we have to do is to get two straight lines $a\,c$ and $c\,b$ drawn from the extremities a and b perpendicular over A and B, and meeting at apex of the arch, which shall give a curve which is as much outside the extrados and as much inside the intrados of the centre third of the arch ring. This is satisfied by the lines $a\,c$, $c\,b$ in Fig. 1, for taking the ordinate 3′ in dotted lines, it is seen that at this vertical—the points f and g being the projection of the middle third of arch ring upon it—that the line $a\,c$ is as much above the point f, the projection of the extrados of middle third of the arch ring, as the line $c\,b$ is below the point m, the projection of the intrados of the middle third of arch ring at the vertical 8′—the points $l\,m$ being the projection of the middle third of the ring at this ordinate. Having determined the position of these lines and drawn them in, project back again the points where the verticals 1′, 2′, 3′, &c., are cut by them, on to the ordinates 1, 2, 3, &c., in full lines, then connecting the points so obtained will give the nearest concentric curve of equilibrium which can be drawn within the arch ring for this loading, and which is shown in Fig. 1. by the curve in full lines. Having drawn this curve, measure its height at centre of span from the line $a\,b$, by the same scale to which the elevation of the arch was drawn; in this case its depth is 6·4ft. $= d$.

Now to check the accuracy of the work, the moments may be run out at the centre. We know that the strain at centre for a weight placed at any point upon the arch—or any other structure—is $\frac{x \times w}{2\,d}$, where x = distance from

arrived at graphically without calculation by drawing the closed polygon and taking any arbitrary value for the horizontal thrust, but it is not so correct as the method illustrated above, there being always the difficulty of drawing the curve with sufficient nicety when beginning at either side that it shall exactly close in on the opposite point.

In all the other Figs., 3 to 7, the curves of equilibrium for various distributions of the moving load have been got out in the above manner, and it is evident, in comparing the 25ft. and 35ft. spans, that the former with a five ring arch is much more severely strained transversely than the latter with six rings of brickwork, the curve of equilibrium departing more from the centre third of the arch ring in the former than in the latter. So long as the curve of equilibrium can be kept within the centre third of the arch ring, and the thrust is normal to the joint, the joints are wholly in compression, but so soon as this limit is exceeded a tension is set up on the side further away from the line of equilibrium.

A. S. H.

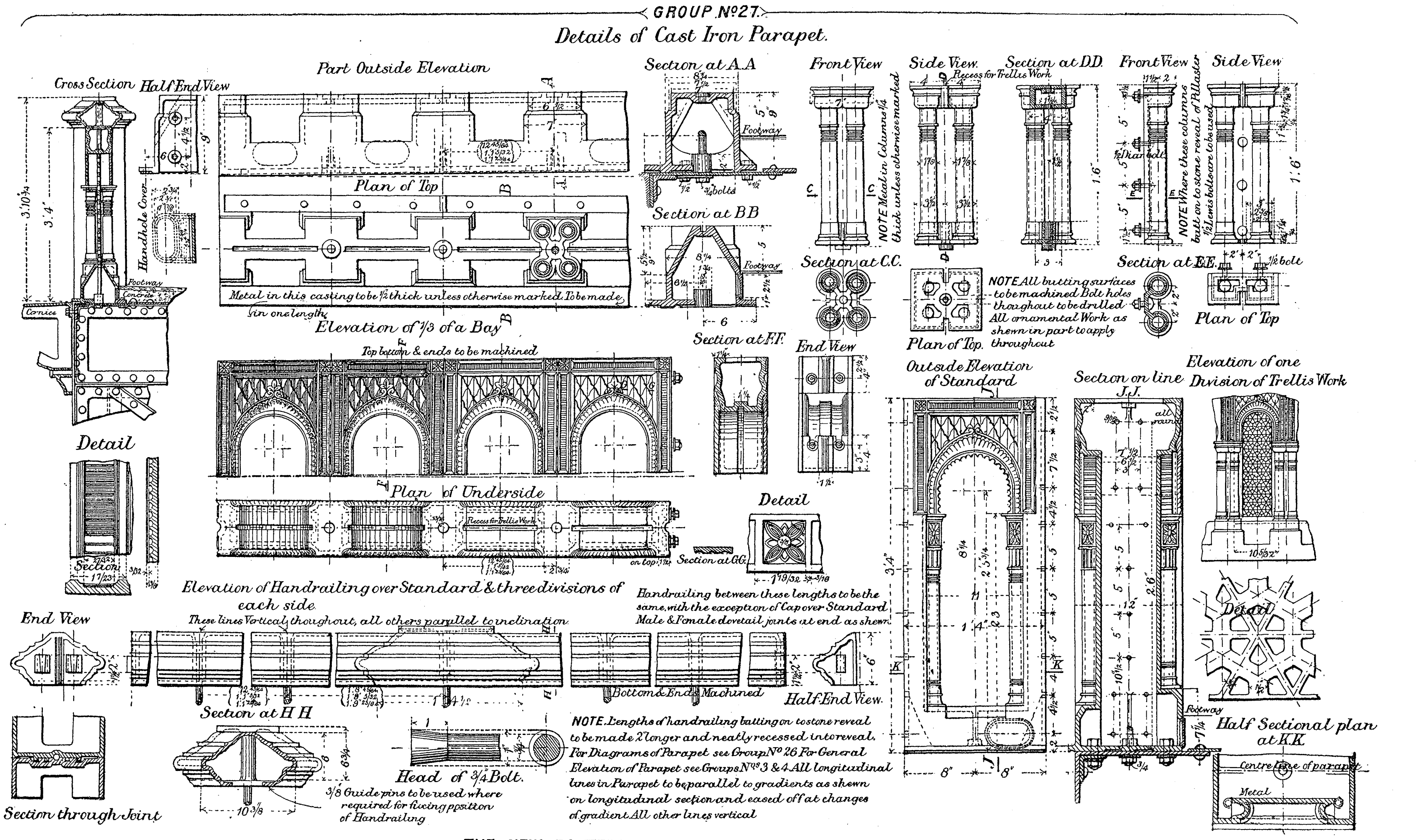
THE NEW BATTERSEA BRIDGE.

IN describing the fine new bridge now in course of construction from the designs of Sir Joseph Bazalgette, and partly illustrated in our last and present impressions, we may abstract the contract specification, and commence with the

Piers and abutments, the dams for which are whole-tide, consisting of a single row of Memel whole timber piles, 14in. by 14in., grooved and tongued and caulked with oakum. The

the face of the granite is to be smooth and fine axed, except the moulded courses, pedestals, and parapets, which in all cases, whether above or below Trinity high-water level, shall be fine chisel-dressed to the true form shown on the drawings, page 65. The whole of the masonry is to be set flush in beds of mortar, composed of 1 of Portland cement to 1 of sand, and properly grouted. The joints not to exceed ⅛in. in thickness. Grout nicks to be cut in all vertical joints of the ashlar work, according to the directions of the engineer, and the slate dowels or joggles, 2in. square and 4in. in length, to be inserted without extra charge whenever such may be considered necessary by the engineer. Under the footway on each side of the abutments are to be formed boxes or troughs for the purpose of containing any pipes which may be laid across the bridge. These troughs are to be formed in the concrete, as shown, and to be in continuation of the wrought iron pipe boxes over the arches. They are to be dipped down under the kerbs and channels at the back of the abutments, and shall be finished off in the position shown. In constructing the Surrey abutment the contractor is to form within it a 4ft. by 2ft. 8in. sewer in continuation of the sewer.

Approaches.—The raising of the Surrey approach is to commence at a point about 352ft. 6in. from the face of the abutment at a level of 14·78ft. above Ordnance datum, and to rise with a uniform gradient of 1 in 30 to the abutment. The approach is to have a uniform width of 60ft. for that part which extends from the abutment to the Folly, beyond which the width is to be gradually reduced to 57ft. at Europa-place. The footway on each side of the approach is to have a uniform width of 12ft., except where widened out at the abutments. The entire surface over the brick arches and piers is to be covered



THE NEW BATTERSEA BRIDGE—DETAILS OF PARAPET.

nearest abutment, w = weight, and d = depth or vers. sin. of arch; but as we elect to divide by d at once, the formula can be written $\frac{x}{2} \cdot \frac{w}{d}$, that is, we halve the distance from the abutments instead, which will come to the same thing. Working this out, it will stand thus:—

$$
\begin{array}{lcl}
24 & \times\ \tfrac{3}{4} & = 18\cdot \\
13\cdot0625 & \times\ 1\tfrac{3}{4} & = 22\cdot859375 \\
35\cdot125 & \times\ 2\tfrac{3}{4} & = 96\cdot59375 \\
8\cdot1875 & \times\ 3\tfrac{3}{4} & = 30\cdot703125 \\
6\cdot9375 & \times\ 4\tfrac{3}{4} & = 32\cdot953125 \\
6\cdot375 & \times\ 5\tfrac{3}{4} & = 36\cdot65625 \\
6\cdot375 & \times\ 5\tfrac{3}{4} & = 36\cdot65625 \\
6\cdot9375 & \times\ 4\tfrac{3}{4} & = 32\cdot953125 \\
8\cdot1875 & \times\ 3\tfrac{3}{4} & = 30\cdot703125 \\
10\cdot125 & \times\ 2\tfrac{3}{4} & = 27\cdot84375 \\
13\cdot0625 & \times\ 1\tfrac{3}{4} & = 22\cdot859375 \\
24 & \times\ \tfrac{3}{4} & = 18\cdot \\
\hline
162\cdot375 & & 406\cdot78125 = \text{moment at centre.}
\end{array}
$$

Then proceed to draw the polygon of forces, as shown in Fig. 2, by setting up the respective units. The reactions for the dead load will of course be half the total load, it being distributed symmetrically both sides of the arch; and for the live load of 25 cwt. at 5ft. 6in. from left abutment, 19·5 cwt. on R, and 5·5 cwt. on R_1, therefore on R there are 68·6875 + 19·5 = 88·1875 cwt., and on R_1 68·6875 + 5·5 = 74·1875 cwt. From the point on the vertical line of loads where these reactions meet draw a horizontal line, its value being $\frac{\text{moment}}{\text{depth}} = \frac{406\cdot78125}{6\cdot4} = 63\cdot56$ cwt. = horizontal thrust. Now complete the polygon. And by drawing lines parallel from the polygon of forces to their respective places in the curve they must coincide in direction, and if this is not so one may be quite sure some error has been made in one or other of the calculations or plotting, which will have to be rectified.

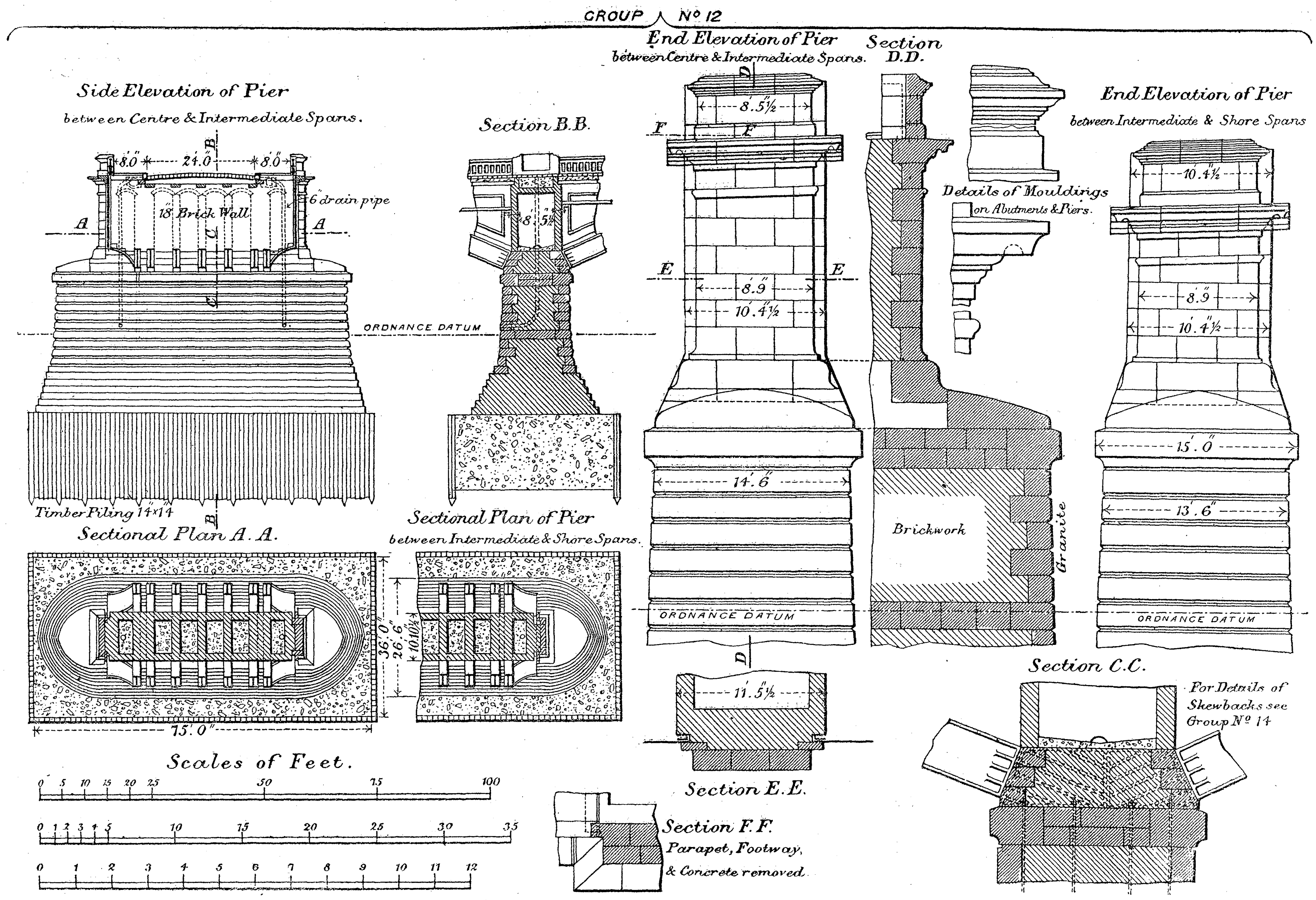
The curve of moments in dotted lines could have been

abutment dams are to have return ends for the perfect exclusion of the water from the excavations, to be sunk on the land side behind them. On all sides of the excavations for the pier foundations is to be driven a dam formed of close piling of whole timber, 14in. by 14in., grooved and tongued, and caulked where necessary above and below the ground level. The points of these piles are to be driven to a depth of 2ft. below the bottom of the concrete foundations. The tops of the piles to be cut off flush with the top of the concrete, which is to be finished off to a truly level surface 18ft. below Ordnance datum. In excavating for the pier foundations the whole of the material down to the level of 6ft. above the bottom of foundations is to be removed. The material below this level is to be excavated in trenches, securely timbered, and the trenches filled with concrete with the least possible delay. The concrete in the piers and abutments is to consist of clean Thames ballast and Portland cement, incorporated in the proportions of 6 to 1—by measure—respectively. The abutments are to be constructed of granite ashlar facing, backed with the best quality of picked stock brickwork set in Portland cement mortar, 2 of sand to 1 of cement, and with Portland cement concrete in the manner shown upon the drawings, page 46. The cast iron skewbacks and the holding down bolts, &c., are to be built in and grouted solid in the brickwork and masonry. The masonry is to be composed of horizontal courses of granite of the vertical depth shown on the drawings, each course to be composed of alternate headers and stretchers. Below Trinity high-water the headers to be not less than 3ft. in depth from the face, and 2ft. in width on the face, and the stretchers not more than 4ft. 6in. in length on the face, nor less than 1ft. 9in. in depth from the face, and above that level the headers to be not less than 2ft. 3in., and the stretchers not less than 1ft. 6in., in depth from the face. The stones in the alternate courses are to break bond with a lap of not less than 12in. The whole of the face of the granite which is below Trinity high-water level is to be smooth and fine axed—except the moulded course—the quality of the work being equal to that of the Victoria Embankment. The horizontal bed joints are to be fine dressed and splayed as shown, but the vertical joints to be plain and perfectly straight and fine picked for at least 15in. inward, the remainder of the granite to preserve its full dimensions and to be fair picked and straight between. Above Trinity high-water level, the whole of

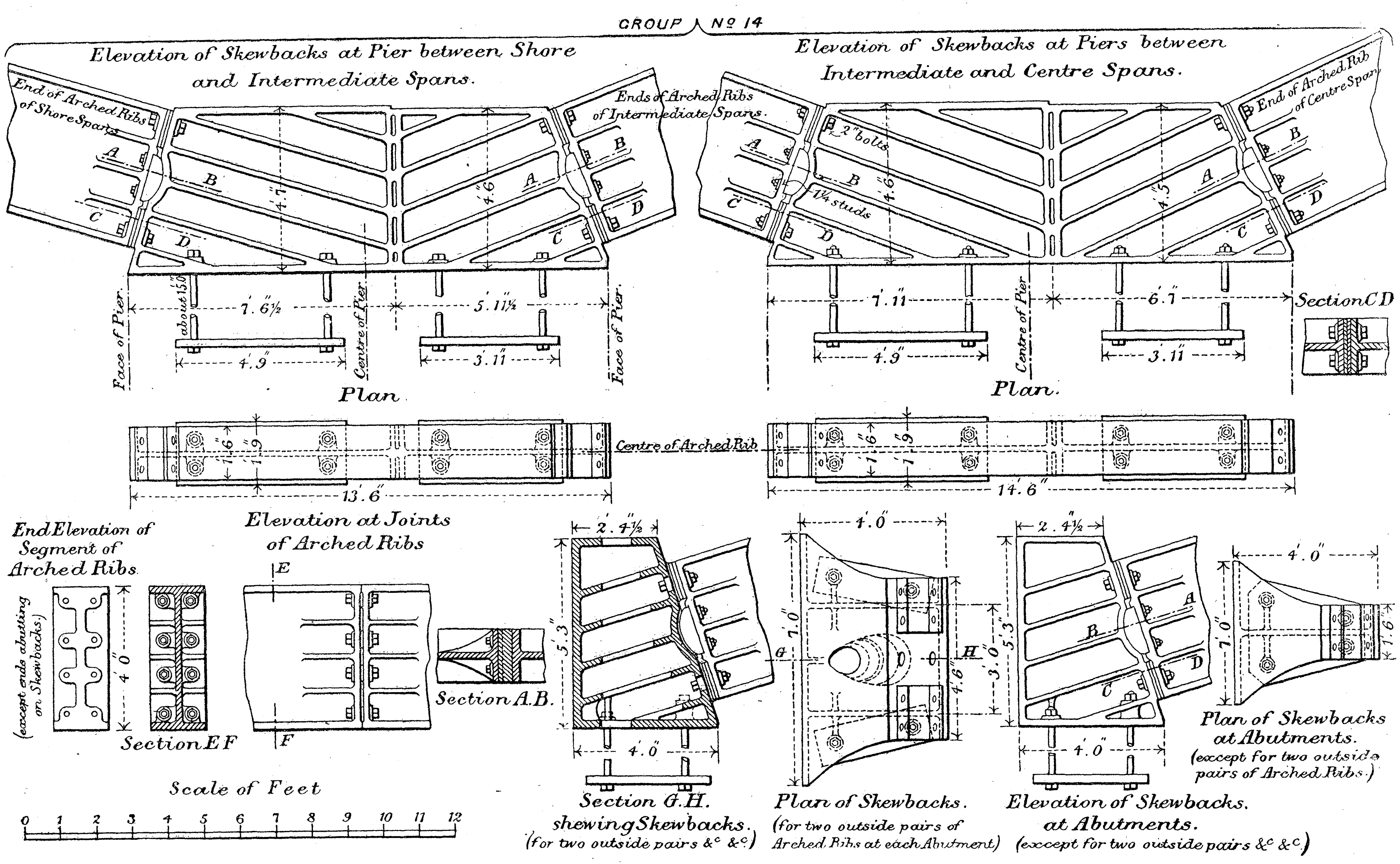
with Claridge's asphalte—quality No. 2—1in. thick, which is to be turned up 6in. at spandrel walls. The approach from the Chelsea Embankment is to commence at a level of 17·5ft. above Ordnance datum, and rise with a uniform gradient of 1 in 30 to the abutment.

Cast iron skewbacks and arched ribs.—At a level 1ft. below Ordnance datum, and immediately under the course of masonry which extends across the whole surface of the piers, and immediately under the lowest course of masonry of the abutments, is to be placed the cast iron washer plates bedded in Portland cement, and the bolts are to be fixed perfectly plumb and held in position by a template at their upper end, so that they may be in the right position for the holes in the skewbacks, and they are to be built up and grouted solid in the brickwork and masonry, no spaces being left. These skewbacks are to be cast and machined upon their skewfaces and in the recesses for the pivots, and each pair which are intended to butt on the piers must be fitted together in the workshops and gauged to the angles of the skewfaces shown on the drawings. There are to be five arches, each consisting of seven cast iron ribs, of the spans and versed sines shown. The radius to the intrados of each cast iron rib must be 193ft. 6in., and the sectional area of the ribs—the same for all arches—to be that shown on page 65. The segments, forming each arched rib, are to be five in number and of equal length. Each segment of the cast iron ribs for the centre and intermediate spans is to have three intermediate radial stiffeners, and each segment for the shore spans two intermediate radial stiffeners, as shown on the drawings. All butting surfaces of the segments are to be planed to radial lines. No bolt holes to be cast, but in all cases drilled, all bosses faced, and all bolts, either for joints or for connecting the wrought iron work, to be turned to an exact fit. On the upper flange, and in the positions required, are to be cast the lugs to which the vertical spandrel pillars are to be bolted. At the ends of the segments intended to form the springing of the arch, the metal of the radial flanges to be made with fillets cast on for holding the pivot. The pivot to be of cast iron and machined to gauge, and surfaced, with its bed, on the arched rib, and with the recess on the face of the skewback, so as to ensure that each arched rib may have a perfect bearing and be free from any initial bending strain at the springing. After the supports of all the arched ribs of a span have been removed so that the ribs take their own

weight, levels are to be taken to ascertain that all ribs occupy their intended position, and any not doing so are to be blocked up again at the supports, and one or more of the segments in such ribs taken out and altered. After all the arched ribs in a span have been ascertained to occupy their correct positions, the steel taper packings shown are to be finally finished off exactly to the required thicknesses and placed in position between the girders. In all angle irons forming the bracing the holes are to be carefully drilled. The lower ends of the T irons forming the pillars are to be neatly joggled to fit the cast iron lugs on the ribs. The bolt holes through the T irons and lugs are to be drilled in place, and the bolts turned to fit. Taper washers to be provided as shown. The construction of the wrought iron box or trough for carrying pipes is to be carried on at the same transverse curvature. At the parts where the above arrangements of curved plates ceases, and the longitudinal girders commence, there will be transverse plates, as shown, connecting angle irons on the lower and upper curved plates, and enclosing the concrete. The longitudinal girders are to be made continuous over the spandrel pillars. The plates for the coving to be of mild steel ¼in. thick, and of such a quality that they can



THE NEW BATTERSEA BRIDGE—THE PIERS AND SPRINGINGS.



THE NEW BATTERSEA BRIDGE—DETAILS OF IRON SKEWBACKS.

face of the skewback and the end of the arched rib, the bolt holes drilled through them, and turned bolts inserted as shown. When the springings of all the ribs of a span have been fixed as shown, the radial stiffeners on the ribs are to receive the L iron bracing. Upon the completion of this bracing, the contractor will proceed to erect the vertical T iron pillars, diagonal bracings, and longitudinal and cross girders; and also the framework which is to support the coving and footways, and upon the time as that of the curved plates of the platform. It shall be continued over the piers and widened out at the abutments, and shall be finished off as shown on the drawings. In all cases the space provided inside the box shall be fully equal to that shown on the drawings. The curved plates for supporting the concrete under the carriage-way at the centre of each span are for some length carried directly on the cast iron arched ribs. These plates are to be bent to a radius of 197·5ft. in addition to their be turned out to the required curves and to the exact form shown on drawing. The curves of the top edge of the coving at the centres of the spans are to be tangential to a horizontal line, and the levels of these curves at the centres such that the minimum distance from the underside of the cornice, 21in. deep, to the top edge of the coving, must not be less than 12in. in any of the spans. On the spandrel face, over the edge of the coving is to be bolted the cast iron cornice shown on page 64.

Paving, &c.—Over the whole surface of the curved wrought iron carriage-way and footway plates—which will have been previously tarred—over the whole top surface of the piers, and over the surface of the abutments to the extent shown, is to be a layer of fine Portland cement concrete to form a bed for the paving. The concrete is to be mixed in the proportion of four of very fine ballast to one of Portland cement; the surface shall be finished off evenly and to the exact curves and levels required, and the concrete is to set hard before being covered by the paving. There is to be one pair of granite trams for the traffic ascending the gradient in each direction, and commencing in a line with the granite setts at each abutment, and ending at the centre of the bridge. They are to be of Aberdeen or Guernsey granite, 12in. wide by 7in. deep, and not less than 3ft. in length, all to be worked fair and fine-dressed on the top face. The kerbs and channels for the total length between the abutment faces are to be of cast iron of the section shown.

Materials and tests.—All ironwork and steel used for the work shall be of British manufacture. The steel for the coving plates is to be capable of resisting a tensile strain of not less than 25 tons per square inch, and not exceeding 28 tons per square inch, and shall elongate not less than 20 per cent. in 8in. All wrought iron must be tough, fibrous, and uniform in character. It shall have a limit of elasticity of not less than 26,000 lb. per square inch. Full size pieces of round, flat, or square iron, not less than 4½in. in sectional area, to have an ultimate strength of 50,000 lb. per square inch, and stretch uniformly 9 per cent. throughout their whole length. Bars of a larger sectional area than 4½ square inches, when tested in the usual way, will be allowed a reduction of 1000 lb. per square inch for each additional square inch of section, down to a minimum of 46,000 lb. per square inch. When tested in specimens of uniform sectional area of at least ½ square inch for a distance of 10in., taken from tension members which have been rolled to a section of not more than 4½ square inches, the iron must show an ultimate strength of 52,000 lb. per square inch, and stretch at least 12 per cent. in a length of 8in. Specimens taken from bars of larger cross section than 4½ square inches will be allowed a reduction of 500 lb. for each additional square inch of section, down to a minimum of 50,000 lb. The same sized specimen taken from angle and other shaped iron must have an ultimate strength of 50,000 lb. per square inch, and elongate 11 per cent. in 8in. The same sized specimen taken from plate iron must have an ultimate strength of 48,000 lb. and elongate 11 per cent. in 8in. All iron for tension members must bend cold for about 90 deg., to a curve whose diameter is not over twice the thickness of the piece, without cracking. At least one sample in three must bend 180 deg. to this curve without cracking. When nicked on one side and bent by a blow from a sledge hammer, the fracture must be nearly all fibrous and showing but few crystalline specks. Specimens from angle, plate, and shaped iron must stand bending cold, and to a curve whose diameter is not over three times its thickness, without cracking. When nicked and bent its fracture must be mostly fibrous. Rivets and pins must be made from the best double-refined iron. The cast iron must be of the best quality of soft grey iron. At least six test bars must be cast from each running of the metal for the cast iron ribs, skewbacks, &c., each be 3ft. 6in. long by 1in. broad by 2in. deep; three bars to be subjected to tensile strain, and three shall be tested transversely by placing them edgeways on bearings 3ft. apart, and loading the centre of the bar, when they must not break with less than 27 cwt. or a tensile strain of 9 tons per square inch. The bricks to be used under this contract, except where otherwise specially provided, are to be picked stock bricks, of the best and hardest quality. No broken bricks or bats are to be brought upon the works. The granite must be Aberdeen, Guernsey, Dalbeattie, or the best quality of Cornish.

FUEL AND SMOKE.*

Lecture II.

The points to which I specially called your attention in the first lecture, and which it is necessary to recapitulate to-day, are these:—(1) That coal is distilled, or burned partly into gas, before it can be burned. (2) That the gas so given off, if mixed with carbonic acid, cannot be expected to burn properly or completely. (3) That to burn the gas a sufficient supply of air must be introduced at a temperature not low enough to cool the gases below their igniting point. (4) That in stoking a fire a small amount should be added at a time because of the heat required to warm and distil the fresh coal. (5) That fresh coal should be put in front of, or at the bottom of a fire, so that the gas may be thoroughly heated by the incandescent mass above; and thus, if there be sufficient air, have a chance of burning. A fire may be inverted, so that the draught proceeds through it downwards. This is the arrangement in several stoves, and in them, of course, fresh coal is put at the top.

Two simple principles are at the root of all fire management: (1) Coal gas must be at a certain temperature before it can burn; and (2) it must have a sufficient supply of air. Very simple, very obvious, but also extremely important, and frequently altogether ignored. In a common open fire they are both ignored. Coal is put on the top of a glowing mass of charcoal, and the gas distilled off is for a long time much too cold for ignition, and when it does catch fire it is too mixed with carbonic acid to burn completely or steadily. In order to satisfy the first condition better, and keep the gases at a higher temperature, Dr. Pridgin Teale arranges a sloping fire-clay slab above his fire. On this the gases play, and its temperature helps them to ignite. It also acts as a radiator, and is said to be very efficient.

In a close stove, and in many furnaces, the second condition is violated; there is an insufficient supply of air; fresh coal is put on, and the feeding-doors are shut. Gas is distilled off, but where is it to get any air from? How on earth can it be expected to burn? Whether it be expected or not, it certainly does not burn, and such a stove is nothing else than a gasworks, making crude gas and wasting it—it is a soot and smoke factory.

Most slow combustion stoves are apt to err in this way; you make the combustion slow by cutting off air, and you run the risk of stopping the combustion altogether. When you wish a stove to burn better, it is customary to open a trap-door below the fuel; this makes the red-hot mass glow more vigorously, but the oxygen will soon become CO_2, and be unable to burn the gas. The right way to check the ardour of a stove is not to shut off the air supply and make it distil its gases unconsumed, but to admit so much air above the fire that the draught is checked by the chimney ceasing to draw so fiercely. You, at the same time, secure better ventilation; and if the fire becomes visible to the room so much the better and more cheerful. But if you open up the top of a stove like this, it becomes, to all intents and purposes, an open fire. Quite so, and in many respects therefore an open fire is an improvement on a close stove. An open fire has faults, and it certainly wastes heat up the chimney. A close stove may have more faults—it wastes less *heat*, but it is liable to waste *gas* up the chimney—not necessarily visible or smoky gas—it may waste it from coke or anthacite, as CO.

You now easily perceive the principles on which so-called smoke consumers are based. They are all special arrangements or appendages to a furnace for permitting complete combustion by satisfying the two conditions which had been violated in its original construction. But there is this difficulty about the air supply to a furnace: the needful amount is variable if the stoking be intermittent, and if you let in more than the needful amount you are unnecessarily wasting heat and cooling the boiler, or whatever it is, by a draught of cold air.

Every time a fresh shovelfull is thrown on a great production of gas occurs, and if it is to flame it must have a correspondingly great supply of air. After a time, when the mass has become red-hot, it can get nearly enough air through the bars. But at first the evolution of gas actually checks the draught. But remember that although no smoke is visible from a glowing mass, it by no means follows that its combustion is perfect. On an open fire it probably is perfect, but not necessarily in a close stove or furnace. If you diminish the supply of air much—as by clogging your furnace bars and keeping the doors shut—you will be merely distilling carbonic oxide up the chimney—a poisonous gas, of which probably a considerable quantity is frequently given off from close stoves.

Now let us look at some smoke consumers. The diagrams show those of Chubb, Gowthorpe, Ireland, and Lowndes, and of Gregory. You see that they all admit air at the "bridge" or back of the fire, and that this air is warmed either by passing under or round the furnace, or in one case through hollow fire bars. The regulation of the air supply is effected by hand, and it is clear that some of these arrangements are liable to admit an unnecessary supply of air, while others scarcely admit enough, especially when fresh coal is put on. This is the difficulty with all these arrangements when used with ordinary hand—*i.e.*, intermittent—stoking. Two plans are open to us to overcome the difficulty. Either the stoking and the air supply must both be regular and continuous, or the air supply must be made intermittent to suit the stoking. The first method is carried out in any of the many forms of mechanical stoker, of which this of Sinclair's is an admirable specimen. Fresh fuel is perpetually being pushed on in front, and by alternate movement of the fire bars the fire is kept in perpetual motion till the ashes drop out at the back. To such an arrangement as this a steady air supply can be adjusted, and if the boiler demand is constant there is no need for smoke, and an inferior fuel may be used. The other plan is to vary the air supply to suit the stoking. This is effected by Prideaux automatic furnace doors, which have louvres to remain open for a certain time after the doors are shut, and so to admit extra air immediately after coal has been put on, the supply gradually decreasing as distillation ceases. The worst of air admitted through chinks in the doors, or through partly open doors, is, that it is admitted cold, and scarcely gets thoroughly warm before it is among the stuff it has to burn. Still, this is not a fatal objection, though a hot blast would be better. Nothing can be worse than shovelling on a quantity of coal and shutting it up completely. Every condition of combustion is thus violated, and the intended furnace is a mere gas retort.

Gas Producers.—Suppose the conditions of combustion are purposely violated we at once have a gas producer. That is all gas producers are, extra bad stoves or furnaces, not always much worse than things which pretend to serve for combustion. Consider how ordinary gas is made. There is a red-hot retort or cylinder plunged in a furnace. Into this tube you shovel a quantity of coal, which flames vigorously as long as the door is open, but when it is full you shut the door, thus cutting off the supply of air and extinguishing the flame. Gas is now simply distilled and passes along pipes to be purified and stored. You perceive at once that the difference between a gas retort and an ordinary furnace with closed doors and half-choked fire bars is not very great. Consumption of smoke! It is not smoke consumers you really want, it is fuel consumers. You distil your fuel instead of burning it, in fully one-half, might I not say nine-tenths, of existing furnaces and close stoves. But in an ordinary gas retort the heat required to distil the gas is furnished by an outside fire; this is only necessary when you require lighting gas, with no admixture of carbonic acid and as little carbonic oxide as possible. If you wish for heating gas you need no outside fire; a small fire at the bottom of a mass of coal will serve to distil it, and you will have most of the carbon also converted into gas. Here, for instance, is Siemens' gas producer. The mass of coal is burning at the bottom, with a very limited supply of air. The carbonic acid formed rises over the glowing coke, and takes up another atom of carbon to form the combustible gas carbonic oxide. This and the hot nitrogen passing over and through the coal above distil away its volatile constituents, and the whole mass of gas leaves by the exit pipe. Some art is needed in adjusting the path of the gases distilled from the fresh coal with reference to the hot mass below. If they pass too readily, and at too low a temperature, to the exit pipe, this is apt to get choked with tar and dense hydrocarbons. If it is carried down near or through the hot fuel below, the hydrocarbons are decomposed over much, and the quality of the gas becomes poor. Moreover, it is not possible to make the gases pass freely through a mass of hot coke; it is apt to get clogged. The best plan is to make the hydrocarbon gas pass over and near a red-hot surface so as to have its heaviest hydrocarbons decomposed, but so as to leave all those which are able to pass away as gas uninjured, for it is to the presence of these that the gas will owe its richness as a combustible material, especially when radiant heat is made use of.

The only inert and useless gas in an arrangement like this is the nitrogen of the air, which being in large quantities does act as a serious diluent. To diminish the proportion of nitrogen, steam is often injected as well as air. The glowing coke can decompose the steam, forming carbonic oxide and hydrogen, both combustible. But of course no extra energy can be gained by the use of steam in this way; all the energy must come from the coke, the steam being already a perfectly burned product; the use of steam is merely to serve as a vehicle for converting the carbon into a convenient gaseous equivalent. Moreover, steam injected into coke cannot keep up the combustion; it would soon put the fire out unless air is introduced too. Some air is necessary to keep up the combustion, and therefore some nitrogen is unavoidable. But some steam is advisable in every gas producer, unless pure oxygen could be used instead of air; or unless some substance like quicklime, which holds its oxygen with less vigour than carbon does, were mixed with the coke and used to maintain the heat necessary for distillation. A well known gas producer for small scale use is Dowson's. Steam is superheated in a coil of pipe, and blown through glowing anthracite along with air. The gas which comes off consists of 20 per cent. hydrogen, 30 per cent. carbonic oxide, 3 per cent. carbonic acid, and 47 per cent. nitrogen. It is a weak gas, but it serves for gas engines, and is used, I believe, by Thompson, of Leeds, for firing glass and pottery in a gas kiln. It is said to cost 4d. per 1000ft., and to be half as good as coal-gas.

For furnace work, where gas is needed in large quantities, it must be made on the spot. And what I want to insist upon is this, that all well-regulated furnaces are gas retorts and combustion chambers combined. You may talk of burning coal, but you can't do it; you must distil it first, and you may either waste the gas so formed or you may burn it properly. The thing is to let in not too much air, but just air enough. Look, for instance, at Minton's oven for firing pottery. Round the central chamber are the coal hoppers, and from each of these gas is distilled, passes into the central chamber where the ware is stacked, and meeting with an adjusted supply of air as it rises, it burns in a large flame, which extends through the whole space and swathes the material to be heated. It makes its exit by a central hole in the floor, and thence rises by flues to a common opening above. When these ovens are in thorough action, nothing visible escapes. The smoke from ordinary potters' ovens is in Staffordshire a familiar nuisance. In the Siemens gas producer and furnace, of which Mr. Frederick Siemens has been good enough to lend me this diagram, the gas is not made so closely on the spot, the gas retort and furnace being separated by a hundred yards or so in order to give the required propelling force. But the principle is the same; the coal is first distilled, then burnt. But to get high temperature the air supply to the furnace must be heated, and there must be no excess. If this is carried on by means of otherwise waste heat we have the regenerative principle, so admirably applied by the Brothers Siemens, where the waste heat of the products of combustion is used to heat the incoming air and gas supply. The reversing arrangement by which the temperature of such a furnace can be gradually worked up from ordinary flame temperature to something near the dissociation point of gases, far above the melting point of steel, is well known, and has already been described in this place. Mr. Siemens has lent me this beautiful model of the most recent form of his furnace, showing its application to steel making and to glass working.

The most remarkable and, at first sight, astounding thing about this furnace is, however, that it works solely by radiation. The flames do not touch the material to be heated; they burn above it, and radiate their heat down to it. This I regard as one of the most important discoveries in the whole subject, viz., that to get the highest temperature and greatest economy out of the combustion of coal one must work directly by radiant heat only; all other heat being utilised indirectly to warm the air and gas supply, and thus to raise the flame to an intensely high temperature.

It is easy to show the effect of supplying a common gas flame with warm air by holding it over a cylinder packed with wire gauze which has been made red-hot. A common burner held over such a hot air shaft burns far more brightly and whitely. There is no question but that this is the plan to get good illumination out of gas combustion; and many regenerative burners are now in the market, all depending on this principle and utilising the waste heat to make a high temperature flame. But although it is evidently the right way to get light, it was by no means evidently the right way to get heat. Yet so it turns out; not by warming solid objects or by dull warm surfaces, but by the brilliant radiation of the hottest flame that can be procured will rooms be warmed in the future. And if one wants to boil a kettle it will be done not by putting it into a non-luminous flame, and so interfering with the combustion, but by holding it near to a freely burning regenerated flame and using the radiation only. Making toast is the symbol of all the heating of the future, provided we regard Mr. Siemens' view as well established.

The ideas are founded on something like the following considerations:—Flame cannot touch a cold surface, *i.e.*, one below the temperature of combustion, because by the contact it would be put out. Hence, between a flame and the surface to be heated by it, there always intervenes a comparatively cool space, across which heat must pass by radiation. It is by radiation ultimately therefore that all bodies get heated. This being so, it is well to increase the radiating power of flame as much as possible. Now, radiating power depends on two things, the presence of solid matter in the flame in a fine state of subdivision, and the temperature to which it is heated. Solid matter is most easily provided by burning a gas rich in dense hydrocarbons not a poor and non-luminous gas. To mix the gas with air so as to destroy and burn up these hydrocarbons seems therefore to be a retrograde step—useful undoubtedly in certain cases, as in the Bunsen flame of the laboratory, but not the ideal method of combustion. The ideal method looks to the use of a very rich gas and the burning of it with a maximum of luminosity. The hot products of combustion must give up their heat by contact. It is for them that cross tubes in boilers are useful. They have no combustion to be interfered with by cold contacts. The *flame* only should be free.

The second condition of radiation was high temperature. What limits the temperature of a flame? Dissociation or splitting up of a compound by heat. So soon as the temperature reaches the dissociation point at which the compound can no longer exist combustion ceases. Anything short of this may theoretically be obtained.

But Mr. Siemens believes, and adduces some evidence to prove, that the dissociation point is not a constant and definite temperature for a given compound; it depends entirely upon whether solid or foreign surfaces are present or not. These it is which appear to be an efficient cause of dissociation, and which therefore limit the temperature of flame. In the absence of all solid contact, Mr. Siemens believes that dissociation, if it occur at all, occurs at an enormously higher temperature, and that the temperature of free flame can be raised to almost any extent. Whether this be so or not, his radiating flames are most successful, and the fact that large quantities of steel are now melted by mere flame radiation speaks well for the correctness of the theory upon which his practice has been based.

Use of small coal.—Meanwhile, we may just consider how we ought to deal with solid fuel, whether for the purpose of making gas from it or for burning it *in situ*. The question arises, in what form ought solid fuel to be—ought it to be in lumps or in powder? Universal practice says lumps, but some theoretical considerations would have suggested powder. Remember, combustion is a chemical action, and when a chemist wishes to act on a solid easily, he always pulverises it as a first step.

Is it not possible that compacting small coal into lumps is a wrong operation, and that we ought rather to think of breaking big coal down into slack? The idea was suggested to me by Sir W. Thomson in a chance conversation, and it struck me at once as a brilliant one. The amount of coal wasted by being in the form of slack is very great. Thousands of tons are never raised from the pits because the price is too low to pay for the raising—in some places it is only 1s. 6d. a ton. Mr. Mc Millan calculates that 130,000 tons of breeze, or powdered coke, is produced every year by the Gas Light and Coke Company alone, and its price is 3s. a ton at the works, or 5s. delivered.

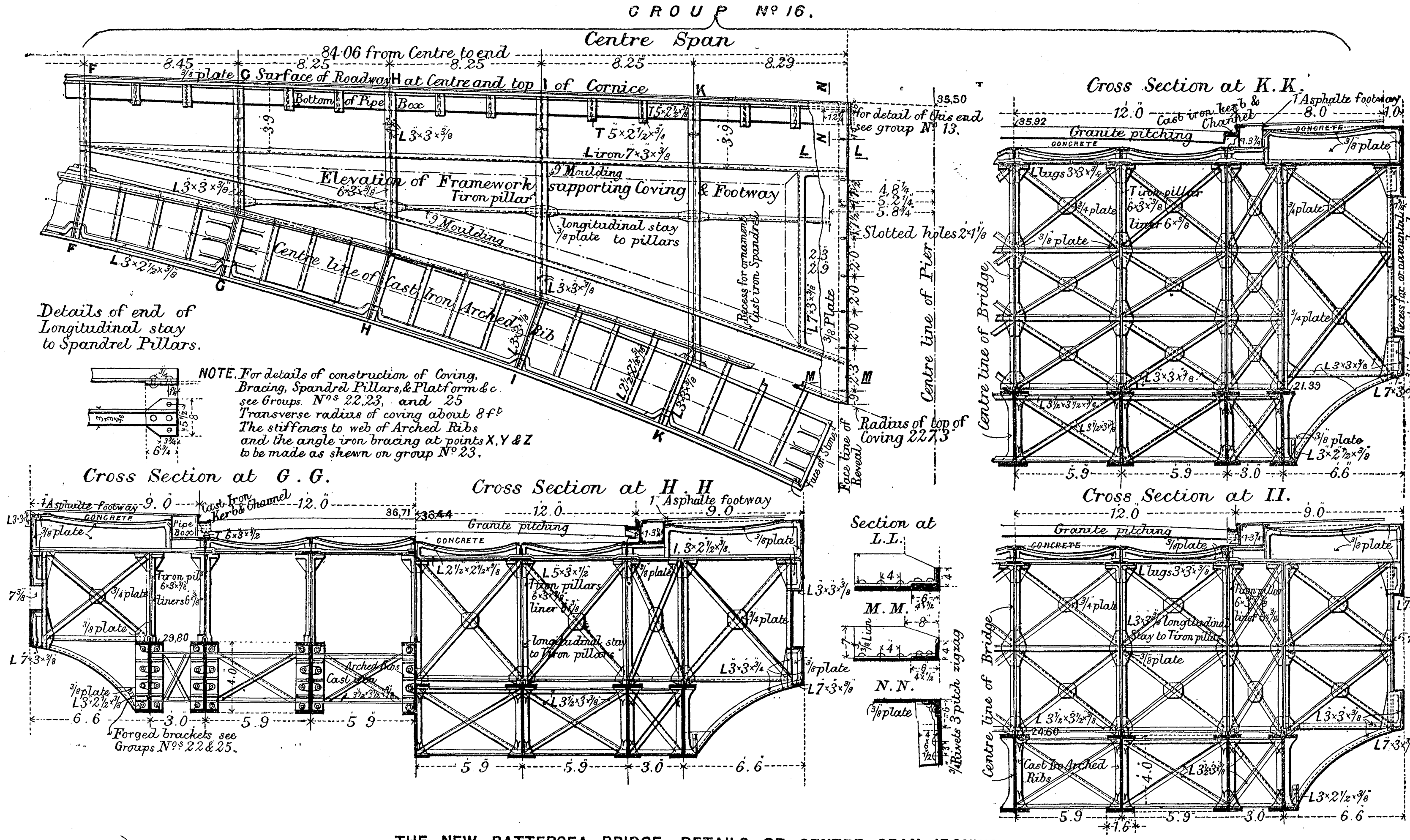
The low price and refuse character of small coal is, of course

* Second of two Lectures delivered by Professor Oliver Lodge, at the Royal Institution, London, on 17th April, 1886.

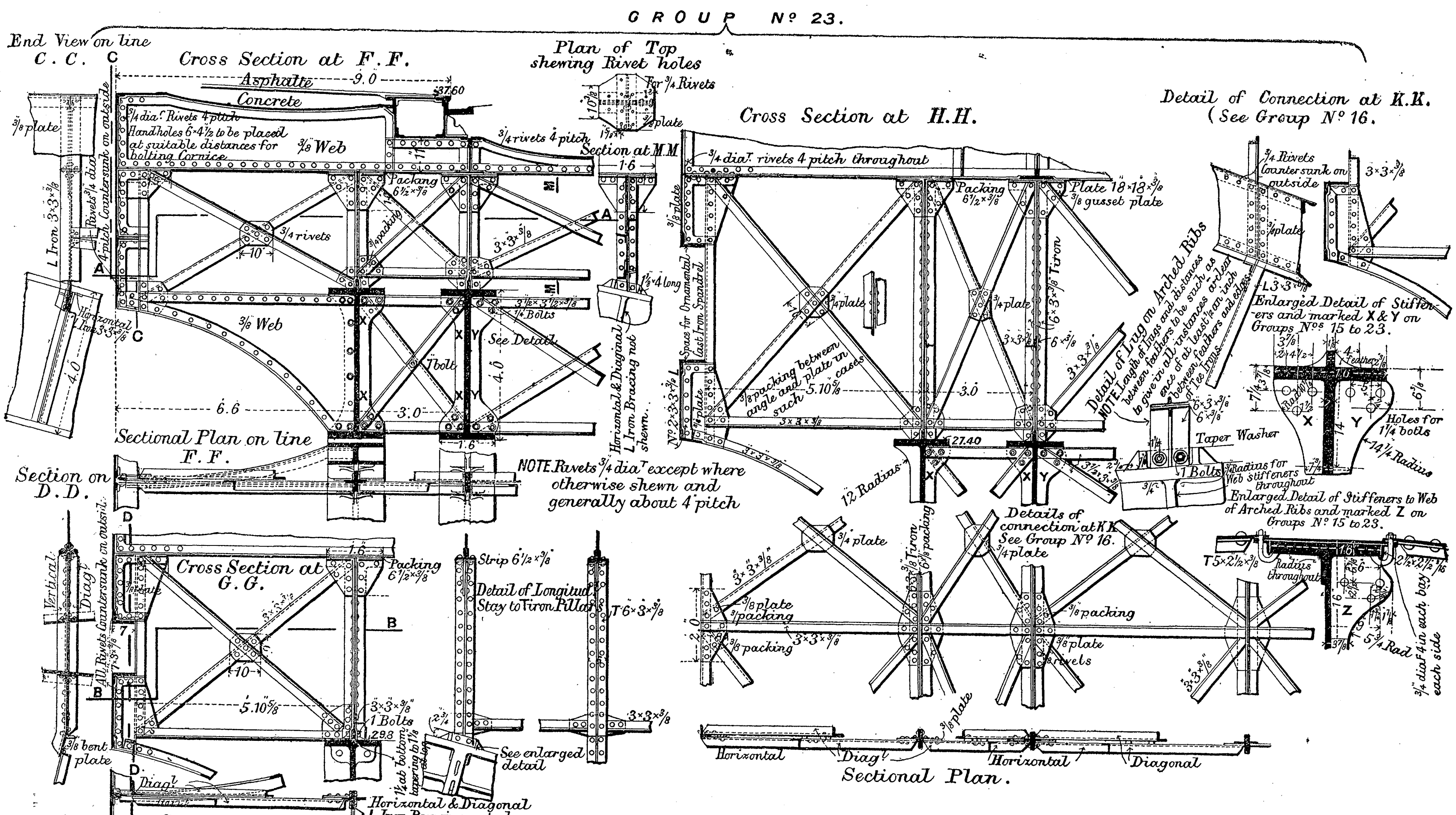
THE NEW BATTERSEA BRIDGE.—DETAILS.

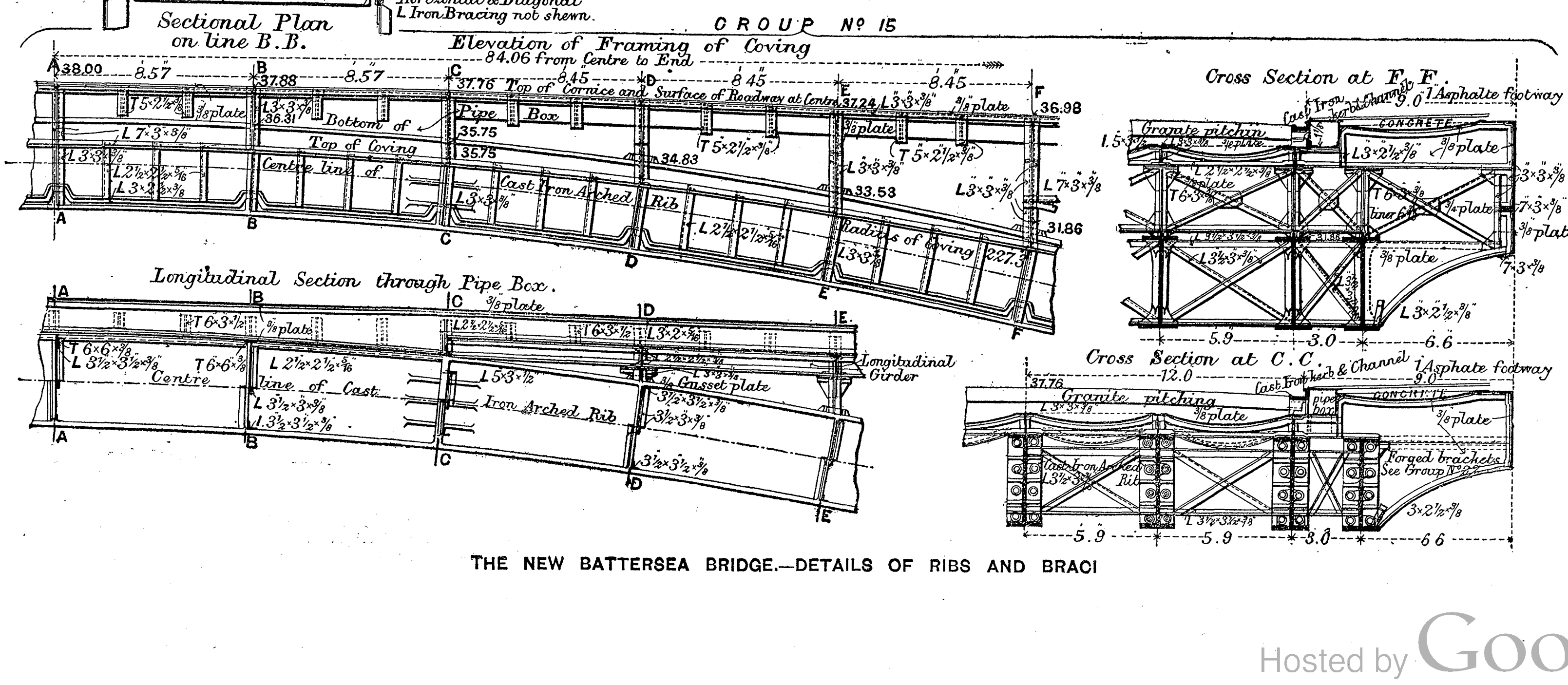
SIR JOSEPH BAZALGETTE, M.I.C.E., ENGINEER.

(For description see page 64.)



THE NEW BATTERSEA BRIDGE.—DETAILS OF CENTRE SPAN IRONWORK





THE NEW BATTERSEA BRIDGE.—DETAILS OF RIBS AND BRACI