THE DUNNACHIE

CONTINUOUS REGENERATIVE GAS-KILN

FOR

BURNING FIRE-BRICK, POTTERY, ETC.

BY

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BY THOMAS EGLESTON, PH.D., NEW YORK CITY.

The adoption of the regenerative principle for burning fire-bricks pottery, etc., has been delayed beyond what would naturally have been expected, because there has been until recently little necessity for high heat in burning such material. But the introduction of processes using very high heats, like the open-hearth steel and the basic processes, has required special attention to be paid to fire-bricks. It has become necessary not only to have the bricks of a much better quality, but also to have them burned at a much higher temperature than formerly. It has been found that if bricks burned at a low temperature are submitted, in the process in which they are to be used, to a higher temperature than that at which they were burned they are likely to undergo considerable change. It has also been found that in burning these bricks in the old way, serious difficulties arise from the introduction of the ashes of the fuel into the brick. To avoid this evil, gas was first employed; but the regenerative system has not been used until recently. It is quite plain from the outset that the regenerative system as it is applied to the ordinary furnace, that is, having the products of combustion passed through a checker-work, whether by the non-continuous or the continuous system of regeneration, would not be applicable to the burning of such material as pottery and brick, even though the fire-brick should command a high price in the market. Any system, to be successful, must accomplish two things: first, regenerate the heat; and, secondly, use for the regeneration, the heat contained in the material itself which is being manufactured. One of the greatest sources of waste of fuel in metallurgical operations is due to the considerable quantity of heat wasted, by being taken out with the material which has been burned, when it leaves the furnace. A serious loss of heat in burning pottery and bricks is incurred while the bricks which have been fully burned are waiting in the furnace to become cool enough for removal. If this heat could be stored up and used in the process, so that the heat contained in the articles being manufactured would be so thoroughly utilized that when the furnace was ready to be discharged, the articles would be very nearly cold, there would be a very great gain. It might be objected that the time lost and the consequent diminution of output would more than counterbalance the fuel saved. This, however, has not proved true in the working out of the process by the few furnaces that have been invented to accomplish this object effectually. To secure the best results, it is not only necessary that a cheap fuel should be used, but that all of it should be burned and turned to commercial account in the course of the operation. There are comparatively few cases where this principle of heat regeneration by means of abstracting the heat from the article manufactured has been applied. It will undoubtedly have a much further extension, and its application will be of the greatest interest to manufacturers..

The successful application of the regenerative principle to brick-making involves several conditions. One of these is that the radiation of heat from the outside of the furnace should be used for some purpose or reduced to a minimum, or entirely prevented. Another is, that the combustible gases should be consumed at the point where the temperature is required to be highest, and that the temperature in the chimney, where the gases are discharged from the furnace, should be only sufficient to produce the draft necessary to carry them off. Several persons have turned their attention to the subject of regenerative kilns for burning fire brick. One of the most successful of these is Mr. Jas. Dunnachie, of Glasgow, who, in September, 1881, introduced his furnace at the Glenboig Fire-brick Works, near Glasgow, and subsequently in several other places. The old-fashioned Newcastle kiln shown in Plate I., was formerly used at Glenboig, and is still in operation there, owing to the fact that a number of kilns of this type were in good order at the time the regenerative kiln was started, and have not since been torn down; but they do not burn as economically as the latter.

The Dunnachie kiln consists of a series of ten chambers arranged five in a row, connected with each other by underground flues. In Plate II. these chambers are shown with a flat arch, but they are usually built hemispherical. The arrangement of these kilns is shown on the ground plan, Fig. 1., Plate II., and in sections 2 and 4 to 7. The chambers are numbered 1 to 5 on one side, and 6 to 10 on the other. The distances between the two sets of five chambers is 20 feet. This space and the whole top of the kiln is

[To accompany Prof. Egleston's Paper on the Dunnachie Kiln.]

PLATE I.—THE NEWCASTLE KILN.

A—Side walls.
B—Back walls between the kiln and the flue.
C—Kiln chambers.
D—Arch over the kilns.
E—Front wall.
F—Buttresses to sustain the kiln.
G—Arch between the two kilns.
H—Ash-pit outside of the kiln.
I—Door of the fire-place, counter-poised.
J—Opening for picking the fire.
K—Door of the kiln.
L—Openings in the roof.

PLATE II.—THE DUNNACHIE KILN.

A—Gas-valves controlling the gas going to the kilns.
B—Producers.
C—Chimney-flues.
D—Side-flues leading to chimney-flues.
E—Main gas-flue.
F—Gas-valves from main to the kilns.
G—Opening admitting air to the floor of the kiln.
H—Kiln-doors.
I—Outside opening to hot-air flue O on the floor of the kiln.
J—Flue connecting chambers 1 and 10.
K—Spy-hole for the inspection of the kiln and for taking off hot air.
L—Flue conveying hot or cold air to upper part of the kiln.
M—Flue connecting chambers 5 and 6.
N—Hot-air opening from one kiln to the other.
O—Flue bringing hot air from kiln to burn gas in the next kiln.
P—Underground flue bringing hot air to O.
Q—Flue bringing gas from R into the kilns.
R—Main gas-flue to kilns, a continuation of E.
S—Lower flue for hot air.
T—Outside opening into the flue L.
a—Slits between the flues for passage of air.
b—Openings for passage of gas.
d—Slabs of fire-clay, closing openings in roof.
e—Fire-clay slab, cutting off hot air from the flue L.
f—Slits admitting hot and cold air from L to kiln.
g—Slits admitting hot air against the gas.
h—Slits regulating passage of gas from R to Q.
i—Slits between P and S.
k—Fire-clay slabs regulating the entry of hot air from P to Q.

covered with a roof as shown in Fig. 2. Under this roof is a floor, partly of iron and partly of wood, used for the purpose of drying the green bricks previous to their being burned. From this floor the dried bricks are lowered by a balance-lift to the space between the two kilns convenient to the charging-doors. As the space between the two sets of kilns below the roof-floor is 20 feet wide by 68½ feet long, it gives a room 68½ feet long by 60 wide heated entirely by radiation, which can be used as a drying floor for 2000 bricks a day and can also be utilized not only for storing the materials ready to go into the kiln that is being discharged, but also for temporarily housing what has been taken out of the kilns. The internal dimensions of each one of the chambers are 17 by 10½ feet, and 10½ feet in height, so that each chamber is capable of burning from 12,000 to 15,000 bricks, the exact number depending upon the size and shape of the brick. Such a kiln as is shown in Plate II. is capable of producing 300,000 bricks per month. As the entire construction is under a roof, and the space between the kilns is high and consequently very light, all the operations of drying, charging, steaming, and drawing the charge can be conducted continuously, the green material being brought automatically from the place where it is moulded, and the finished material being discharged from the kilns at the same time to be carried away to the warehouses. The operation of charging is going on on one side and the operation of discharging on the other, so that there is no waste of time in carrying out the operations.

At one end of these chambers on the outside are two producers *B* of any ordinary construction. The gas is carried by a down-take to an underground flue *E*. The producers used at Glenboig can burn 4 cwt. of a poor slack coal per hour, and give off sufficient gas, with the hot-air regeneration by the cooling bricks, to bring the bricks being burned up to a white heat. The underground flue *E* connects by means of alternate flues *R* with each one of the kilns. To regulate the supply of gas for each kiln, ten valves *A*, one for each kiln, are placed in a straight line in the flue *E* at the extremity of the flue *R*, carrying the gas from the main flue to the kiln, so that any quantity of gas may be delivered to any one of the kilns independently of the others, or be shut off from them entirely. The gas-valves *F* are made of firebrick. They are hemispherical in shape, and are bound on the outside with an iron ring. The iron stem attached to the hand-wheel by which they are moved is fastened by a nut which enters the bottom of the valve about three inches.

The hole so left is plugged with fireclay. The valve-seat is also of firebrick. It is placed over the opening in the flue *E*. The stem for moving the valve is fastened to the floor by a cast-iron foot-plate, in which there is an observation-hole, to visit the valve, which is closed with a cast-iron stopper. The valve *F* is raised or lowered by the hand-wheel *A*, so as to regulate the supply of gas for combustion. The cold air enters from the openings *O*, and *I*, and *L*, on the outside, which, like the gas valves, can be opened or closed to any extent required. On the side of the flue *R*, and running across the whole width of the kiln, are carefully adjusted openings *h*, through which the gas passes in equal volumes and at equal pressures, the whole width of the kiln, Figs. 4 and 5, and enters *Q*. This space *Q* is 9 inches wide. The gas meets the air a little below the floor-level; thence, as shown by the arrow, it passes into the floor of the chamber upon one side. The gas is brought into the burner *Q* through flues 9 inches square, separated by one brick, whose only purpose is to strengthen the masonry and to prevent the obstruction of the passage *Q*. There are fourteen of them in the width of the chamber. They are all alike, and extend the whole width of the chamber. This space *Q* is called the burner. In filling the chamber the bricks to be burned are piled close to it, leaving between them and the wall of the chamber a space 9 to 10 inches wide the whole height of the bricks. The openings from the gas-flue *R* into the burner *Q* consist of a series of slits *h*, Fig. 4, which are $4\frac{1}{2}$ inches wide and the whole height of the gas-flue. There are fourteen of them which connect with the 9 inch flues that form the burner. The middle slits are filled with loose bricks so as to leave openings 6 inches high, but the end ones are left full size, so as to furnish more gas at these points. The separation between the slits *h* is a 9 inch brick. It is impossible to regulate exactly beforehand the size of these openings. They are, therefore, made much larger than is necessary, and are filled more or less with brick, according to the indications which are given by the color of the burned bricks. Hot air from the cooling bricks is made to pass through the chambers in front, and when it is sufficiently cooled, can be made to pass into the chimney by means of a damper. By this arrangement the gas can be allowed to enter in any quantity to any of the chambers, or be entirely shut off from them. The end chambers 5 and 6 connect with the underground flue *M*, and the chambers 1 and 2 with the flue *J*, Figs. 1 and 4, through 17 slits in the wall of *P*, so that there is a constant circuit of the gas coming from the producers on either side maintained by means of this flue. All around the outside of the chambers and connected with them on the opposite end from the gas are other channels, *D* and *C*, which lead to the main chimney, so that the supply of gas and air can always be constant, and the draught, with or without pressure, can always be regulated in each one of the chambers by means of the dampers, exactly as required for the particular phase in which each one of them happens to be at the time. The supply of hot air comes in through special slits *a*, Fig. 5, arranged in the floor of the chamber. They are all 18 inches long by 2 inches wide, except the end ones against the outside walls, which are $2\frac{1}{2}$ inches wide. There are twenty-three of them across the chamber. They are controlled by valves *k*, 21 inches long, which work over two rectangular outlets *m*, 15×10 inches in size, Figs. 5 and 6, made in the roof of the flue *P* at each end of it. These valves are controlled from the outside through the openings *I*, which, when the furnace is in full fire, are closed with bricks laid up dry and plastered over on the outside with mortar. The air generally comes through the cooling burnt-off bricks two or three chambers behind the one which is burning and enters, through the openings *m* and the slots *g*, Figs. 4 and 5, which are 3 to four inches in size. There are five rows of these slots, the lowest row of which enters the burner *Q* either at or a little below the level of the floor. If a supply of hot air is required higher up, it may be brought in hot through the openings *N*, Fig. 7, which are each 21 inches long. They are made in the ends of the flue *L* by moving the damper *e*, which covers two arched holes *N* in the next chamber, near the end of the flue *L*, Figs. 4 and 7. Cold air may be brought from the outside by closing these dampers and opening the connections with the outside air at the end of the flue *L*. The holes *f*, Fig. 4, run the whole width of the furnace. There are four rows of them, made by separating the bricks in alternate rows about 2 inches. This flue *L* thus serves for the admission both of hot and of cold air as well. The air for the ordinary uses of the furnace is brought through the bricks which are being cooled down to be regenerated, passes down through the floor of the kiln into an underground flue *S*, of about the same size as the opening *R*, and from here through a series of openings *i*, Figs. 4 and 7, made in the brickwork into the flue *P*, in the lower part of the dividing wall. From here by means of openings in the arches, which are regulated by valves *k*, Figs. 4, 6, and 7, it is introduced into a flue *O* above, and discharged as shown by the arrows, either a little below or directly on the floor-level, against the gases which have come up from the flues upon the opposite side. The damper *k*, Fig. 4, is shown in the drawing on the level of the floor of the chamber. It is usually placed a little below it, so that there are two of the openings *g* below the floor. By this arrangement the combustion commences in the burner *Q* a little below the level of the floor of the chamber. As the dampers give complete control of both the gas and the air, any given quantity or quality of flame may be produced. The combustion of the gases by the hot air produces sheets of flame the whole width of the kiln, which pass upward on the side-walls. These walls and the arched roof produce a very large amount of radiation, but in order to provide for complete combustion in all cases, openings are made in the dividing walls about half way up. These openings, *L*, Figs. 4 and 7, are made for either cold or hot air, which may be made to pass in either to bring up or reduce the temperature of the gases at this point. If the air is to be cold it comes from the outside; if hot, from the burned-off chamber. This air meets the hot gases from the neighboring chamber, which pass into *L* through openings *N*, Fig. 7, made for the purpose. These openings are regulated by the valves *e*, which permit, when necessary, sufficient air to be introduced at this point to prevent the bricks from being burned in any one part of the chamber at a higher temperature than those in front of them. It is not usually necessary, in the ordinary work of the furnace, to use these openings *N*. They are generally used when, for any reason, the fire in the burning-chamber is not hot enough, when the hot air from this flue from the chamber next is introduced. When the kiln is too hot and there is danger of melting the bricks, cold air from the outside is introduced through the same flue. The walls of the chamber offer a very large radiating surface. As it is not filled up to the roof, the space between the charge and the roof also permits a considerable radiation, which is utilized for the heat in the kiln, and also for the drying-floor above it. As the bricks shrink about one-twelfth of their bulk, this radiating chamber, as it may be called, increases in size as the bricks are burned. In some cases it has been found advantageous to use a blower instead of a high chimney, as the gas from the producer generally comes off at a very slight pressure. When a blower is used, a considerable economy may be gained by steaming the green bricks freshly charged in the kiln with air blown through the burned-off bricks, which are no longer hot enough for heating the air for combustion, but too hot to be discharged from the kiln. When a chimney is used, unless the draught is very strong, this cannot be done.

The operation of preparing the bricks for firing consists, first, in the preliminary tempering on the floor above the kilns and in the space between them, so as to drive off sufficient water to permit the handling of the bricks. They still, however, contain a considerable quantity of moisture, and it would not be safe to subject them at once to a high heat, as there would be danger of their cracking and spliting. They are therefore charged into the kiln through the door *H*, and when the kiln is full the door is closed hermetically by two rows of bricks laid up dry and plastered on the outside. Hot air from the burned-off kilns is turned into them, or, if this is not convenient, some gas from the producer, which is ignited so as to give a low and gradually rising temperature. During this time of steaming, the stoppers *d* are withdrawn from the openings in the roof and the products from the heated bricks charged with steam, are allowed to escape into the open air. The bricks are not heated to a high temperature until all this steam has escaped. During this time the two passages *G* and *I* remain open. When the steaming is finished they are closed. A chimney about 100 feet high is sufficient to produce the draught. Stronger draught may be produced by means of a blower. The gas leaves the producers at a temperature of from 600 to 800° Fahr. It is passed into the chambers and there burned by the admission of air which has been highly heated by passing through two or three burned-off chambers which have been brought up to a high temperature, as high as the melting-point of steel. As the operation is continuous, we will suppose that chambers Nos. 3 and 4, Fig. 1, have been burned off. The gas from the producers is turned into chamber No. 5, which has just been steamed. Chamber No. 2 is open, and, cooling off, the air is made to pass through Nos. 3 and 4, which are burned-off and cooling down. No. 3 will then be red hot, and No. 4 at a white heat. From No. 4 the air descends through the slits, *a*, Fig. 5, into the flue, *S*, Fig. 4, through the slits, *i*, to the flue, *P*, and thence through the rectangular openings *m*, Fig. 5, which are regulated by flat plates of firebrick *m*, Fig. 5, which are controlled from the outside by the slab *k*, through *I*, into the flue, *O*. This flue is provided with openings, *g*, which extend the whole width of the furnace, and are so calculated as to supply the exact quantity of air which is required for the perfect combustion of the gas. The rule in this respect is to make the capacity of the air opening two and a half times that of the gas

The combustion commences a little below the level of the floor, and extends some distance above it. The air passes through these openings into the burner, where it meets the gas coming up from the flue, *Q*. Chamber No. 5 is thus in full fire. It is filled with clear, bright flame. The products of combustion are made to pass through No. 6, which is called the benefit kiln, before going to the chimney. No. 6 is thus brought up to a bright red heat, and, in its turn, when No. 5 is burned off, becomes the full fire kiln by turning off the gas by the damper *A* and turning it on to No. 6. Nos. 7, 8 and 9 are in front filled with green brick in process of steaming; No. 9 is filling; No. 10 is ready for filling; and Nos. 1 and 2 are being emptied. Thus all the operations are continuous: No. 2, open and being cooled off; No. 3, red hot, No. 4, white hot, both burned off and cooling; No. 5, burning in full fire; No. 6, in the preparatory stage to full fire; Nos. 7, and 8 steaming; No. 9 filling; No. 10 ready for filling, and No. 1 discharging.

When the gas is first turned on to No. 5 the chamber No. 2 will still be too hot to be discharged, and for the first five or six hours the air is made to pass through chambers 2, 3, and 4, to reach No. 5. After this time the gain would be too small, so that No. 2 is cut off, although the bricks still retain considerable heat. This is done by shoving in the firebrick slab *k*, which closes the opening *m*, so that the air no longer passes them. The cold air is introduced by taking down the bricks which close the opening *I* in chamber No. 3. During very damp weather and in the winter the heat of the chamber corresponding to No. 2 is made use of by introducing a square pipe into *K*, Fig. 3, and blowing cold air into the kiln. This pipe connects with another which carries the air thus heated to the drying-floors, thus utilizing the heat which would otherwise be lost and cooling down the chamber at the same time. The main pipes are put up permanently, with branches leading to each chamber. The ends of these branches are closed when not in use. The moveable pipe fits all the branches.

In the preliminary heating, which is called steaming, there is a very considerable quantity of moisture given off from the bricks, which moisture, as it is likely to absorb a large amount of heat, is allowed to escape from the openings in the roof *d*, Figs. 4, 6, and 7, the stoppers from which are removed for the purpose. This is done by introducing into these kilns a little producer gas, and burning it by means of cold air. All the air-ports and roof-vents remain open during the whole of this stage of the process, and are only closed when the chambers are ready to fire. As soon as the steam ceases to condense in each chamber, the openings are closed, so that none of the gas escapes. They are also used when it is desirable to cool a chamber quickly. The chamber No. 7 would in this instance be called a green chamber, since the bricks in it have not been burned. Behind it there would be two—or as many as three—other chambers which were being cooled off, that is, say, 4, 3, and 2. The temperature in chamber 5 can be increased in 24 to 36 hours up to a steel-melting heat, that is, to the stage of full firing. While this operation is going on, the next chamber in the series will receive the gases, so that the bricks in chamber 6 will be dried and brought nearly up to red heat. Into this the heat would be passed so that the operation would go on in the following chamber in exactly the same way.

In order to burn the brick successfully a white heat is required. To maintain this, it is necessary to have the proper admixture of gas and air and to keep it at the proper temperature and under entire control. Without such control it would be quite possible that the temperature upon one side of any one of the chambers might be sufficient to melt the bricks, and on the other not sufficient to burn them. It is for this reason that the flames are so divided in the underground channels, and that flues are made in the upper part as well as in the lower. Under these conditions there is no danger of unequal heat, or that any ash or other material will be brought in with the gas, thus causing danger of fluxing the surfaces of the brick and making them rough. This kiln can be adapted to use for many other purposes besides that of making brick.

In the original design of this furnace the idea was fully considered of having each chamber arranged in such a way as to be independent of its neighbor, and so that it could be used, skipping one, two, or three chambers, on either or both sides. But the expense of construction was so much increased, the complication of the flues so great, and the advantage to be derived from it so small, that the idea was finally abandoned without constructing any furnaces in this way. The wisdom of doing so has been fully confirmed by subsequent experience, for it has been found in actual practice that there is ample time between the burnings for the most serious repairs, which fortunately up to this time have not been required.

The result of this method of burning is a saving of from 50 to 75 per cent. in the cost of manufacture. This saving is large, but not much larger than should have been expected, and results, first, from the use of gas and regeneration; second, from economizing the heat in the preliminary stages by using the waste heat to bring the bricks up through the preliminary temperatures; third, from the use of the radiated heat for drying the bricks. This last saving may be still farther increased by extending the floor over the bricks 20 feet beyond the walls and all around them, which would greatly extend the drying space and thus facilitate the work, and still further economize the heat. Such a construction would about double the capacity of the drying-floors above the kiln. The output of the kiln is, however, so large that some drying-stoves must always be used with it as with every other kiln.

Mr. Dunnachie has made a series of experiments with the Siemens water pyrometer with a copper bulb, to ascertain what the temperature of the gases escaping into the chimney was:

Time of observation after	Temperature of the chimney when there was but one chamber of green bricks.	Temperature of the chimney when there were three chambers of green bricks.
4 hours,	150° F.	90° F.
12 "	200°	120°
24 "	250°	150°
36 "	300°	180°

In making the observations with only one chamber of green bricks between the chimney and that in full fire, the copper bulb could only be held in the flue 3½ minutes, for fear of melting the wire to which it was attached, so great was the heat. But, when there were three, it was left for an hour before the temperatures were read. This shows, conclusively, the saving of heat and consequent economy of the furnace.

The average of cost of burning bricks in the old Newcastle kilns at Glenboig was 8*s.* 2*d.* per thousand. In the hopper kiln, invented by Mr. Dunnachie about 1865, it was 6*s.* 6½*d.* per thousand. In the present Dunnachie kiln it is 2*s.* 9½*d.* per thousand. The saving in fuel effected by the use of these kilns is from 50 to 75 per cent. At Glenboig, where everything is very carefully done, it reaches 75 per cent. There is also a very considerable reduction in labor and repairs. The product is of better quality and more uniformly burned. This is accomplished mostly because of the simple construction of the kiln, which allows of regulating the temperature at any phase and of having it constant through all parts of the kiln. As the floor of the kiln is solid, there being no flues or openings in it except at the sides, where they are quite large, they do not break and crack, nor do the flues become obstructed with sand or broken brick, as is the case with most other fire-brick kilns. The kilns used at Glenboig have been run continuously for eighteen months without repairs of any kind. As the mixture of gas and air is always under perfect control, and the passages of the upper part are also regulated by valves, the heat may be raised or lowered, according to indications given by looking into the kiln from the outside, and is always uniform from one end of the furnace to the other, so that there is no breaking from sudden or unequal heating, and almost no hard or soft bricks are produced.

The output of these kilns is almost double that of the old kilns, the capacity being the same, but only half the time being required to burn in the new ones. The cost of a set of ten chambers with two gas-producers, arranged as in the drawing, is from 1500 to 1600 pounds sterling, for kilns having the capacity of 300,000 bricks per month. I am indebted to Mr. Dunnachie for the following estimates of the construction of both kilns. The data are given in English money, which can be easily converted into dollars and cents by counting the pound at $4.84 and adding the price of exchange.* The cost per thousand bricks, using a good quality of coal, was in September, 1885, in the Newcastle kiln 8*s.* 9*d.*, and in the Dunnachie kiln, using a cheap slack, 2*s.* 9*d.* for the best quality of Glenboig bricks. For those of a lower quality, which are required to stand less heat, the cost would be very much less. The reputation of the Glenboig brick is such that only first-class bricks are made there.

The labor in the gas-kiln is much less than in the older ones. As the men are not constantly employed with the kilns, the work is less fatiguing, and the number of workmen can be very much reduced, when these furnaces take the place of the old kiln. In most of the works where this kiln has been constructed, it works side by side with the old kiln, so that the men are busied sometimes with one and sometimes with the other. The kilns are burned off about three times a month. The time that the bricks are in the new kiln is as long as in the old one, since they are used for regeneration; but there is greater economy in this, since all the heat stored up in them is utilized instead of being lost as before. The steaming stage lasts four shifts of twelve hours each, or forty-eight hours in both kilns. The full-fire stage takes from four to six shifts, or from forty-

* The cost of the pound sterling varies generally, in New York, from $4.90 to $4.96, depending on the rate of exchange. In making preliminary estimates it is best to count $5.00 to the pound.

eight to seventy-two hours, in the old kiln, and two to three shifts, or from twenty-four to thirty-six hours, in the regenerative. The heating and cooling are much more gradual in the regenerative than in the old kiln, and consequently there is less deterioration in the material manufactured. In the Newcastle kiln, it is necessary frequently to open the doors while the brick is almost at a white heat, thus cooling those which come in contact with the air and reducing the temperature of the kiln at times very greatly. In the regenerative kiln, the doors are hermetically closed at the commencement and remain so until the end. In the Newcastle kiln the air is full of smoke from the incomplete combustion of the fuel, while in the regenerative kiln the combustion is so perfect that at the point where the duty begins the carbon is all burned, and there is no smoke at any point when the kiln is properly worked. Ordinary laborers can learn to work the kiln with great ease, because what is going on in the interior of every kiln can be seen from the outside, through the spy-holes made for the purpose in the built-up door of the kiln. These are closed when not in use with a fireclay plug. The gas and air are regulated so as to have a clear flame from one chamber to the other. The moment any smoke is seen either in the chambers or in the chimney top, perfect combustion can at once be secured by opening or shutting the proper valve.

The drawing, Plate I., of a pair of Newcastle kilns shows the method of firing and the size and general disposition of the kiln. As compared with the regenerative kiln it will be seen that the construction is not much more simple, while the holes in the floor, as shown in the drawings, make the furnace much more difficult to manage. The number of bricks used in each furnace is about the same, and the cost of construction is not very different; so that there is every advantage in using the regenerative kiln.

Specification of Materials Required for One Set of 10 Chambers of Dunnachie's Continuous Regenerative Gas-Kiln.

EXCAVATIONS:

Cutting for Foundations of Kilns, allowing for Scarcements:

68x42x3½ feet=352½ cubic yards.

Flue round outside of Kilns:

272x4½x3⅓ feet=149½ "

Main Gas Flue between Kilns:

60x5x5 feet= 55½ "

557½ 1 s. per yd., £27 17s. 06d.

£27 17s. 06d.

*Bricks

Used in Building Set of Kilns, including Flues:

Square bricks, 9x$1\frac{1}{2}$x3 ins., ...	293,000
For Crowns:	
End arch bricks, 9x$4\frac{1}{2}$x3–x$2\frac{1}{2}$ ins., . . .	37,000
For Flues, Etc.:	
Side bricks, 9x$4\frac{1}{2}$x3 and 2 ins., ...	30,000
Horse blocks, 24x9x7 ins., ...	250
Between Horse Blocks:	
Scone bricks, 9x$4\frac{1}{2}$x2 ins., ...	450
For Steaming Holes:	
Covers, 18x12x3 ins., ...	250
	360,950

Abstract of Value of Bricks:		
260,450 bricks (1st quality), 40s., ...	£520 18s. 00d.	
100,000 bricks (2d quality), 20s., . . .	100 00 00	
250 horse blocks, 1s. 6d. each, . . .	18 15 00	
250 covers, 9d. each, ...	9 07 06	
		£649 00s. 06d.
Building		£676 18s. 00d.
Of one set of Kilns (Labor):		
£17 for each of 10 chambers, ...	£170 00s. 00d.	
		£170 00s. 00d.
Woodwork:		
Centres and cleading used in building crowns of kilns—three sets required at once, at £6 each set, ...	£18 00s. 00d.	
Ironwork:		
Kiln Binders:		
24 cast-iron upright binders, 13 ft. long, $12\frac{1}{2}$ cwt. each = 14 ton 14 cwt., £5 2s. 6d. per ton, ...	£75 06s. 09d.	
20 cast-iron cross binders, 12 ft. 3 in. long, 9 cwt. each = 9 tons, £5 2s. 6d. per ton,	46 02 06	
12 malleable iron binding rods, 21 ft. long, by $1\frac{1}{2}$ ins diam., $13\frac{1}{4}$ cwt., 6s. per cwt.,	3 19 06	
		£125 08s. 09d.
Capacity of Kilns:		£990 06s. 09d.

10 chambers, each containing 14,000 bricks, 9x$4\frac{1}{2}$x$2\frac{1}{2}$ ins., 140,000.

Specifications of Materials Required for the Drying-stove above the Gas Kilns.

Wrought-iron Girders.

For tops of Columns:

6 girders 13′–$0\frac{1}{2}$″ long	6″ × 8″ I				
2 girders 13′–6″ long	"		t. cwt.		
2 girders 12′–4″ long	"	=	1 8	£6 per ton.	£8 8s. 0d.

* Of the above quantities, about 100,000 may be bricks of second quality for packing, butts and between arches, etc.

Between kilns:

6 cross gird'rs 20′–0″ long, 6″ × 10″ I				
14 " " 13′–6″ long, 4″ × 3″ I	= 2	$6\frac{3}{4}$	"	14 0s. 6d.
14 " " 12′–4″ long "				
42 " " 13′–0″ long "	= 4	$7\frac{3}{4}$	"	26 6s. 6d.
Cast-iron Plates for Floors:				
372 plates 4′x2′x$\frac{5}{8}$″ thick, $1\frac{1}{2}$d. each,	= 27	18	£4 5s. p. t.	118 11s. 6d.
Wood Floring between Kilns:				
800 linealfeet joisting $6\frac{1}{2}$″x$2\frac{1}{2}$″,			1d. per foot.	3 6s. 8d.
110 square yards flooring,			1s. 1d. p. yd.	5 19s. 2d.
				£176 12s. 4d.

Specification of Materials Required for Six Newcastle Kilns (in pairs).

EXCAVATIONS:

Cutting for Foundations of Kilns:

34x30x$4\frac{1}{3}$ ft., each pair for 6 kilns, 507 c. yds.

Cutting for Butts:

For 6 kilns, ... 79 "

Flues outside of Kilns:

Average distance from kilns to chimney, ... $149\frac{1}{2}$ "

$735\frac{1}{2}$ 1s. per yd., £36 15s. 06d. — £36 15s. 06d.

*BRICKS

Used in Building Six Kilns.

For Side-Centre Walls:

From foundations to spring of arch, square bricks, 9x$4\frac{1}{2}$x3 ins., ... 45,080

For Flues

Inside of kilns, and flues outside of kilns to chimney, 9x$4\frac{1}{2}$x3 ins., ... 40,000

For Crowns:

End arch of square bricks, ... 53,280

For End Walls:

Square bricks, ... 55,200

For Butts:

Square bricks, ... 105,000

For Floors of Kilns:

Packing between arches and causewaying for fuel, square bricks, ... 35,650

334,210

Abstract of Value of Bricks:

234,210 bricks (1st quality) 40s. per 1,000,	£468 08s. 05d.	
100,000 bricks (2d quality) 20s. "	100 00 00	
		£568 08s. 05d.
		£605 03s. 11d.

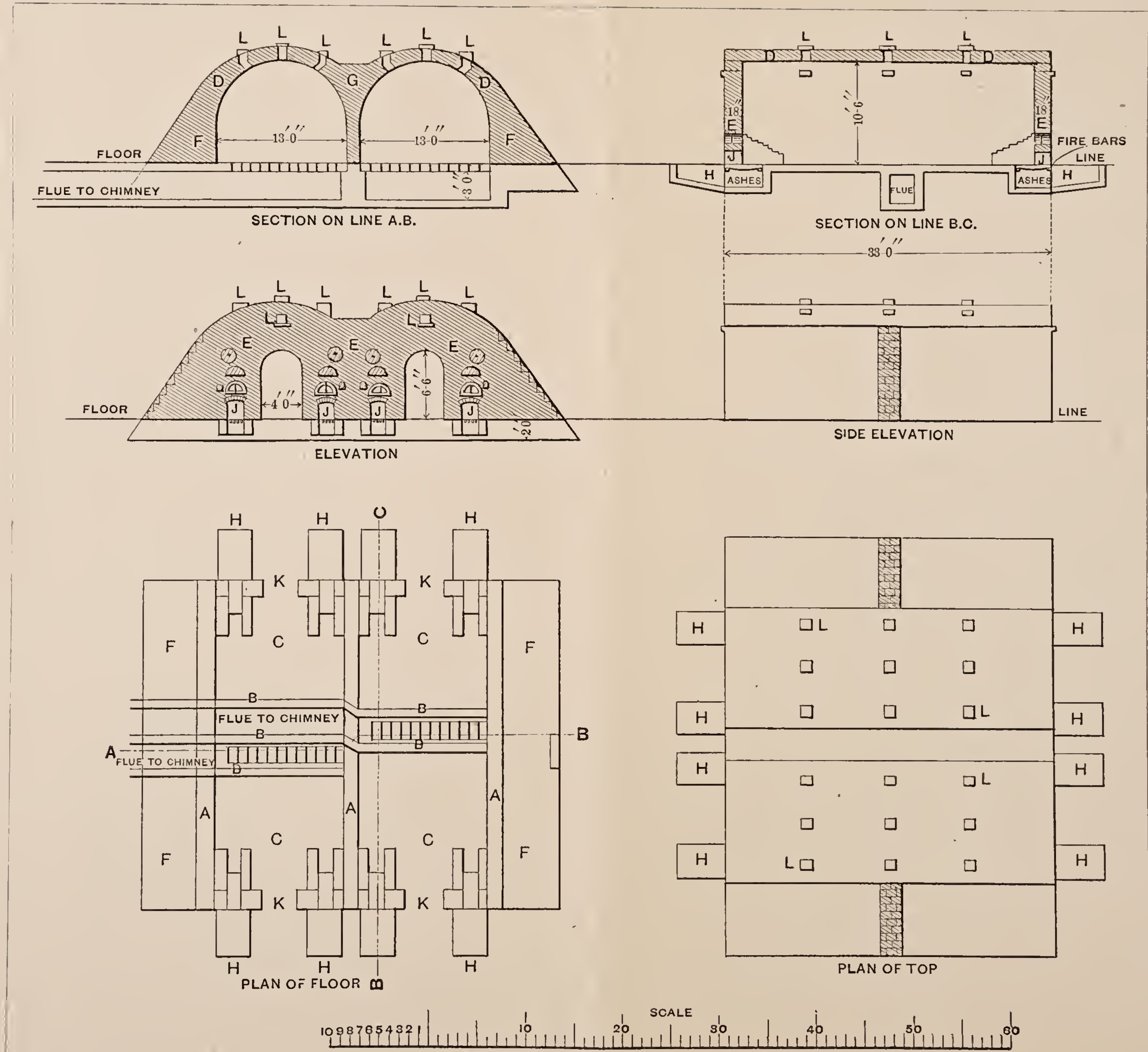
* Of the above quantities, about 100,000 may be bricks of second quality for packing butts and between arches, etc.

BUILDING		
Of Six Kilns (Labor):		
Cost of building per rood, equal for gas or Newcastle kilns, ...	£170 00s. 00d.	
		£170 00s. 00d.
WOODWORK:		
Centres and cleading for two chambers, £9 each set, ...	£18 00s. 00d.	
		£18 00s. 00d.
IRONWORK:		
Kiln Binders:		
18 cast-iron upright binders (6 to each pair of kilns), 12¼ cwt. each = 11 tons ½ cwt., £5 2s. 6d. per ton, ...	£56 10s. 01d.	
12 cast-iron cross binders (4 to each pair of kilns), 10¼ cwt. each = 6 tons 3 cwt., £5 2s. 6d. per ton, ...	31 10 05	
9 malleable iron binding rods, 34 ft. long 1½ ft. diam., 16 cwt., at 6s. per ton, . .	4 16 00	
		£92 16s. 06d.
Capacity of Kilns:		£886 00 05d.
6 kilns, containing in the aggregate 140,000 bricks, 9x4½x2½ ins., 140,000.		

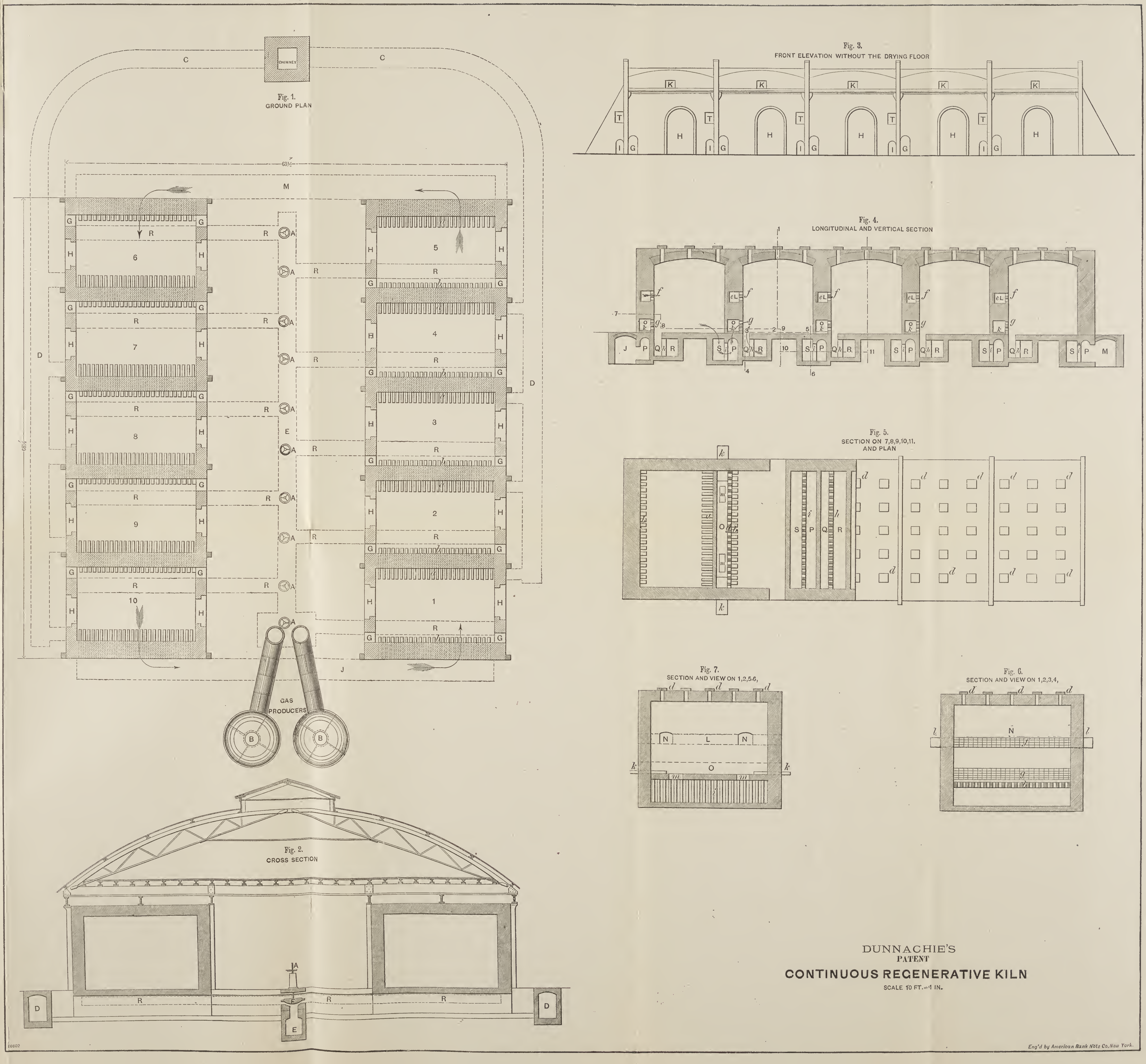
It is well to have the floor of these kilns on the same level with the floor of the drying stove, both of which should be about one foot at least above the ground level outside, to prevent water entering. The amount of excavation will depend on the ground level.

The depth of flues inside the kilns is 4 feet from floor, and the flue bottom is a brick on edge, so that the whole depth from kiln floor to bottom of excavation is 4 feet 4½ inches, say 4⅓ feet, but as the floor is one foot above the ground level, the excavation will be only 3⅓ feet deep.

The expense of filling, cooling, and emptying is the same in gas kilns as ordinary kilns, viz., for filling 1*s.* 3*d.* per 1000 bricks, and for emptying, 9*d.* per 1000 bricks. The expense for firing is also the same in both cases. One man takes charge of a set of ten kilns, having full charge of gas-making and brick-burning. In the regenerative system one kiln is always in full fire, and one is always rising to it by the spare heat of the burning kiln passing through it. There are also two steaming kilns ahead of the burning kilns, preparatory to the higher heats, the gas and air in this case passing in direct, as high heat is not wanted at this stage.



Pair of Newcastle Kilns.



DUNNACHIE'S
PATENT
CONTINUOUS REGENERATIVE KILN
SCALE 10 FT.=1 IN.