A DESCRIPTION OF A TRIPLE-EFFET APPARATUS,

Containing 14,000 square feet of heating-surface with surface condenser, main air-pumps, auxilliary air-pumps, and voiding-pumps, designed for a Sugar-factory on the Clarence River, N.S.W.

BY HECTOR KIDD, ESQ., M.I. MECH. E.

IN offering this short Paper to the members of the Association I would point out, that the use of the Triple-effet Apparatus for concentrating sugar-solutions dates back many years, and that nothing new in principle has been added to it since it was introduced into America by Rillieux; but in the apparatus about to be described, the design has been simplified, its cost cheapened, and its evaporative efficiency increased. I would further remark that the principle on which the apparatus works will have much interest for Marine Engineers, who are making every effort to obtain the highest duty possible from a pound of coal by means of higher boiler-pressures and triple-expansion, as the apparatus having a somewhat similar name and requiring three vessels to complete the operations, can claim a practical co-efficient of 2·6, that is to say, for every pound weight of steam used in the first vessel of the apparatus 2·6 pounds weight of water is evaporated; or assuming that eight pounds of water can be evaporated per one lb. of coal by the ordinary method, 20·8lb. of water per lb. of coal can be evaporated by means of the Triple-effet Apparatus. As it is not the intention of this paper to make comparisons between the designs of the various makers, I will proceed to describe the latest design for a Triple-effet Apparatus for the Colonial Sugar Refining Co., Ltd., Sydney. But before commencing the detailed description, I may state that it is the practice, in modern sugar factories, to work all the steam engines under a back-pressure on the exhausting side of the pistons, or from 10lb. to 15lb. per square inch, and all the back pressure steam (which is the total steam supplied from 14 steam-boilers having an aggregate heating surface of 13,000 square feet, minus liquefaction or condensation due to the mechanical or dynamic work performed by the engines in driving the machinery and the losses caused by friction and radiation) is used up in the triple-effet and vacuum-pans for evaporating and concentrating the sugar-solutions obtained from the crushed sugar-cane.

The Triple-effet Apparatus now under description is designed for a back-pressure of 6lb. per square inch, when the apparatus is clean; but, as the tubes become coated towards the end of the week, this back-pressure will rise to 10lb. or 12lb. per square inch, and this pressure becomes necessary for increasing the temperature-difference between the steam outside and the juice inside the tubes, so that the same rate of evaporation may be maintained when the insides of the heating tubes are coated with a slight lime-scale, which is removed once every week.

The apparatus (Plate V) consists of three vessels which may, for the purpose of this description, be named 1st, 2nd, and 3rd vessels, and as they differ only in their dimensions, a detailed description of one of them will serve to explain the general arrangement of the various parts.

The first vessel is 10ft. 1in. internal diameter, and consists of the following parts, namely:—calandria A, body B, bottom C, and top D. The calandria is that part containing the small tubes forming the heating surface, which in the first vessel, number 1,792, and are 2in. (external diameter) by 4ft. 6in. long, No. 15, B.W.G. thick, and have a total heating-surface, measured on the inside of the tubes, of 3,942 square feet. The tubes are fitted into two tube-plates by an ordinary expander; a small recess is cut in the tube-holes of the top tube-plate, into which the metal of the tubes is pressed in the operation of expanding them. The object of these small shoulders formed on the tubes is to prevent them from being displaced during the operation of cleaning them by scrapers. The tube-plates are shown made in two pieces, for the convenience of the maker, and are supported by 30 solid stays. In the centre of the tube-plate there is a copper circulating-pipe, 24in. (internal diameter) for the purpose of returning to the bottom space the juice which has passed up the small tubes in the operation of boiling, so that an active circulation of the juice is promoted. On the casting which forms the body of the calandria there is an annular space 26in. by 5in., having 10 openings 26in. by 1½in. leading into the steam-space. These openings are spaced at equal intervals round the circumference, so as to distribute equally amongst the small tubes, the steam entering at the 16in. diameter inlet. The body of the vessel is built of cast-iron plates, eight in number, and 5ft. in height, and has the following fittings for regulating the working of the apparatus:—Three sight-glasses in the front part and one at the back, near the top. The light enters at the top sight-glass, and the attendant observes the level of the juice through the front glasses and regulates, by means of the feed-cock E, the working-level of the juice. One thermometer, one vacuum-guage and vacuum break-valve are fitted to each vessel, for the purpose of controlling the working of the apparatus. The bottom of the vessel is cast in one piece, and contains openings for the manway, the inlet and the outlet pipes. The top is also cast in one piece, and contains an opening to which is fitted the head box, which also acts as a save-all, for catching any juice that may prime over, should the attendant, by accident, allow the juice to rise to too high a level. The guage-glass, fitted on the head-box, will show when the apparatus is priming over, and when this happens the attendant opens the steam-cock E, and the jet of steam blowing on top of the juice stops the priming. In the head-box there are holes arranged, so that any liquor that may prime over may fall back into the vessel.

The second vessel of the apparatus is similar to the first, but 10ft 10in. diameter, and contains 2,082 tubes, having a total heating-surface of 4,580 square feet. The third vessel of the apparatus is similar, in the general arrangement of its parts, to No. 1 and 2, with the exception of the "Hodett" save-all, which, in this vessel, is of special design, and is made very large, so that the vapour-speed passing through it may be very slow, as the juice is more liable to prime over (on account of its increased density), at this stage of the operation, and also by the greater vacuum carried.

The third vessel is 11ft. 9in. diameter, and contains 2,498 tubes, having a total heating-surface of 5,490 square feet. By comparing the areas of the heating-surfaces in the three vessels, it will be seen that the second contains 16 per cent. more heating-surface than the first, and that the third contains 20 per cent more heating-surface than the second. These ratios between the vessels have been determined so that the apparatus will carry the following sequence of vacuum; from 3 to 4 inches in the first, from 14 to 15 inches in the second, and about 26½ inches in the third. With this sequence of vacuum, and 6lb. of steam in the calandria of the first vessel, the areas of the heating-surface in each (multiplied by the temperature-difference between the steam or vapour outside of the tubes and the juice inside of the tubes) are found to give an equal evaporative duty for each vessel.

When the doors, cocks, and valves of the apparatus have been properly set, the air pumps are started and a vacuum formed (this vacuum when starting will be exactly the same in the three vessels; but it will fall to the proper sequence as the apparatus becomes fully charged). Cane-juice at a density of 5 degrees Beaumé (containing 9 per cent. of solid matter) is drawn into the first vessel through the inlet-regulating-cock E, and when the juice shows level with the top tube-plate, the low-pressure steam is turned on at the 16in. diameter valve H. As soon as the steam is turned on to the first vessel, the inlet-regulating-cock J, of the second vessel, is opened, and the second vessel slowly filled. When the juice shows level with the top tube-plate of the second vessel, the regulating-cock K, of the third vessel, is opened, and slowly filled. The rate of filling is so regulated that by the time the third vessel is filled the apparatus is fairly started, and the vacuum in the three vessels will stand, approximately in the following sequence:—First vessel, 3½in; 2nd, 14½in.; 3rd, 26½in.; and the temperature corresponding with the vacuum in the three vessels will be, for the 1st vessel, 205° Fahr.; for the 2nd, 180° Fahr.; and for the 3rd, 140° Fahr. Now, as the steam entering the calandria of the 1st vessel has a temperature of 230° Fahr. which corresponds with the back-pressure of 6lb. per square inch, there is therefore a temperature difference between the steam on the outside of the tubes and the juice on the inside of the tubes of 230°—205°=25° Fahr.; and this is sufficient to cause the rapid evaporation which takes place in the body of the 1st vessel (namely) 2,800 gallons of water per hour. If this is figured out, it gives the rate of transmission as

$$\frac{28,000 \times 1,000}{3,942^{\circ} \times 25^{\circ}} = 284 \text{ units of heat per square foot per hour per}$$

1° of temperature. These figures do not take into account the duty of raising 10,000 gallons of juice from a temperature of 175° to 205°, which is equal to a rise of temperature of 30° Fahr. Adding this duty, which is equal to a heat-transmission of

$$\frac{100,000\text{lb.} \times 30^{\circ}}{3,942^{\circ} \times 40^{\circ}} = 19 \text{ units per square foot per hour per degree}$$

of temperature, and 284 × 19 = 303 units as the total heat transmitted per square foot per hour per degree of temperature. Now, there is condensed, in the steam-space of the first calandria, 2,800 gallons of water, or 28,000lb. of steam; and this has been done by the evaporation of an equal weight of water into vapour (less a slight loss by radiation). In the body, etc., of the vessel the 2,800 gallons of condensed water are let off from the calandria by an ordinary steam-tap through pipe G. The vapour from the juice in the first vessel passes up through the head-box L (where any juice that may prime over is caught and returned) down the 20-inch vapour-pipe through the belt-space and into the vapour-space of the 2nd vessel. As the vacuum in the body of the second vessel is 14½ inches, and the temperature corresponding to this vacuum is 180° Fahr., there is therefore a temperature-difference between the vapour at 205° Fahr. on the outside of the tubes of the second vessel and the juice on the inside of the tubes of 205°—180°= 25° Fahr.; and this difference causes a brisk evaporation in the body vessel. Figuring this out, it is equal to a rate of transmission of $\frac{28{,}000 \times 1{,}000}{4{,}580^{\circ} \times 25^{\circ}} = 244$ units of heat per square foot per degree of temperature per hour. As there have passed over from the body of the 1st vessel 28,000lb. of vapour, it has been condensed in the vapour-space of the 2nd vessel by the evaporation of an equal weight of vapour in the body of the 2nd vessel; and as there is a vacuum of $3\frac{1}{2}$ inches in the vapour-space of the 2nd vessel (it being in direct communication with the body of the 1st vessel) the 28,000lb. of condensed water have to be drawn off by an auxiliary air-pump, provided for that purpose. Again, the 28,000lb. of vapour formed in the body of the 2nd vessel pass through the head-box down through the 26in. diameter vapour-pipe through the belt-space and into the tube-space of the 3rd vessel. As the temperature of this vapour is 180° and the temperature of the juice is 140°, 180—140=40 degrees is the temperature-difference and this is found ample to produce a rapid evaporation. The rate of heat-transmission through the tubes of the 3rd vessel is $\frac{28{,}000 \times 1{,}000}{5{,}490 \text{ sq. ft.} \times 40} = 127$ units per square foot per hour per degree temperature.

You will observe that the rate of heat-transmission is for the 1st vessel 303, for the 2nd 244, and for the 3rd 127 units of heat per square foot per hour per degree of temperature. This falling off in the rate of heat-transmission is caused by the lower temperature of the vapour in the 2nd and 3rd vessels, and also by the increased density of the juice. When the juice entered the 1st vessel it contained 9 per cent. of solid matter, and as it is drawn off from the third vessel it contains 53 per cent. In the tube-space of the third vessel there is condensed 28,000lb. of vapour at a temperature of 180°, by the evaporation of an equal weight of vapour in the body of the third vessel. The 28,000lb. of water condensed in this vessel is drawn off by an auxiliary air-pump provided for that purpose, and the vapour formed in the body of the third vessel passes over through the 48-inch diameter vapour-pipe to the surface-condenser, where it is condensed and pumped out by the main air-pump. It can now be seen why this apparatus is called a triple-effet; for in the first vessel there are condensed 28,000lb. weight of low-pressure steam; which evaporate 28,000lb. weight of steam in the first vessel, 28,000lb. in the second vessel, and 28,000lb. in the third vessel; or, for the expenditure of 28,000lb. of steam in the first vessel, there are evaporated in this apparatus 84,000lb. of water, or three effets. These figures are not quite correct, as I have been describing a perfect apparatus, working without any loss; and in practice 2·6 is the co-efficient instead of 3; the difference of ·4 is caused by the loss of heat passing off in the condensed water running from the first vessel and loss by radiation. The surface-condenser contains 3,000 square feet of cooling surface, and is made large at the top so as to give ample area for the vapour to pass or flow among the tubes. Provision is made to cause the water to traverse the condenser five times; the water entering at the bottom on one side and passing out at the top on the opposite side. The speed of the condensing water through the tubes is from 240 to 250 feet per minute, and at this speed the condenser is designed to condense 10lb. of vapour per square foot of cooling surface per hour. This is a fair duty, considering that the cooling water pumped from the river often rises to a temperature of 85° Fahr. during the summer months. The condensing water required for this apparatus and other duties in this factory is 150,000 gallons per hour, which will be pumped by a duplex pumping engine into a reservoir tank, and it is estimated that 100,000 gallons of water will pass through this condenser every hour.

The first vessel draws the juice from a supply tank through the feed-regulating cock E; the second vessel draws the supply of juice from the first vessel through the regulating cock J; and the third vessel draws its supply from the second vessel, and a voiding pump is arranged for drawing off the concentrated juice from the third vessel at M. All the regulating cocks are adjusted so that there is a continuous flow of juice through the apparatus. The quantity of juice which enters the first vessel is 10,000 gallons per hour, and there are 1,600 gallons of concentrated liquor drawn off by the voiding pumps. The difference (10,000 — 1,600 = 8,400 gallons) has been evaporated in the three vessels by the heat given out by 32,3c8lb. of low-pressure steam, which is equal to an evaporation of 2·6lb. of water per lb. of steam condensed in the first vessel.

I will now point out some of the leading features that have been carried out in this design, as compared with the general design of the Apparatus :—

Firstly, the number of pipes and cocks has been reduced to one-third the number usually fitted.

Secondly, all the isolating valves have been dispensed with, as they are not found necessary for the working of the apparatus,

Thirdly, the circulating tubes have been made larger than usual, so as to allow better circulation.

Fourthly (and this is the principal feature of the design), all the steam and vapour pipes have been figured to keep the velocity of the steam and vapour passing through them as nearly as possible to 6,cooft. per minute; and we find in practice that at this speed there is very little loss of pressure in the first calandria or vacuum in the various vessels and condensers. You will observe that the low-pressure steam inlet is 16in. diameter; vapour-pipe from first to second vessel, 20in. diameter; from second to third vessel, 26in. diameter; and from third vessel to condenser, 48in. diameter. The areas of these pipes have been obtained by making them directly proportional to the relative volume of the steam vapour passing through them, which, in round numbers, are, for steam at 6lb. pressure, 1,165; vapour in a vacuum of 3½in., 2,000; vapour in a vacuum of 14½in., 3,000; and vapour in a vacuum of 26½in., 9,000. These numbers are only approximate. The importance of making these pipes of ample area, thereby reducing the loss of pressure or vacuum caused by the friction at high velocities, is very great in an apparatus where evaporation takes place in a vacuum, as the evaporation increases at a very rapid rate with a slight increase of vacuum. For example: If 25 expresses the rate of evaporation in a vessel carrying a vacuum of 24in. when it is increased to 25in. the increased rate of evaporation should be, theoretically, as 25 : 36; but, practically, it is about 25 or 30, or, with 1in. increase of vacuum, the rate of evaporation is increased by 20 per cent.

If greater economy is required than that obtained from Triple-effet, a Quadruple-effet may be used, which would give 3·38lb. of water evaporated per lb. of steam used or 26·72lb. of water evaporated per lb. of coal. The principle may be extended further than the Quadruple-effet, but in that case some of the vessels must be worked under pressure. The nature of the liquid to be evaporated and the cost of fuel will determine the number of effets that may be most advantageously used in any particular case. When there is no objection to work some of the vessels under pressure, the system may be carried to Eight-effets, which would give, say 70lb. of water evaporated per lb. of coal, or 15,680 gallons per ton of coal.

There are many industries the successful working of which is only possible by the use of a Multiple-effet Apparatus, and this paper has been read before this Association in the hope that a clear statement of such a simple economical evaporating apparatus may lead to the starting of new industries in these colonies to work up many of the waste products from other manufactories.

The following are some of the industries that require a Multiple-effet evaporating apparatus for their successful working: Manufacture of glue, salt, caustic soda, glycerine, tannin, glucose, wood pulp, liquid beef, grape-must, extract of logwood, etc. There is one application of the principle of Multiple-action which deserves attention from Marine Engineers, and that is to supply the make-up feed required in compound and triple-expansion engines, by pure condensed water without the expenditure of any extra coal. This may be done by fitting an evaporating vessel between the low-pressure cylinder and the condenser. The action of this vessel would be similar to the third vessel of a Triple-effet; the exhaust steam leaving the low-pressure cylinder at, say, 180° would, on its passage to the main condenser, evaporate the quantity of water required as follows: Let us take, for the sake of demonstration, the third vessel of the Triple-effet. The vessel would be supplied by salt water from the discharge side of the circulating pump, at a temperature of, say, 115° Fahr. The top or body of this vessel would be in direct communication with the main condenser and air-pump, and would carry, say, 26 inches vacuum. The temperature corresponding with a 26in. vacuum is about 130° Fahr. Then there is a temperature-difference of $180° - 130° = 50°$ Fahr., between the exhaust steam passing through the tubes and the salt water on the inside of the tubes; and it is only a question of fixing the area of heating surface in the vessel in order to obtain the make-up feed water required. It will readily be seen that there is no extra fuel required for the duty done by this vessel, and the same sized condenser and air-pump are also ample. The only extra pieces of machinery are the evaporating vessel and a voiding pump for drawing off the brine from the vessel, so as to keep any desired degree of saturation.

In conclusion, it may interest the members of the Association to know that the Colonial Sugar Refining Company, Limited, have nearly 100,000 square feet of Triple-effet at work in their various sugar factories; and it is in a great measure due to the use of this apparatus in the manufacture of sugar that it can be produced so cheaply.

I take this opportunity of thanking Mr. Knox for his kindness in lending the drawings; also Mr. German and Mr. Ferrier for preparing them.

The President, having expressed his appreciation of the value of the Paper, invited discussion upon it.

Mr. C. Van de Velde said that the Paper just read was of great value and enunciated very important principles. There were a great many apparatuses of a similar kind at work in New South Wales and Fiji, but the majority were constructed on wrong principles, and unless they were properly constructed, economy in fuel could not be arrived at.

He believed that in Queensland the loss of saccharine juice was very great through mechanical defects in the save-alls. Last year he had visited a sugar district in that colony, where he made this remark to a planter who was using one of these machines, and told him that some were so badly constructed that he (Mr. Van de Velde) had actually found sugar in their boilers. All the French manufacturers provided vertical cylinders instead of these save-alls. He believed the latter were not sufficient to prevent loss of the juice, and the French engineers were evidently of the same opinion, as they placed between the pumps save-alls of a very large capacity, so that it was impossible for any juice to escape. The pumps shown on the diagram were fitted with ordinary valves, but with hot liquor free valves did not always act, and a certain quantity of liquid remained in the tubes, with the result of the loss of a certain amount of heating surface. Mr. Kidd had found it advantageous to increase the size of the vapour-pipes, and must be complimented on the improvement. The Company which the speaker represented was turning out a large number of these Triple-effet machines annually, in which they had adopted a great many of Mr. Kidd's valuable suggestions, and had supplied to the Colonial Sugar Refining Company the first Triple-effet apparatus ever erected in Australia. Mr. Kidd had doubled the working power of the apparatus by doubling the size of the pipes.

Mr. ANGUS McKAY thought that there could be no question as to the usefulness of the Triple-effet process in connection with numerous industries that might yet be established by its means in these colonies. The vast strides made in the sugar industry among us would be seen on comparing the machinery used now with what was employed here twenty years ago. At that time he was actively engaged in the sugar business, but only ten tons of sugar were made from the same quantity of cane that was now made to yield seventeen tons. For these enormous improvements the colonies were greatly indebted to the Colonial Sugar Refining Company. As to the merits of rival machinery of this nature, opinions of experts would continue to differ as the machinery continued to be improved. He had for many years been convinced, having been intimately acquainted with the sugar industry in most parts of the world, that if it had not been for the

Colonial Sugar Refining Company, the industry would have become extinct in New South Wales long ago. It was a great compliment to the Association when an engineer of Mr. Kidd's abilities laid before them the benefit of his great experience in this matter, and pointed out how the use of similar machinery could make profitable certain colonial manufactures now carried on at a loss. In wine making, for instance, the juice must be condensed, and the grape-must would have to be treated in large factories by skilled men of known mechanical experience, otherwise Australia would never obtain the high position in wine making which the material is capable of reaching. When the sugar business was carried on by unskilled men without proper appliances and capital, it did not pay; but as soon as mechanical skill and sufficient capital were brought to bear upon it a new order of things arose.

Mr. R. Pollock thought the temperature of the exhaust steam from the low-pressure cylinder would not be sufficient to cause an evaporation in any vessel placed between it and the condenser, so as to yield the necessary quantity of make-up water.

The President considered it advisable to defer further discussion on the paper until the next meeting, as it contained some important statements. He did not know what they did with the exhaust steam in the old days, but the results got from the present apparatus were truly wonderful. Some of the writer's details he could not exactly follow, but it was evident that Mr. Kidd got double the efficiency attained before. There could be no doubt of the correctness of the principle, although the mechanical details might require some subsequent modification. The difficulties hitherto experienced by the French sugar-boilers seemed in a fair way to be abolished by Mr. Kidd's improvement of enlarging the areas of the pipes, so as to ensure a continuous flow with a minimum of priming. With regard to what had been said about the primitive appliances used in Queensland and Fiji, etc., no doubt a comparatively educated person was necessary for working the Triple-effet Machines. The Association might well congratulate Mr. Kidd upon his interesting and successful Paper, and postpone further discussion thereon till the next monthly meeting.

Mr. KIDD (who regretted that he would be absent from the next meeting) in reply, stated that in Fiji the Colonial Sugar Refining Company had three of these Triple-effet Machines; and one Indian Coolie worked the three, although they were 80ft. apart. They were started at about two o'clock on the Monday morning, and worked without cessation all the week till about eight o'clock on the Saturday night. The cocks were so well regulated that they rarely wanted touching. The testing-apparatus enabled the man in charge to determine the gravity of the juice when necessary. It always remained at 28° Beaumé. The man soon learned to keep the liquor at a proper level in the pots so as prevent priming. The Sugar Refining Company's engineers attached very much importance to the prevention of priming over, but by a recent valuable addition to the save-alls the vapour-speed had been reduced to two miles per hour. They now got 150 gallons of juice for every ton of cane crushed, but they added 100 gallons of boiling water for macerating purposes, so that they had to evaporate 250 gallons of juice per ton of cane crushed. He had seen one of these Triple-effet machines run for four hours without touching at all. This Company considered they got their cane crushed for nothing, or their vaporization done gratis. Under the old system twice as many boilers and engines would be required. The whole of the available heat could be used in this apparatus. Four effets could be got if necessary, and they might be doubled into eight, but it was desirable to boil the sugar at a low temperature. When sugar was evaporated in an open pan a very large amount of loss took place. Mr. Kidd then replied to some of Mr. Van de Velde's objections, and added that the Sugar Refining Company used ¾lb. of caustic soda every day for each boiler, to neutralise the effect which the water, from the Triple-effet Apparatus (no matter how pure it might be) was always sure to have upon the boilers. The engineer in charge tested the water at intervals with litmus-paper, and it was also subjected to test in the laboratory.