THE DEVELOPMENT OF PROCESS STEAM AND POWER

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The past 50 years has seen remarkable developments in the general application of steam for heating and power production, and with the modern application of atomic energy, it is possible that further rapid strides will be made in this direction. As no effective international control of the vital materials for the production of atomic energy is yet in sight, the entry of this new form of energy into industry will probably be delayed for some considerable time—a period of 25 years may easily elapse. Therefore the generation of steam for the conveyance of heat in process and power requirements will remain the most effective method for some considerable time.

In all factories which require the utilisation of steam in manufacturing processes combined with power for other purposes, the lowest production costs are dependent upon the degree of economy in their use. Except in isolated cases, a full appreciation of the necessity for the economical use of fuel and the efficient control of the subsequent heat evolved, is not evident to any great extent in this country and it is pleasing to note in this connection that the sugar industry of Natal is one of the exceptions where diligent and efficient control has been introduced.

Almost all overseas countries have active fuel research bodies, who are continually interesting themselves in the problems of fuel conservation and efficient heat control methods. In Britain during the last war, the British Government launched a vigorous campaign for improving the efficiency with which fuel was used in industry and as a result, virtually every factory of importance was visited by competent fuel technologists who gave advice to the management on fuel saving methods. These inspections revealed, that although substantial improvements could be made in boiler house practice, there was at least as great scope for economy in the application of heat for manufacturing processes. The activities of the fuel research bodies cover such points as the obtaining of a precise knowledge of the country's available fuel reserves, the physical and chemical properties of these reserves, the most efficient methods of mining and the correct utilisation of the fuel and the effective control of the heat evolved. It will be realised that all these activities are necessary if the future expenditure of a dwindling national asset is to be wisely planned.

The more common types of fuel such as coal and oil do not have much general application in the sugar industry except in certain cases such as that existing at Messrs. Hulett's S.A. Refineries and in other instances where irrigation load is required, owing to the considerable quantities of bagasse available as a source of fuel.

Nevertheless economic factors may be introduced in the future, when it is possible that the by-product value of bagasse for the manufacture of more valuable items of commercial interest will render the possibility of the use of coal or other heating agencies, such as atomic energy, an economic possibility. It is also possible that new cane varieties may produce a residue that is insufficient to meet the heating and power requirements.

Other factors involved in the paper illustrate simple circuits which show the use of back pressure and gas turbines, introducing interesting controversial points, which might make it possible to combine power production in the sugar industry with a general network taking surplus power for sugar and cane traffic on an electrified railway scheme. The control of these smaller types of power plants should not present insuperable difficulties, especially when it is realised that a joint scheme of this nature has been in operation at Messrs. Hulett's, S.A. Refineries at Rossburgh during the last 22 years.

This scheme has met with considerable success and has been of evident value to the parties concerned. The cost of electricity generated under this scheme is 0.1d. per unit, a very formidable figure.

Fundamental Conceptions of Heat Control and Theories of Energy and Thermo-Dynamics.

The utilisation of steam for process work necessitates very careful control and the engineer is looked upon to provide the necessary organisation to deal with the problems effectively. This control means that careful heat and material balances must be prepared and analysed regularly and naturally focusses attention on:—

(a) The quantity and quality of heat required for process requirements in the factory.

(b) The quantity and quality of heat rejected from the units in the circuit.

(c) Any corrosive, abrasive and fouling defects due to entrained solids in the steam, etc., resulting in heat loss and inefficient unit operations.

(d) The insulation of boilers, piping and process units.

(e) Leakages.

(f) Faulty operation by factory personnel.

(g) The best inter-relation of the constituent process units or heat exchangers in the circuit, the sections being matched so that where possible the reject heat from one unit is used to operate the next with the least possible loss of "Thermal Head."

Before proceeding with the applications of steam circuits, it would be interesting to discourse somewhat lightly on the laws of energy and thermodynamics which form the underlying theory of the subject we are discussing. In striking heat and energy balances, the work involves the application of fundamental laws of physical sciences that underlie practically all technology and one of the most important enunciations is that of J. Clerk Maxwell which states that "The total energy of any material system is a quantity which can neither be increased or decreased by any action between the parts of the system, though it may be transformed into any of the forms to which energy is susceptible," that is, energy may be transferred from one body to another or transmuted from one kind to another but the energy lost by one body is gained by the other and vice-versa.

This important law indicates that matter cannot be either created or destroyed and in this connection it means that the materials entering any process must either accumulate or leave the process. In effect, the simple application of input must equal output, which is identified as a material balance. In the same manner the Law of Conservation of Energy applies to heat balances and therefore must indicate the equality of heat input to heat output. In both cases of material and heat balances it is possible to strike a balance sheet over the complete process, any unit of the process, or any part of the system as desired.

Two other very important laws are the first and second laws of thermo-dynamics which are as follows;—

(a) *First Law of Thermo-dynamics*, which states that heat and mechanical energy are mutually convertible and "Joule's equivalent" is the rate of exchange, that is, $W=JH$.

(b) *Second Law of Thermo-dynamics*, which states that "There is no process by which heat may be conveyed from one body to another at a higher temperature without the expenditure of mechnical energy." This means in effect that the momenta of all molecules at the same temperatures are constant and that upon elastic impact the energy exchange is always from the body with the greater momentum (temperature) to the body with the lesser.

In addition to the laws mentioned previously it is necessary to consider one or two other important conceptions such as:—

(1) The relations between physical and chemical processes, which are the important aspect of equilibrium.

(2) The laws governing the rate of change in systems not in equilibrium, that is the rate of reaction.

When systems are undergoing a change they do so in a definite direction and if allowed to proceed of their own accord will reach a stationary point when no interchange of heat occurs. This static point is called a state of equilibrium and cannot be altered unless some agency is employed to alter the conditions governing the system.

In discussing the rate of reaction of systems the subject matter becomes more abstract, as many factors may be introduced which will materially affect the rate of reaction in a system, and the same results can be produced by different agencies. The simplest analogy would be in connection with a means of mechanical circulation of water in a boiler, instead of relying on the natural circulation currents. In this case it would be possible to increase the rate of reaction by introducing a force so that a difference of temperature occurs between the heat exchanging bodies; this force would, however, reach zero at the equilibrium state, that is when the bodies have reached the same temperature.

Another very important point involved in heat and energy investigations for a factory are the relationships between latent heat, sensible heat and total heat with increased pressure ranges and Figure 1 indicates the point showing the gradual increase of total heat up to 449 lbs. per square inch absolute and the gradual falling off after this pressure.

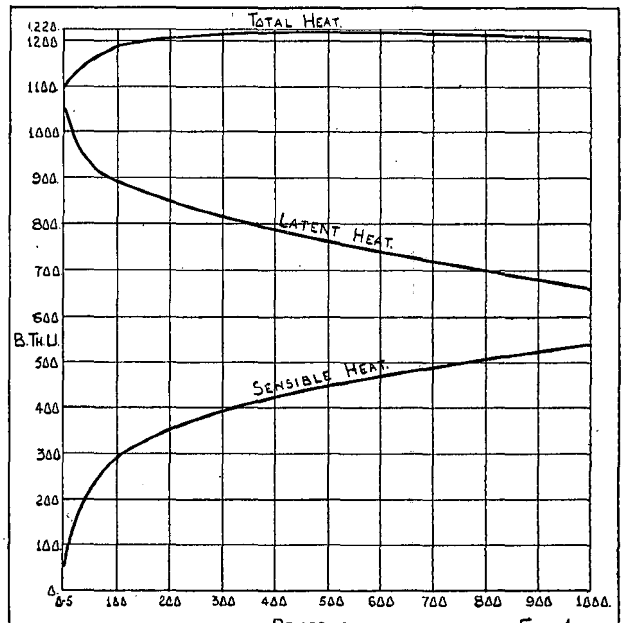


Fig. 1

The latent heat decreases throughout the range and finally reaches a zero point at 3,200 lbs. per square inch and a temperature of 706.4 degrees Fahrenheit when the total heat of saturated steam and water is at a value of 932 B.T.U.'s. The phenomenon is best illustrated in Figure 2 by means of the temperature-entropy diagram.

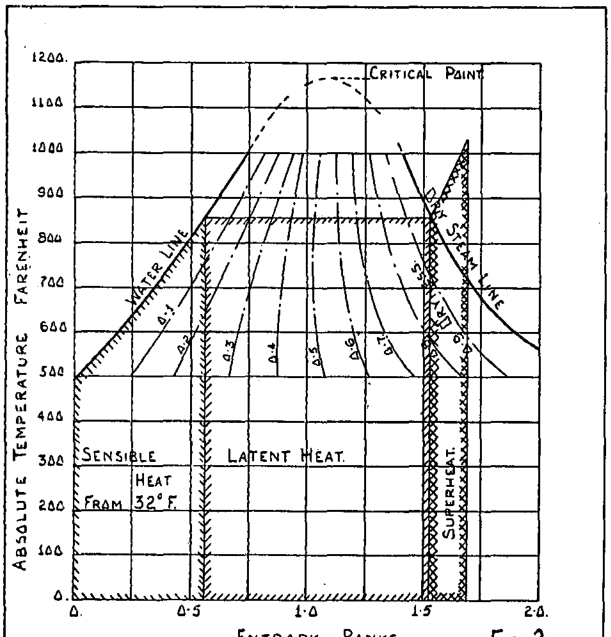


Fig 2.

The production of steam of high pressure requires the expenditure of very little more heat than is required for the production of low pressure steam, so that a boiler can generate high pressure steam with a coal or oil consumption very little in excess of the consumption required for the production of low pressure steam.

The ultimate aim is to attain pressures in the region of the critical pressure and temperature, as the latent heat diminishes the more it approaches this point, and ultimately becomes zero at the critical point. For instance, take some points for comparison: At 200 lbs. per square inch the latent heat is 843.2 B.Th.U., at 600 lbs. per square inch is 742 B.Th.U., and at 2,199 lbs. per square inch it becomes 63.0 B.Th.U., approaching zero in the vicinity of 3,200 lbs. per square inch.

This means that there is only one stage of applying heat, i.e., the heating of water, the process of converting the water at boiling point into steam at the same temperature being unnecessary, because as soon as the critical point is reached the water instantly flashes into steam.

The water and steam lines are shown converging at the critical point, the pressure being 3,200 lbs. per square inch, temperature 706.3 degrees Fahrenheit with a density of 20.1 lbs. per cubic foot.

Another advantage is that the higher the pressure the more heat per lb. there is available for use as the adiabatic drop in B.Th.U. per lb. increases with the increase in pressure.

The curves indicate the evident advantages of low pressure steam for process work owing to the high latent heat content at low pressures and also illustrates the clear advantages of high pressure steam generation for power production owing to the diminishing latent heat and consequent lesser total heat required to raise the steam with its consequent saving in heat units.

However it is realised that the foregoing points do not finally govern any proposed scheme as other important factors are involved in process and power work necessitating a close economic and technical study of many other factors including such conditions as:—

(a) The most suitable steam temperature for the process work.
(b) The availability of cheap fuel.
(c) Practical difficulties involved with high pressure steam generation and the possible contamination of the feed circuit.
(d) The cost of high pressure plant and equipment.
(e) The availability of skilled personnel.
(f) Maintenance difficulties.
(g) The balancing of steam load with power load.

Whilst discussing steam pressures it should be possible in the sugar industry to use pressures up to 400 lbs. per square inch without detracting from the safety of the plant or ease of operation and maintenance. The preceding factors have been briefly mentioned to illustrate the many factors involved in the consideration of steam and power circuits and now the paper will proceed to the development of these circuits.

The Utilisation of Heat.

There can be little doubt that the greatest opportunity for economy can be obtained by interlinking the various sections of a factory, and by combining the generation of electricity with the use of the heat in the exhaust steam for process requirements from an exhaust turbine. However, the question of whether it is more beneficial for a factory to generate electricty or purchase it from a public utility company needs careful consideration and is quite outside the scope of this paper. The problem requires planning of a high order especially when deciding on the balance between power and heat requirements in a factory and the operation and maintenance of the equipment.

It is not essential to maintain a heat and power balance within the factory, if the excess power which could be produced is available for use on an outside electrical network. Though the question of thermo-electric combinations has been given considerable attention in overseas countries, the matter lies more or less dormant in this country except in the well known pioneering cases. There is a strong trend overseas for the utilisation of thermo-electric combinations wherever possible and there is no reason why town planning should not be arranged so that industries using steam for process work be grouped around a central thermo-electric power plant with interconnected arrangements for heat and power requirements.

The abundance of cheap fuel and lack of serious competition points to the cause of the lack of interest in important matters of this nature, but there is every reason to believe that the old order will change rapidly with the industrialisation of this country, when it will be realised that more efficient use of heat will be necessary if our fuel resources are to be conserved and production costs lowered to meet competition. In the established manufacturing countries great importance is placed on utilising every thermal unit to the best advantage and is indicated in such usages as the installation of heat exchangers on vapors normally exhausted to atmosphere, the reclamation of heat from laundry wash waters, the recovery of heat from boiler blowdowns, the recovery of heat from bottle rinsing effluent for boiler feed water heating, and the recovery of heat from waste liquors from wood pulp mills. Only in industries handling corrosive materials, in which equipment deteriorates rapidly, is the reclamation of low grade heat difficult to justify.

There are many heat and energy circuits which may be evolved for a factory, the product of which is obtained by the use of steam for process work and power for the carrying out of other manufacturing requirements; the selection of the initial and process mains pressures are governed by many factors.

For instance if the factory is near an electrical network and the return feed conditions are capable of close control and the avoidance of pollution, it would be possible to select a high initial pressure so that the maximum power could be developed from the process steam requirements. Any surplus power generated over the factory usage could be exported to the city electrical network as is the case at the refinery at Rossburgh. In this instance 56 per cent. of the power produced by the back pressure turbo-alternators is exported to the Durban Corporation network and by the judicious use of steam accumulators in conjunction with the correct capacity of generating plant, load factors of 98 per cent. are obtained year in and year out.

However, in the selection of equipment the following factors must be considered:—

(a) Whether facilities are available for absorbing surplus power which could be obtained by taking full advantage of the steam available. If exporting of surplus power can be accomplished, factory costs will be reduced.

(b) The factory steam and power requirements.

(c) The possible variations in power output that may arise through an unstable steam demand. When generating plant is linked to a network, these variations are not serious.

(d) The process steam pressures and temperatures required. This is governed by the factory requirements for the process and the distance of the process steam units from the source of supply. It is usual to allow for the heat drop in process mains to prevent undue condensation and in the case of a back pressure turbine 30 to 50 degrees of superheat will be available at the turbine exhaust. The steam quality at the process unit should be such that ready availability of the latent heat is possible for process requirements.

(e) Any large variations in process steam demands which may be in excess of the boiler instantaneous capacity and results in low efficiency steam raising results. To offset this condition which can result in considerable dis-organisation of factory routine, the well known Ruth's accumulator system has met with considerable success in the sugar industry at Rossburgh and Mount Edgecombe.

To illustrate the gains to be obtained by using thermo-electric combinations in factories, a comparison will be drawn with a central power station using a condensing system.

With the condensing system 60 per cent. of the useful heat is thrown to waste in the circulating water, whereas in the back pressure power unit the exhaust steam is usefully applied in process work giving an overall thermal efficiency of 68 per cent. against the 25 per cent. which represents the best power station practice in this country using complicated heat recovery equipment. Another factor involved is the saving in distribution losses on the electrical network to which the factory is coupled.

In order to proceed with the development of process steam circuits, an illustration in Figure 3 indicates a simple circuit where a boiler supplies heating load through the medium of a reducing valve.

In this system steam is generated at a pressure, so selected that after passing the reducing valve, the steam is at a suitable elevated temperature to offset process main condensation. In this case power requirements are small and can be purchased from an outside source, or power requirements may be produced by diesel electric or hydro electric plants.

The scheme finds favour in small factories where steam is required at a large variety of pressures and where the skilled supervision of the heating circuits is not required.

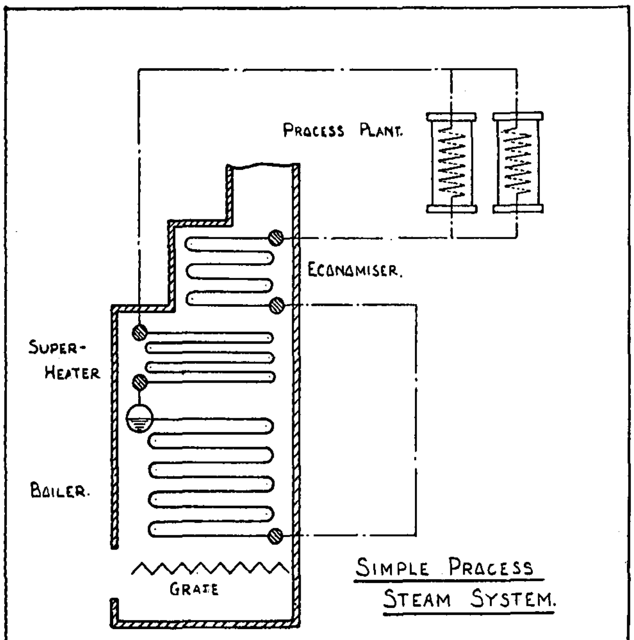


Fig. 3.

The Steam Turbine.

The steam turbine, whether as a condensing, back pressure or a combination pass-out set, has dominated the fields of power production in central electric schemes or in thermo-electric combinations where steam is used for heating purposes. In many industries and particularly the sugar industry, steam is used exclusively as a means of heat exchange. Back pressure and pass-out sets have the more general application and power is produced in the turbine at the expense of additional fuel consumed in the boiler over that required for normal process work. The increase is small and about 80 to 85 per cent. of this additional heat appears as additional power, whilst only 15 to 20 per cent. is necessitated by the additional losses resulting from the higher boiler pressure and from friction in the turbine bearings. The power produced in the back pressure turbine does not involve any additional losses in the steam circuit of the factory, since no alterations are made in the system to bring it into operation. Hence in all progressive manufacturing countries, the object is to produce as much power as possible by back-pressure plants. It is self evident that the maximum conservation of fuel supplies would be achieved if the total power requirements of a country could be produced in this manner and thus eliminate the use of condensing equipment as much as possible.

Figure 4 indicates the inclusion of the back pressure turbine in the simple circuit shown in the previous illustration. In this system, which incidentally gives the highest efficiency, the back pressure turbine is used as a pressure reducing vale between the high and low pressure systems. A further application of this system is the inclusion of pass-out connections, possibly one or two as necessity arises, when steam is required at different state conditions than that obtainable at the exhaust of the turbine. The provision of pass-out connections reduces the overall thermal efficiency of the circuit according to the amount of pass-out steam utilised. The different types of prime movers that can be considered for factory power requirements are as follows:—

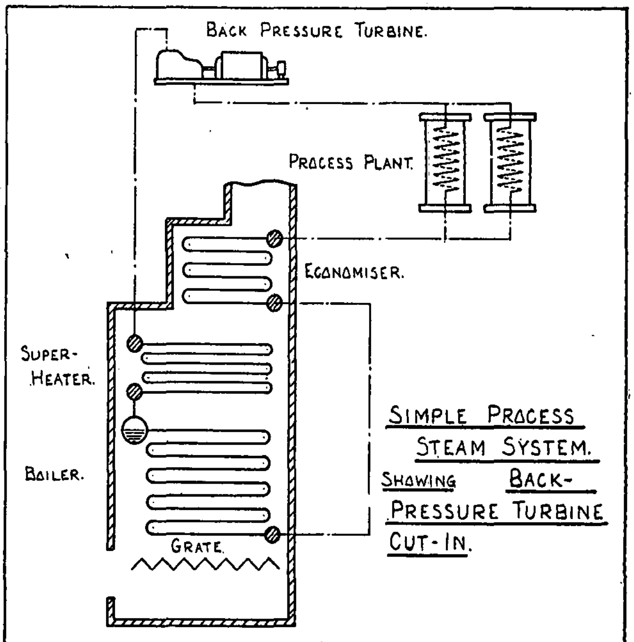


Fig. 4.

(a) Plain Back Pressure Unit consuming steam at a high pressure and high superheat, exhausting at a low pressure and superheat into process mains.

(b) A combination Back Pressure and Pass-out unit whereby the bulk of the steam for process work is supplied at the exhaust of the turbine, provision being made at one stage for supplying steam at a state condition other than that available at the exhaust of the turbine.

(c) Pass-out condensing sets where provision is made for bleeding at one or more stages for heating requirements, the remainder of the steam passing to a condenser. This system is resorted to when large power requirements are necessary owing to the non-availability of power from a central undertaking, or where a convenient power supply is required in off seasons quite independently of the factory activities. The irrigation requirements of the Natal Estates is an outstanding example of the application of this unit for the purpose stated previously.

The Gas Turbine.

For many years now the field of power production and combined thermo-electric combinations has been dominated almost exclusively by the steam turbine. This prime mover has been capable of universal application with a high degree of flexibility, efficiency and reliability combined with a wide choice of steam pressures and temperatures to suit the particular economic requirements of the various activities of industry. However, in recent years rapid strides have been made with a new type of prime mover identified as the gas turbine to distinguish it from the steam turbine, the name implying that the turbine utilises the expansion of products of combustion or other hot gases. The medium in the gas turbine is practically air, the weight of fuel burnt being less than 1 per cent. of the weight of air handled by the compressor. The products of combustion, therefore, represent about 10 per cent. of the total, that is, the medium in the turbine contains approximately 90 per cent. pure air.

The gas turbine has been proved to be a useful complement to the steam turbine, but for large power requirements, such as large central power stations, the steam turbine will remain the most economical prime mover. For smaller power applications such as power boosting on peak periods or load conditions as experienced in most industrial concerns, the gas turbine with its easy handling and rapidity of starting will have a wide field of application.

This modern prime mover is not a modern invention as John Barber, of Greasley in the county of Nottingham, toyed with the idea of discarding the steam engine and, using a turbine driven by the products of combustion, eventually patented his gas turbine invention in 1791.

Prior to the last war, great activity was taking place in the gas turbine field and this research has resulted in the practical use of the unit in a large variety of applications. In previous years when coal was used as a fuel, it was the general practice for economic, technical and practical reasons to use a steam plant as a means of converting the energy released by combustion, with the result that considerable development occurred both in the variety of the designs of boilers, and the subsequent inclusion of superheaters, economisers and pre-heaters. Parallel development was taking place in turbines with the use of high pressures and temperatures and low pressures on the exhaust of the turbine approaching perfect vacuum conditions. Attempts were also made in America to improve the conversion of heat energy by using mercury boilers; the scheme did not meet with much general support. The gas turbine was the next attempt at evolving more efficient types of prime movers and for many years it was not possible to obtain any excess power from the cycle for useful purposes. However, the modern development of the gas turbine has reached the stage where its general application to industry is assured and suggestions are being made for a combination of gas and steam turbines in central power plants. The success of the modern gas turbine unit has been due to the following factors:—

(a). The ability to design and construct axial compressors having adiabatic efficiencies of 85 per cent. and over, thus cutting down the compressor power required.

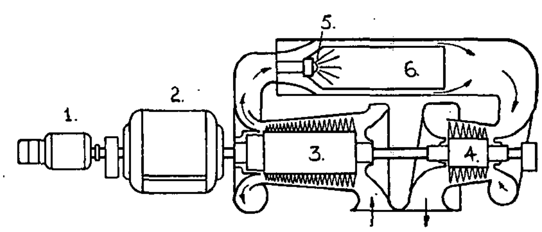
(b) The development of modern alloys to withstand high temperatures up to 650 degrees Centigrade having high strength creep resisting characteristics.

(c) The application of modern developments in aerodynamics for the design of heat exchangers giving low resistance paths in the circuit combined with high heat transfer rates.

(d) The attainment of high stage efficiencies in the turbine.

Though the general opinion is that gas turbines have not yet approached the thermal efficiencies of steam plants or internal combustion engines, some leading manufacturers claim to have reached the point of equal performance with the average modern steam practice.

GAS TURBINE DIAGRAM.



1. STARTER MOTOR.
2. ALTERNATOR.
3. COMPRESSOR
4. TURBINE.
5. BURNER
6. COMBUSTION CHAMBER.

FIG 5.

To illustrate the gas turbine cycle, Figure 5 shows the arrangement, and the various parts of the equipment are identified as follows:—(1) indicates the starting motor which is used to run the machine up, until sufficient speed is obtained for the axial compressor—(3); to deliver air to burner—(5); and the combustion chamber—(6). The products of combustion are then expanded through the reaction turbine indicated at (4); surplus power being developed in the alternator shown at (2). The air for combustion is compressed to a pressure ranging from 4 to 24 atmospheres depending on the design of the plant and the inlet temperature at the turbine is in the region of 1100 degrees Fahrenheit, the exhaust temperature being about 600 degrees Fahrenheit.

The chief advantages of the gas turbine can be summarised as follows:—

(1) Low capital cost.

(2) Rapid starting characteristics.

(3) Favourable weight power ratio.

(4) Great flexibility of operation.

(5) Independence of water supply consideration.

(6) Low maintenance cost.

(7) High thermal efficiency, and some manufacturers confidently expect the gas units to approach and exceed the efficiencies of the steam turbine.

(8) The economic prospects of the gas turbine increase with shorter running hours, cheap oil fuel, restricted space considerations and low atmospheric conditions.

The gas turbine has found practical application in the following industries and for the following uses, namely:—

(a) Gas-driven compressors.

(b) Electric power generation.

(c) Locomotives.

(d) Peak load conditions on electrical networks.

(e) Blast furnace plants.

(f) Ship propulsion.

(g) Power production using hot gases from chemical and other processes.

(h) Power production on a closed cycle using hot air.

The units have been made in fairly large capacities and the well known firm of Brown Boveri are installing a 27,000 k.w. unit at Beznau in Switzerland, as part of a 40,000 k.w. station for the generation of electric power. The set is expected to be in operation during the winter of 1948 and will use fuel oil as the heating medium. The foregoing information is stated to show that the gas turbine has entered the competitive field as a prime mover, the development being of such proportions that its appearance in this country can be confidently expected in the near future.

One very important development has been the introduction of the closed cycle evolved by Escher Wyss, which consists of a closed cycle in which air is circulated under pressure. The supply of heat for the medium in the cycle is obtained from an external source by placing a pressure heater of the tubular type in the pass of a boiler, heat being extracted from the flue gases. Heat recuperation, compressor cooling and reheating are important features of the system.

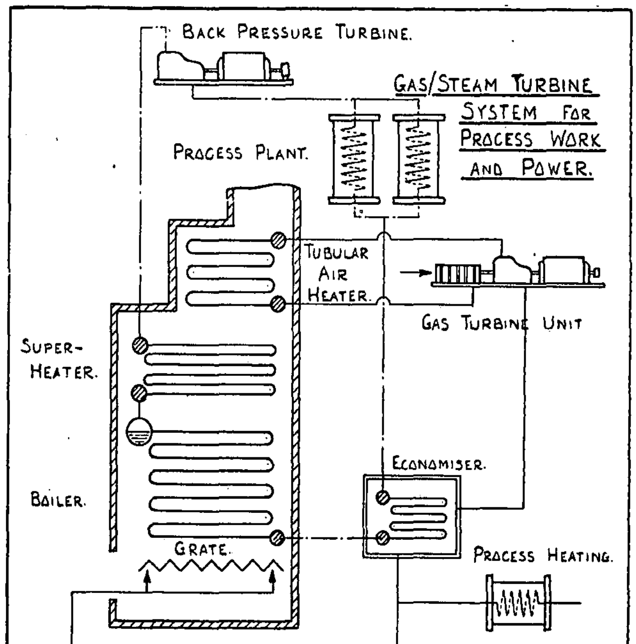


Fig. 6.

Figure 6 indicates a typical closed cycle application of the gas turbine as a complement in a system using a back pressure steam turbine. This interesting application in a steam plant should be of interest to engineers handling factories using process steam for heating purposes. It has been confidently stated by experts that, by the incorporation of a gas turbine, the power output of a back pressure steam plant can be practically doubled and the additional power is secured with efficiencies of the order of 50 per cent. when the exhaust air from the turbine is not used for useful purposes and above 60 per cent. when this heat is used. When consideration is given to the rational use of fuel as mentioned in the forepart of the paper, it is evident that the incorporation of a gas turbine unit in combination with a back pressure steam plant becomes an attractive proposition. To produce the power stated it is necessary to burn 16 per cent. more fuel in the boiler to provide the requisite heat units. The gas turbine extension can, of course, be included when there is no back pressure unit and can be installed in new and existing installations.

The function of the installation shown in Figure 6 would be as follows:—

The steam circuit is much the same as in Figure 4 with the exception that the exchange of heat in the economiser is derived from the exhaust from the gas turbine. The gas turbine cycle starts with the compression of atmospheric air in the axial compressor which discharges the air to a heater in the pass of the boiler for heat exchange. The air is then discharged from the air heater and passes to the turbine where expansion takes place thus producing energy to drive the compressor and the alternator. After expansion in the turbine the exhaust air is discharged through an economiser where the feed water for the boiler is raised in temperature. As the amount of heat which may be rejected from this unit may be of large proportions, heat may be diverted to the process system and the balance of the air with its residual heat content will then be passed on to the combustion circuit as pre-heated air for combustion purposes.

It will be seen that the system is an ingenious one and owing to the high thermal efficiency obtained and the simplicity of the plant, the gas turbine extension represents a profitable addition.

The gas turbine in the form of an air turbine can be embodied very easily in steam plant circuits and can be used to obtain additional power with a low fuel consumption. It has been established that increased power output equal to that obtained from a back pressure unit can be confidently expected and the efficiency at which the power is obtained is considerably in excess of that which can be expected from large central condensing stations.

Conclusion.

The author has endeavoured to show the development of the process steam system, indicating the salient features of the various types of prime movers and culminating with the modern phase of the gas turbine.

There can be little doubt in our minds that the gas turbine, which is an innovation in the power generation field, has come to stay as an efficient and reliable prime mover, and is well past the experimental stage.

It is not suggested that the gas turbine is the answer to all power problems, but rather is it intimated that in combination with steam driven power units it will be possible to make more effective use of the heat resources available, and thus tend to reduce the capital outlay involved in plant requirements combined with reduced running costs. At the end of 1945, one well known firm had ten gas turbine sets under the course of construction, the capacities ranging from 1,200 k.w.'s to 10,000 k.w.'s. The efficiencies at the terminals of the machines ranging from 23 per cent. in the case of a single stage machine and 29 per cent. with a two-stage turbine installation equipped with double stage cooling and recuperators.

In the case of the application of the gas turbine unit for traction purposes, A. E. Muller in *The Brown Boveri Review* of October-November 1945, stated that "From experience obtained to date, the gas turbine locomotive is particularly suitable for long distance service in countries and regions with a cold or moderate climate and where cheap oil is available. The gas turbine locomotive has proved that it is simple to operate and requires little maintenance so that drivers quickly become familiar with this unconventional traction unit."

A further development in this direction is the pulverised-coal gas turbine on which experiments are being carried out in connection with a 2,000 h.p. plant. It is evident that a unit of this type would be of incalculable value, and the further progress of this unit will be watched with interest.

Before concluding, I would like to thank the members of the Council of the South African Sugar Technologists for the privilege of reading this paper and at the same time to give due recognition to the authors of the many works and papers that I have consulted.

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The PRESIDENT stated that, as a chemist, he did not agree with the tendency in the South African sugar industry of separating chemists from engineers. He could see no clear dividing line between chemistry in industry and engineering in industry applied to chemical processes. The paper looked forward into the future and he felt that there must come a closer relationship between chemist and engineer in the sugar industry for both were interested in similar subjects.

Mr. WILSON thought the paper to be a valuable contribution and was very interested in the figures showing that power output could be increased by over 50 per cent. by the gas turbine in conjunction with the back-pressure steam turbine.

The Refinery had a working arrangement with the Durban Corporation since 1925 which had been beneficial to both parties. This arrangement consisted of the supply of excess current, which was generated at normal working, from the Refinery to the Corporation, and taking power from the Corporation during the shut-down periods. This system had resulted in a large financial saving to the Refinery, and to quote figures he said that in 1944-45 the Refinery generated 16,734,200 units. Of that quantity, the Refinery used 7,923,746 units. The cost per unit to the Refinery was .104d. In 1945-46 the total generated was 15,762,500 units; 1946-47, 15,987,000 units and the cost in 1945-46 was .101d. in 1946-47, .12d. Now previous to the Refinery entering into the agreement in 1925, it purchased a considerable amount of power from the Durban Corporation. The cost then was .56d per unit, and the total cost in 1944-45 was £3,434. Had it been on the old system of .56d., the total cost then would have been £18,488, a very considerable difference. The system had been very beneficial to both parties, and if factories, which would also have an exportable surplus of current if completely electrified, linked up with the public electrical supply when the North and South Coast railways were electrified, there would be similar benefit to both parties concerned.

Mr. WYATT said that in the days when sugar was made by cheap labour, and fuel was cheap, steam plant was installed without much thought being given to the use of exhaust steam, although large quantities of heat were required for process work. The advantages of combined power and heating were still not always appreciated. A broad outlook should be taken on the subject of capital expenditure to see that the plant purchased was designed for most economical results.

Combined power and heating schemes might be divided into three classes:—

1. Where the demand for steam for power generation is often in excess of that required for heating.
2. Where these demands are about equal.
3. Where more steam is required for process work than is necessary for power generation. Sugar factories and refineries fall in the third class.

Serious consideration has been given to the question of linking up the sugar factories of Natal and supplying cheap power into a larger network. This proposition still found a considerable number of supporters but there were others who were of the opinion that the supply of power by the larger electricity supply stations represented best economy. Under their system of condensing it must be agreed that results in this country were good and compared favourably with overseas figures.

In the case of private generating plant installed where the current is required, in addition to the saving of heat, heavy losses associated with long distance transmission, transformation, and possibly conversion of current are avoided. In the case of a plant in which the whole of the exhaust steam could be used for process work, the waste heat condensing plant is dispensed with, together with the cost of operating it, and the heating equipment acted as a high temperature useful heat condensing plant.

The subject of initial boiler pressure was debatable. A pressure of 400 lbs. per sq. inch had been mentioned as a possibility for the sugar industry. Theoretically, the initial pressure should be as high as possible and the process pressure as low as possible. As the author had mentioned, however, there were maintenance difficulties and troubles, such as those resulting from contaminated feed water, which were magnified as boiler pressure increased.

As far as power plant was concerned, no serious difficulty was presented by a high exhaust pressure, and where high and low pressure steam systems existed in the same premises consideration should be given to the installation of prime movers designed to operate between the two pressures. Engines and turbines taking steam at 350 lbs. and exhausting at pressures as high as 190 lbs. per square inch were not unknown.

Mr. DUNN said the paper was more or less an engineering ideal. He referred to figure 6 in which the gas turbine utilised heat from the boiler. It therefore could not be used without putting the boiler on, and it was a question as to whether the gas turbine could use the heat more efficiently than the steam turbine, and thus if anything would be saved. The gas turbiue was an engineer's dream but he thought it might be some time before it came into general commercial use. In America the steam locomotive was being replaced by the diesel-electric unit, although this would seem to be a good field for the gas turbine.

Mr. MACBETH said he would like to add his thanks and congratulations to Mr. Lownie for his paper. He thought the paper submitted by Mr. Lownie was undoubtedly the most instructive and outstanding one on the development of process steam and power ever read before the Association.

The fundamental conceptions of heat control, as set out in the paper, were not altogether unknown to most of us, but the author had introduced the subject from another angle in some respects and this would provide further food for thought.

It was a distinct compliment to the sugar industry that the author considered that diligent and efficient control was exercised in power and heat distribution. However, a great deal was still to be accomplished.

During the past few years approaches had been made to various sugar companies for the release of bagasse for production of by-products, and ths industry in his opinion would one day lose bagasse as a fuel. There were difficulties to overcome such as the conversion of boiler furnaces so that they could burn either bagasse or coal with equivalent efficiency.

Under the heading of the utilization of heat, the question of whether it was more beneficial for a factory to generate electricity or to purchase it from a public utility company, needed careful consideration. There would be no benefit to a sugar factory as large quantities of steam were required for process work and what more economical arrangement could there be than the present double use of steam?

One of the essential factors in sugar manufacture was an ample supply of process steam, and without this uneconomical conditions prevail to the detriment of the product, overall efficiency and continuity of operations.

The most suitable steam temperature for process work needed closer study. Some authorities believed that a little super-heat was an advantage but it was not known to what limit superheating could be applied. Too much would cause caramelisation, with undesirable specks in the sugar.

Cheap fuel was very important and the sugar industry was fortunate in having bagasse for this purpose. In the early years efficient burning of bagasse was a problem, but today very creditable performances have been achieved, especially in view of the fact that the fuel had only about one third the calorific value of coal. In some instances the figures obtained from bagasse-fired boilers even beat those from coal-fired boilers. Of course, this had not come about without extensive investigation and large capital expenditure.

It might be an advantage to centralise industry using process steam around thermo-electric power plants, but he did not think sugar factories could be so arranged. It was most economical for factories to be sited centrally in the fields which supplied the raw material, and a factory must be self-contained and independent of outside connections unless the utilization of a by-product such as bagasse for other purposes prevented this.

Whilst the progressive tendency today is to increase boiler pressures, especially in power plant installations, and to a lesser degree in industry, he was not, at that stage, so enthusiastic as the author about increasing boiler pressures to 400 lbs. per square inch in a sugar factory, for one reason alone, i.e. contamination of the feed circuit. He would prefer to be conservative on this score until some secure safeguards were devised to prevent the present irregularities and unavoidable contamination by cane juice and massecuite. Pressures up to 200 lbs. per square inch in his opinion should not be exceeded in the meantime, otherwise excessive maintenance costs might be incurred.

The information detailed in regard to the gas turbine was very interesting, and it would appear that this unit would prove to be very economical. From diagrams it was noticed that a starting motor was required. It would be interesting to know the approximate cost of fuel, based on kilowatt demand. He wondered if the author could supply this information?

Mr. Kinsman said that in connection with the operation of the arrangement between the Durban Corporation and the Refinery, the scheme was an example of close co-operation and amicable relationship between the two parties.

The author had rightly stressed that the success of a back-pressure turbine set exporting its surplus electric energy into transmission mains, depended upon the proximity of the plant to a suitable demand. The Refinery was fortunately placed, because the surplus power it exported was consumed within a mile and a half.

Mr. Lindeman referred to the statement that control of subsequent heat was not evident to a great extent in this country, but it was pleasant to know that the sugar industry of Natal was an exception where diligent and efficient control had been introduced. He had travelled all over the Free State and the Cape and had experience of various industries as well as gold and coal mining. He was of the opinion that the Natal sugar industry was one of, if not the most efficient, in South Africa. Natal was very fortunate in having a very efficient industry and very efficient engineers.

There was one flaw and that was, as mentioned by the President, the weak link between the chemist and engineer. It was strange also that the chemists had failed to approach the Government to have their status put on a legal basis and he suggested that the incoming Council give this matter attention.

With regard to boilers, it seemed that pressures of 600 lbs. per square inch were more or less standard practice. After listening to Mr. Wyatt and Mr. Macbeth, he felt that high pressures might not suit a particular industry but more research should be done.

Mr. P. Murray pointed out that the Association had done much valuable research work on the subject of steam in the sugar industry. He thought the boiler work was perhaps the most valuable done for the industry, and it had been responsible for increase in recovery. Twenty years ago some figures obtained from boilers showed a gross thermal efficiency of 20 per cent. Today thermal efficiency was in the neighbourhood of 65 per cent., due largely to the efforts of this Association.

He considered that bagasse furnaces, although very efficient, should be improved by the installation of chain gates to avoid the present opening up and cleaning with attendant loss of steam.

As far as process steam was concerned, its use twice or three times had not yet been developed.

That development was coming and would meaa more available heat which would in turn lead to still higher recoveries.

Mr. Dawson thought the author should be thanked for indicating how the cost of power could be reduced.

A note of warning should be sounded in case millers had the idea that they were in the same favourable position for generating export current as was the Refinery. There was no boiler difficulty at the Refinery where a moderate steam pressure was sufficient to give quite a large export, but the bulk of the amount available for export from the Refinery would be consumed in a cane sugar factory however, for the power required for crushing and so on. If export from a factory were considered, steam pressure would have to be increased. At high pressures of 400 or 600 lbs. per square inch contamination of boiler feed was a very important aspect and strict control was essential.

In addition, if factories produced export power in comparatively large quantities, any interruption of the supply on the general network would be serious. Sugar factories did not, for economic reasons supply stand-by plant. No miller would put in an extra train of mills for example, and run it at half capacity so that in the event of a breakdown full throughput could be maintained. From an engineering point of view the problem was not insoluble, but from the economic side very careful investigation was required.

With regard to the gas turbine scheme, he recalled that sugar factories were usually short of steam. If an additional 16 per cent. of heat were required for the gas turbine from the furnaces, this would mean about 16 per cent. less steam and may not be welcomed by millers who generally wanted more steam.

Mr. Lownie said that on the question of thermal efficiency and the power plant, it was true that the modern super power station was reaching the economic limit, but they have gained a higher thermal efficiency. One station in America had a thermal efficiency of 34 per cent.

Doubts had been expressed on the use of boilers at 400 lbs. to the square inch. He had had a few years experience with such boilers and found that from a maintenance point of view they were better than lower pressure boilers. In his opinion the introduction into power plants in this country of 625 and 650 lbs. per square inch boilers was too early. Superintendents of power stations using these boilers say they have lots of defects and are not really reliable. For reliability for power plants in this country today, 400 lbs. pressure should be used.

With regard to the elevation of temperature in process work, if the degree of superheat is too high, it is known that the rate of reaction is slow and it is difficult to get the heat out of the steam.

The thought had been expressed that there was not a large general application for the gas turbine. From what he had read it seemed there was a world-wide race to make use of them. South American countries, Egypt, Switzerland, the United States and Britain were all concerned. Evidently more benefit was derived in countries with a low initial temperature. While the efficiency of the individual parts of the gas turbine was slightly lower than the steam turbine it used a slightly more advantageous thermal cycle. The calculations and theory of gas turbines and axial compressors were very involved and he referred those interested to papers which dealt with the whole equipment of a gas turbine cycle.