of a discerning vision of the reciprocal relations between the requirements of the various industries and the creation of an atmosphere of friendly co-operation for a common benefit.

Mr. G. O. Simcock, in moving a vote of thanks, said the Address contained matter of special interest to many engineers.

Mr. W. R. Pollock, seconding the motion, said the paper was a complement of Mr. Bennie’s previous address, and was a distinct acquisition to the Proceedings.
Mr. A. E. Battle, Senior Vice-President, said that they were singularly fortunate in having heard a very interesting address. The subject was really self-contained, and admitted of no criticism.

The President briefly thanked members for their appreciation. The paper, he said, was a record of work and progress in older countries, and suggested lines of further advance. Referring to the coming year, he said that necessarily at the present time there were no opportunities for presenting papers on large works under construction, but still he hoped there would be ample material for an interesting year. Several papers had been promised, and he hoped to be able to arrange a few visits to works of general interest.