William Perceval C. E. May 1853.

THE

BUILDING

ERECTED IN HYDE PARK

FOR THE GREAT EXHIBITION

OF THE

WORKS OF INDUSTRY

OF

All Nations,

1851.

ILLUSTRATED BY TWENTY-EIGHT LARGE PLATES, EMBRACING PLANS, ELEVATIONS, SECTIONS, AND DETAILS, LAID DOWN TO A LARGE SCALE FROM THE WORKING DRAWINGS OF THE

CONTRACTORS, Messrs. FOX, HENDERSON, and Co.

BY

CHARLES DOWNES, Architect.

WITH SCIENTIFIC DESCRIPTION BY

CHARLES COWPER, Assoc.Inst.C.E.

LONDON:
JOHN WEALE, 59, HIGH HOLBORN.

1852.

LONDON:
GEORGE WOODFALL AND SON,
ANGEL COURT, SKINNER STREET.

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INTRODUCTION.

VARIOUS descriptions of the Building of the Great Exhibition in Hyde Park have already appeared, and it may, therefore, be necessary to state in what respects the present work differs from them. While preceding works have generally aimed at giving a popular account of the Building and its history, with but few engravings, and those rather explanatory than exact, the present work consists of a scientific description of the construction of the Building, and contains numerous large plates, showing the details of the construction and the dimensions of every part. The object has been to produce a work so correct and complete as to enable an architect or engineer to erect a similar building if necessary. The whole is founded on authentic information, the illustrations having been prepared with great care from the original drawings in the possession of the contractors, Messrs. Fox, Henderson, and Co.

There are several peculiarities in the construction of the Building which are particularly deserving of the attention of the engineer and architect.

In the first place it is constructed entirely of iron, wood, and glass; and it is worthy of remark that there are no *large* pieces of either material employed. The heaviest pieces of cast iron are the girders, which are 24 feet in length, and none of which weigh more than a ton; the wrought iron consists chiefly of round and flat bars, angle irons, bolts, screws, and rivets. A large quantity of sheet iron is also employed in the construction of the louvres.

Wood is used in the main gutters and Paxton gutters, the arched ribs of the Transept, the sash-bars and ridges, the ground-floor and gallery floors, the lead flats and the external wall, and in some of the girders or trusses. The glass is sheet or cylinder glass, in panes 10 in. × 49 in., and weighs 16 oz. per square foot.

The materials, therefore, are not of such a nature as to restrict the construction of similar buildings to any particular country. Timber is found almost everywhere; and all civilized countries possess glass manufactories. Iron, although widely distributed, is not quite universal; but its transport in pieces of the dimensions required is sufficiently easy to place it within the reach of those countries which do not naturally possess it. In many parts of the building iron might be substituted for wood, and wood for iron, by proportioning the dimensions accordingly, and iron or wood might be substituted for the glass. The Building may be described generally as consisting of a framework of columns, united by girders or trusses, and covered with glass, arranged in a succession of ridges and furrows. One of the most important features in the construction is the form of girder or truss adopted by the contractors, and which has two distinct duties to perform. The first and most obvious duty of the girders is to support the roof, but their second and equally important duty is to give lateral stiffness to the whole structure. A girder of any form, provided its strength were sufficient, would have served to carry the roof, and might merely have rested on the top of the columns; but this would have given no lateral stiffness to the building, which might then have been levelled with the ground by the first storm. The contractors, therefore, in place of devising separate and independent means of supporting the columns and preserving their perpendicularity, adopted the plan of distributing the metal of the girders in a form which should possess a much greater depth than is usually employed in cast-iron girders; and then, by firmly connecting the top and bottom of each girder to the columns, they at once obtained the desired result. The columns and girders thus connected may be compared to an ordinary four-legged table in which the side rails, which support the upper surface, are firmly fixed to the legs. A want of comprehension of this effect of the girders was the cause of a great waste of criticism on the presumed weakness of the structure.

To obtain the requisite depth of girder, without unnecessarily increasing its weight or diminishing its thickness, it became necessary to cast it open, and the proper form of the apertures through it had to be decided. Various ornamental forms were proposed, but it was necessary to study strength as the first consideration. The trellis form, shown in Fig. 3, Plate X., was therefore adopted, and its great superiority over any other form will soon be perceived. It consists of a top and bottom rail or flange, A and D, united by four perpendicular struts, B B, C C, and the diagonals E F G, and the load is supported over the two struts B B.

If we dissect this girder, and consider first the top rail A, the struts B B, the diagonals E E, and the central portion of the bottom rail D, we have a simple trussed beam, the rail A being exposed to compression, and prevented from deflecting by the struts B B, which discharge the weight on the parts E D E, which in effect form a tie suspended from the two ends of the rail A, which keeps it extended. The struts C C rest on the columns, and support the whole. If we now disregard these parts, and consider merely the bottom rail D, the diagonals F F, and the central part of the top rail A, we have an arch F A F confined by the tie D. If, however, a weight is placed on only one of the struts B (which may happen by crowds moving along the galleries), there would be a tendency to distort the form of the arch. This is effectually prevented by the introduction of the diagonals G G. If we now view the girder as a whole, we find that it combines both the trussed girder and the arch, and that the central part of the top and bottom flanges is active in both cases. This part, therefore, is exposed to a greater strain than the other parts, and is accordingly strengthened by widening the flanges. The whole of the metal is thus distributed exactly in the parts in which it is required for supporting the load. At the same time the whole forms a stiff frame admirably adapted for connecting the columns and preventing their deviating from the perpendicular.

The arrangement of all the principal dimensions of the building, in multiples and sub-multiples of one primary dimension, which in this case is 24 feet, is another point which is deserving of attention. It not only facilitates and economizes all the operations by the frequent repetition of the same parts, but it also produces perfect symmetry in the building, and creates beautiful effects by the long vistas which are seen between the columns in every diagonal direction, as well as in the longitudinal and transverse views. These effects were very apparent before the building was occupied, but are now interfered with by the fittings and the goods exposed, which in many cases reach to the galleries. The frequent recurrence to the same dimensions renders it easy to erect buildings, on this construction, of any required size. Thus an additional strip of 48 feet wide is added to the main building on the north side. Another point to which we would call attention is the employment of columns whose external diameter and form are the same throughout the building, but whose internal diameter and thickness of metal are varied according to the pressure to which they are subjected. If the external diameter had been altered, variations would have been required in the length of the girders and many other parts, and the difficulties of the construction, and the time required to design and erect it, would have been much increased. At the four corners of the junction of the Nave and Transept, where the columns are exposed to the greatest pressure, the thickest columns are used, and the load is supported by two columns at each corner in place of one.

Another point to which we would particularly direct attention is the fact that all the columns are turned or faced at their ends, and the surfaces to which they are connected are also faced. This proceeding, although it may at first sight appear an unnecessary and expensive refinement, proved of the utmost importance in facilitating the rapid erection of the building, and effected a real economy. In fact, it is scarcely saying too much to affirm that the building could not otherwise have been erected in the short space of time granted for that purpose.

The method of cutting out the arched ribs of the Transept roof without waste of timber is worthy of notice, as also the cambering of the gutters to facilitate the flow of the water. The open boarding of the floor is a very effectual expedient for getting rid of dust. The ventilation of the building is effected by several thousand square feet of louvres, made of galvanized sheet-iron plates corrugated in an S form, which not only gives great stiffness to the plates, but also forms a good joint between the louvres. Several hundred feet are opened simultaneously in a very simple manner.

ORIGIN OF THE GREAT EXHIBITION BUILDING.

The History of the Great Exhibition of Industry is well known, and we shall therefore not enter into it here farther than is required to illustrate our subject, as our object is to confine ourselves to the construction of the building viewed as an engineering work.

The appointment of the Royal Commission in January, 1850, and the success of their appeal to the public for subscriptions to carry out the undertaking without applying to the Government for funds, sufficiently demonstrated the feasibility of the Exhibition in a pecuniary point of view. The site in Hyde Park was selected, and the first point then to be determined was the plan of the building required. A general invitation was issued to architects and engineers to furnish designs adapted to the site, and in accordance with certain specified conditions; and the invitation was met by two hundred and forty-five designs from architects of all nations. Many of these designs were totally unadapted to the site, and in other respects did not comply with the conditions, and others were far too expensive for the purpose. A new design was consequently prepared by the direction of the Royal Commission, for which tenders were invited and received. In this design, seventeen millions of bricks were to be employed, and as a large portion of them must have been laid in the winter, there is every reason to believe that the building would not have been ready by the 1st of May, 1851, and that, when ready, the walls would have been so wet as to injure the goods placed in proximity to them. The Royal Commissioners, however, left the matter open, so as to admit of their receiving any suggestions from contractors tendering for the erection of the building.

Messrs. Fox, Henderson, and Co., accordingly, in tendering for the Commissioners' design, added to their tender another design by Mr. Joseph Paxton, together with a separate tender for its erection at a much lower price than that demanded for the first. Mr. Paxton's design was for a structure composed of glass, iron, and wood, on the same principle as one previously erected by him at Chatsworth, as a conservatory for the gigantic water lily called the Victoria Regia. This design was subsequently improved by the introduction of the Transept, a feature which is universally acknowledged to add greatly to the general effect of the building.

It was determined to cover the Transept with a semi-cylindrical vault of the same span and construction as that of the Great Conservatory, erected several years ago by Mr. Paxton, at Chatsworth, while the flat ridge and valley roof of the Victoria Regia house was retained for the remainder of the building. By this means the large trees in the centre of the building were included within it, and covered by a magnificent glass vault, rising to a height of more than a hundred feet from the ground. It will thus be seen that the principal elements of the Crystal Palace are derived from Mr. Paxton's previous erections at Chatsworth.

The general character of the building being thus decided upon, the arrangement of the supports or framework for supporting the whole had next to be determined. For obtaining the necessary stiffness in the structure, the contractors adopted the principle of employing girders and trusses of considerable *depth*, connected both at top and bottom to the columns. To facilitate the whole of the operations, they determined to adopt one unit of length throughout the building. It was found that sheet glass could be procured of the length of 49 inches, but that a greater length would be much more expensive, from the difficulty of blowing and handling such long pieces. Glass of this length, placed on a slope of $2\frac{1}{2}$ to 1, was found suitable for a ridge and valley roof, in which the pitch or distance from centre to centre of gutters is 8 feet. Three times this pitch, or 24 ft., was considered to be a convenient length for the cast-iron girders, and was therefore adopted as the unit of length. The wider avenues were made twice this unit, or 48 ft. wide, and the Central Avenue, or Nave, was made three times this unit, or 72 ft. wide. We thus see that the difficulty of manufacturing glass of greater length than about 4 ft. was the primary cause which determined the dimensions employed throughout the building.

Messrs. Fox, Henderson, and Co., having arranged the details sufficiently to enable them to prepare an estimate of the cost, offered to erect the building and remove it after the close of the Exhibition for the sum of £79,800, or to leave it standing as the property of the Royal Commission for the sum of £150,000. Their tender was accepted on the 26th July, 1850, but the contract was not signed till the 31st October, and in the meantime the contractors had expended many thousand pounds in preparations and in actual work erected, for the first column was fixed on the 26th September, and from that time the Crystal Palace rose rapidly on all parts of the eighteen acres which it now covers.

The details and strengths of the various parts were arranged by the contractors, under the superintendence of Mr. William Cubitt, the Chairman of the Building Committee, assisted by Mr. Charles Heard Wild, and the painting and decoration generally of the building were entrusted to Mr. Owen Jones. The steady perseverance of the last-named gentleman against a violent and clamorous opposition from the self-appointed arbiters of taste, enabled him to carry out his ideas of the true principles of decorating such a structure, with a success which is now acknowledged by all parties to be complete.

The superintendence of the construction and erection of the building was specially entrusted by the Royal Commission to Mr. William Cubitt, President of the Institution of Civil Engineers, who was indefatigable in his devotion to the duties of this arduous and responsible office.

DESCRIPTION OF THE BUILDING.

The general form of the building will be gathered from the plans shown in Plates I., II., and III., and the elevations in Plates IV. and V.

It consists of three stories or tiers, rising one above another, the length of all of them being equal, but their widths decreasing as they rise. Thus, the width of the lowest tier is 408 ft.; the width of the second tier is 264 ft., and that of the third tier is 120 ft. The length of all three tiers is 1848 ft., measuring to the centres of the columns, or about 1850 ft. over all. The Eastern and Western ends, therefore, present vertical faces of the full height of the building. On the Northern side, an additional piece, of 936 ft. long and 48 ft. wide, has been added to the lower tier, as shown in the plan, Plate I.

Plate VI. is a transverse section of the building, at the line A B in Plate I. Plate VII. is a longitudinal section, at the line C D in Plate I.

It will be seen that the structure consists of a series of cast-iron columns, united by trellis girders and trusses of three different lengths, viz., 24 ft., 48 ft., and 72 ft.

COLUMNS.

The details of the columns are shown in Plate VIII. Fig. 1 is an elevation, with sectional plans, of one of the outer columns in the first tier or story. The column is of cast iron, cast hollow, and cylindrical on the interior. On the exterior it has four flat and four cylindrical faces. The upper portion of the column A is formed with a socket *a*, which is turned out slightly conical, and rests on the turned top of the lower part of the column B. This socket joint is shown on a larger scale in Fig. 2. It only occurs in the external columns on the ground floor. The base of the column spreads out into a flat plate, 2 ft. long by 1 ft. wide. This plate is fixed upon a mass of concrete, about 2 ft. by 3 ft., resting on the stratum of gravel which extends over the whole area.

The depth of the mass of concrete varies from 1 ft. to 4 ft., but in some few places, where the ground was bad, a much greater depth was employed.

The length and breadth of the concrete foundations vary with the different loads which they have to carry, and the base plates of the columns vary from 1 ft. by 2 ft. to 3 ft. by 2 ft. The thickness of the columns varies with the loads from $\frac{5}{8}$ in. to $1\frac{1}{4}$ in., but their external diameter is in every case 8 in., the internal diameter only being varied. The length of the columns below the ground floor varies with the form of the ground; their height above the ground floor is 18 ft. $11\frac{3}{4}$ in., and the top of the socket is 4 ft. 9 in. above the floor. On the top of the column is fixed, by two $\frac{7}{8}$ in. bolts and nuts, a connecting piece C, 3 ft. $4\frac{1}{2}$ in. long, which serves for supporting and securing the girders.

Fig. 3 is an elevation and plans of one of the inner columns of the first tier. The column A is formed with four lugs at each end. It is connected by four 1 in. bolts to the lower portion B. D is an outlet pipe for the passage of the rain water, which descends through the column. It is 7 in. diameter outside, and $\frac{1}{2}$ in. thick at the column, and $\frac{3}{8}$ in. at the end. The top of the length B is $3\frac{3}{4}$ in. above the floor. The column A is 18 ft. 8 in. long, and the connecting piece C is 3 ft. $4\frac{1}{2}$ in. long. It is united to the column by four 1 in. bolts. It has a flange with four snugs at each end for supporting and securing the girders and trusses, as will presently be explained.

Fig. 4 is an elevation and plans of one of the outer columns of the two-story building. The lower part of this column is similar to Fig. 3, but an additional column E, of 16 ft. $7\frac{1}{2}$ in. in height, is bolted to the top of the connecting piece C, and another connecting piece F, similar to that marked C in Fig. 1, is fixed on the top of the column by two bolts and nuts. The base plate is 2 ft. long by 1 ft. 6 in. wide.

Fig. 5 represents similar views of one of the inner columns in the two-story building. It is similar to Fig. 4, but the upper connecting piece F is adapted for securing four girders or trusses instead of one, and is secured by four bolts and nuts to the column. The base B is provided with rain-water outlets D.

Fig. 6 represents one of the outer columns of the three-story building. It is similar to Fig. 5, but has another column 16 ft. $7\frac{1}{2}$ in. long placed upon it, and surmounted by another connecting piece H, 3 ft. $4\frac{1}{2}$ in. long, so that the total height from the ground floor is 62 ft. $4\frac{1}{4}$ in. The base plate is 3 ft. by 1 ft. 6 in.

The two lower connecting pieces, C F, are each adapted for securing four girders or trusses, while the upper one, H, is only adapted for receiving one.

Fig. 7 is one of the inner columns of the three-story building. The lower connecting pieces, C F, are each adapted for supporting three girders, while the upper one, H, is constructed to receive four.

Fig. 8 shows one of the columns in the three-story building employed for supporting the light 72 ft. truss, 6 ft. deep at the edge of the lead flat which is described below. The connecting piece K, and the upper length of column I, are cast in one piece, instead of being connected by bolts and nuts.

Fig. 9 shows one of the columns supporting the strong 72 ft. trusses at the angles formed by the junction of the Nave and Transept. This column is similar to the last, with the addition of a socket L, cast in one piece with the upper length, which serves to receive the end of one of the arched ribs of the Transept. The base plate is 3 ft. by 2 ft. and is shown in plan in Fig. 11.

Fig. 10 is one of the columns which support the arched ribs of the Transept roof. These columns do not carry any of the 72 ft. trusses. The socket L and connecting piece K are cast in one piece, and are fixed by four bolts and nuts to the column I. The base plate is similar to that of Fig. 9, and is shown in plan in Fig. 11. The thickness of the columns is proportioned to the loads which they have to carry, and the lower lengths are made thicker than the upper ones. The four columns at the junction of the Nave and Transept are the strongest, and are moreover relieved of a portion of the weight by four additional columns, the details of which are shown in Plate XX. The diameters of the bolts used for connecting the columns and connecting pieces vary from $\frac{7}{8}$ in. to $1\frac{1}{8}$ in.

The ends of each column and connecting piece were turned or faced in a lathe, so that when placed together, with a piece of canvas covered with white lead between them, they made a water-tight joint, and required no packing or adjustment to bring them perpendicular and in line with one another.

Fig. 12 is an elevation, and Fig. 13 a plan, of one of the connecting pieces, showing the method of fixing the girders.

Each flange P, of the connecting piece C, carries four projections or snugs, in each of which is a groove $\frac{3}{4}$ in. wide and $\frac{1}{4}$ in. deep. The lower part of the girder Q has a small projection R, which fits into this groove, and in the upper part of the girder is a groove which corresponds with the groove in the snug; a wrought-iron key S is driven into these two grooves, and the position of the girder is thus secured. In order, however, to tie it firmly to the columns, a key T is driven in at top and bottom, between the snugs and the projecting ends U of the girder. The keys T used for fixing the girders across the building are of wrought iron, and similar keys are used for a distance of 200 ft. from each end of the building, and for the same distance on each side of the

Transept. The two intermediate portions, each of the length of about 500 ft., are keyed up with wooden keys, so as to allow a small degree of elasticity, and admit of the expansion and contraction of the metal. The four flat faces of the column afford great facilities for attaching the trusses, &c., to them, and at the same time improve the appearance of the columns, especially when coloured.

The depth of the girders being 3 ft., the respective heights from the ground floor to the top of each range of girders are 22 ft. 2 in., 42 ft. 2 in., and 62 ft. 2 in.

Vertical diagonal bracing is introduced at intervals between the columns at the places marked *a* in the plans, Plates I., II., and III., for the purpose of adding to the stiffness of the structure.

Plate IX., Fig. 1, is an elevation of the diagonal bracing in two tiers of columns. A A are the upper columns; B the cast-iron girder; C C, C C are four pairs of inch round rods; each rod is forged with an eye at one end, and is screwed at the other, to receive a nut. The bolts, which connect the columns to their short connecting pieces D, pass through these eyes and secure the rods C. The screwed ends of the rods enter a circular cast-iron boss or hoop E, where they are secured by the nuts. Fig. 2 shows the connection with the column drawn to a larger scale, the same letters being used to denote the same parts as in Fig. 1. F F are the bolts and nuts; G G, H H are four wrought-iron clips, $1\frac{3}{4}$ in. by $\frac{1}{2}$ in., which embrace the column, as shown in the plan Fig. 3, in which the column A is shown in section. The bolts F pass through these clips. Fig. 4 is an elevation, and Fig. 5 a section of the hoop E. The rods C are passed through the holes I, and secured by the nuts, and two light cast-iron caps K K are placed on the sides, and fixed by screwing one of the caps on a wrought-iron pin L, previously screwed into the other cap. M M, M M are wooden bosses, one of which is fixed on each pair of rods. Each boss consists of two pieces of wood connected by a wood screw, and embracing the rods, as shown in Fig. 4 and Fig. 6. The diagonal bracing C′ to the lower columns A′ is the same as to the upper ones, with the exception of the attachment at the lower part, which is shown on a larger scale in Fig. 7. The bolts N N are prolonged to support the clips O O, of which there are eight of $1\frac{3}{4}$ in. wide by $\frac{3}{8}$ in. thick, forming a double ring round the column.

GIRDERS AND TRUSSES.

Having described the vertical supports of the building, we shall now proceed to examine the girders and trusses which rest upon them and connect them into one rigid frame-work. As we have already mentioned, these girders and trusses are of the trellis form, or, in other words, consist of a top and bottom rail united by vertical struts and a series of diagonals.

The trellis girders or trusses vary in their strength, construction, and material, according to their position in the building and the duty they have to perform. There are no less than nine varieties of these girders or trusses, viz. 24 ft. wooden trusses, three strengths of 24 ft. cast-iron girders, 24 ft. wrought-iron trusses, 48 ft. wrought-iron trusses, and three strengths of 72 ft. wrought-iron trusses.

WOODEN TRUSSES.

Plate X. shows the detail of the 24 ft. wooden trusses. Fig. 1 is an elevation, and Fig. 2 a plan. The top rail A consists of a piece of oak 3 in. deep by $2\frac{1}{2}$ in. wide, surmounted by a deal board 1 in. thick and 6 in. wide, parallel between the vertical struts B B, and tapered off to 3 in. wide at the ends. C C are vertical oak struts, at the ends 4 in. $\times$ $2\frac{1}{2}$ in., and B B are oak struts 4 in. wide and $1\frac{1}{4}$ thick. The distance from centre to centre of the columns being 24 ft., the length of the girder itself is only 23 ft. $3\frac{1}{4}$ in., a space of $4\frac{3}{8}$ in. being left at each end to afford space for the column. The distance from centre to centre of the struts B B is 8 ft. The bottom rail D is formed of two flitches of deal, 4 in. deep by $\frac{7}{8}$ in. thick, placed side by side, and fixed by wood screws to a deal board $\frac{1}{2}$ in. thick and 8 in. wide between the struts B, and tapered to 3 in. at the ends. The two flitches are connected at the ends by pieces of oak, 2 ft. long, 4 in. wide, and $\frac{3}{4}$ in. thick, placed between them. A wrought-iron strap K, 2 in. wide, $\frac{1}{8}$ in. thick, and 2 ft. long, is passed round the upright C, to which it is secured by a $\frac{1}{2}$ in. bolt. Two similar bolts secure the strap to the flitches of the bottom rail. The diagonals E E, F F, G G are 4 in. $\times$ $\frac{1}{2}$ in.: E E, being exposed to tensile strain, are secured at each end by three $\frac{1}{2}$ in. bolts passing through wrought-iron straps H H, I I, 2 in. wide and $\frac{1}{8}$ in. thick. The straps H H are 10 in. long, and one is placed on each side. The straps I I are 2 ft. long, and pass round the upright C. The diagonals E E are of oak. The diagonals F F, being exposed to compression, are merely notched into the top and bottom rails, as shown by the dotted lines. The diagonals G G are notched into the top rail, and rest upon the $\frac{1}{2}$ in. board of the bottom rail, being secured by a pin passing through the two flitches. The struts B B are secured at bottom by a pin $\frac{1}{2}$ in. diameter passing through the two flitches, and are notched into the top rail, and secured by a wooden pin.

These wooden trusses are employed in a longitudinal direction in the one-story building under the roof, and serve to connect the columns and preserve the symmetry of the building. The weight upon them is very trifling, being merely that of one Paxton gutter, and the wooden truss supplies the place of the tie-rod used to truss and camber the other Paxton gutters.

CAST-IRON GIRDERS.

Plate X., Fig. 3, is an elevation, and Fig. 4. a plan, of one of the cast-iron trellis girders used for connecting the columns, and for carrying the transverse main gutters, shown in Plate XII., which support the roof.

The small Figures show the sections at the different parts drawn to a larger scale, and with the dimensions marked upon them. The depth of the girder is 3 ft., and its length 23 ft. $3\frac{3}{4}$ in. The sectional area of the bottom rail and flange in the centre of the girder is $6\frac{1}{4}$ square inches, and the girders were proved by applying a pressure of 9 tons equally divided between the two points B and B. This trellis form of girder gives much greater stiffness to the building than a girder of the ordinary form of the same weight, on account of its *depth* being much greater. If it had been attempted to cast a girder of the same depth, but of the ordinary form, the substance of metal would have been so small that the girder would have been deficient in stiffness, besides being difficult to cast. The weight of each of these girders is about 9 cwt.

The second series of small Figures shows the sections of some stronger cast-iron girders which are employed under the galleries. These girders were proved to 15 tons, divided between the two struts B B. Their weight averages about 12 cwt.

The third series of small Figures represents the sections of some stronger girders used in supporting the galleries at the ends of the Transept, where the trussed joists, which support the gallery floor, are placed longitudinally, and rest upon these cast-iron girders, which are placed transversely, and which thus have to carry a much greater weight than the girders employed in the other parts of the galleries. These girders were proved to $22\frac{1}{2}$ tons, equally divided between the points B B. Their weight is from 18 to 20 cwt.

These girders and the wooden truss are secured to the connecting pieces of the columns in the manner shown in Plate VIII., Fig. 12, and already described.

WROUGHT-IRON TRUSSES.

The transverse girders and trusses which support the roof are of three different lengths, and vary in construction accordingly. The 24 ft. transverse cast-iron girders have already been described. Trusses of 48 ft. and 72 ft. in length are employed in other parts, and are constructed of wrought iron, still retaining the trellis form.

Plate XI. shows the detail of the 48 ft. wrought-iron trusses. Fig. 1. is an elevation of a portion of the truss, which is 3 ft. deep. The top rail A consists of two angle-irons, each 4 in.

deep, 2 in. wide, and $\frac{1}{4}$ in. thick, with a space of 1 in. between them. They are in three lengths, and are connected by two $\frac{1}{2}$ in. wrought-iron plates, 4 in. wide and 1 ft. 4 in. long, and four $\frac{7}{8}$ in. rivets at each joint, as shown at *b b*, and on a larger scale in Figs. 2 and 3. A wrought-iron plate, 1 ft. 4 in. long, 5 in. wide, and $\frac{3}{8}$ in. thick, is riveted to the top of the angle-irons by eight $\frac{7}{8}$ in. rivets. The angle-irons are also connected with one another at every 4 ft. by a wrought-iron plate, 9 in. by 2 in., and $\frac{1}{4}$ in. thick, fixed by two $\frac{1}{2}$ in. rivets, as shown in Figs. 4 and 5. The main gutter is bolted to these plates, and assists by its width in stiffening the top rail of the truss. The bottom rail B consists of two flat wrought-iron bars, $4\frac{1}{2}$ in. deep, each consisting of three lengths jointed at *c c*, as shown on a larger scale in Figs. 6 and 7, by means of four joint plates, 1 ft. 2 in. by $4\frac{1}{2}$ in., the central ones being $\frac{1}{2}$ in. thick, and the outer ones $\frac{1}{4}$ in. thick, and secured by four $\frac{7}{8}$ in. rivets. The bars of the end lengths of the bottom rail are $\frac{1}{4}$ in. thick, and those of the central lengths are $\frac{3}{8}$ in. thick, the strain upon them being greater than upon the ends. The vertical struts *d* are of cast iron, and of the form shown in Figs. 5 and 8. Their section in the centre is of the form of a cross of 3 in. each way, and the thickness of metal is $\frac{5}{8}$ in. The ends of the strut are made flat, and are 1 in. thick; they enter between the angle-irons of the top rail, and between the flat bars of the bottom rail, and are secured at each end by a $\frac{7}{8}$ in. rivet. They are formed with shoulders to bear against the top and bottom rails. The distances from centre to centre of the struts are 8 ft., so that the truss is divided into six spaces of that length. The end standards C are also of cast iron, and are shown in Figs. 9 and 10. Their section is of a T form, and they have shoulders at top and bottom to receive the angle-irons of the top rail and the flat bars of the bottom rail. A $1\frac{1}{8}$ in. rivet secures each rail to the standard. Projections are formed at the top and bottom, and a key-groove is formed at the top of the standard, for the purpose of securing it by keys to the connecting piece of the column in the manner already described, and shown in Fig. 12, Plate VIII. The diagonal ties D E F are formed of flat wrought-iron bars, 4 in. wide. The bars D are $\frac{11}{16}$ in. thick, and are fixed at each end by a $1\frac{1}{8}$ in. rivet. The bars E are $\frac{1}{2}$ in. thick, and are fixed by $\frac{7}{8}$ in. rivets. The bars F are $\frac{5}{16}$ in. thick, and are fixed by $\frac{3}{4}$ in. rivets. Wrought-iron washers are employed to make up the thickness of one inch, which is the space left between the angle-irons of the top rail, and between the flat bars of the bottom rail. The bars G are all of wood, $3\frac{1}{2}$ in. by $\frac{3}{4}$ in., and are fixed by a $\frac{3}{8}$ in. rivet at each end, and a $\frac{3}{8}$ in. wood screw passing through the diagonal iron ties. They are not intended to carry any part of the weight, being merely introduced to preserve the uniformity of the appearance of the truss. The other dimensions are figured on the Plate.

In Plate XI. is also shown the detail of the 72 ft. wrought-iron trusses. These trusses are similar in construction to the 48 ft. trusses, but are of greater scantlings, and are divided into nine spaces of 8 ft. each, instead of into six spaces of the same length. The depth is the same as that of all the trusses and girders above described, viz. 3 ft.

Fig. 11 is an elevation of a portion of the truss.

The top rail H consists of two angle-irons, $4\frac{1}{2}$ in. deep, $3\frac{1}{2}$ in. wide, and $\frac{3}{8}$ in. thick, placed 1 in. apart. They are in four lengths, united at the centre of the truss, and at two other points marked *e e* in Fig. 11, and shown on a larger scale in Fig. 13, and in section in Fig. 12. The joint consists of two $\frac{1}{2}$ in. plates, 1 ft. 4 in. long and $4\frac{1}{2}$ in. deep, placed between the angle-irons, and secured to them by four $\frac{7}{8}$ in. rivets. A $\frac{3}{8}$ in. plate, 1 ft. 4 in. long and 8 in. wide, is riveted on the top of the angle-irons by eight $\frac{7}{8}$ in. rivets. These angle-irons are connected and stiffened by a wooden plank, $2\frac{1}{2}$ in. thick and 1 ft. 2 in. wide, which forms the bottom of the main gutter, shown in Plate XIII., Fig. 1. This plank is secured to the angle-irons at intervals of 4 ft. by means of $\frac{1}{2}$ in. bolts and nuts, which pass down through the sides of the main gutters, and also serve to secure the Paxton gutters in their places. The angle-irons are riveted to the end standards K by $1\frac{1}{8}$ in. rivets, and to the intermediate standards *g* by $\frac{7}{8}$ in. rivets.

The bottom rail I is in four lengths, being jointed in the centre of the truss and at two intermediate points *f*. The two central lengths each consist of a pair of flat bars $4\frac{1}{2}$ in. deep and $\frac{3}{4}$ in. thick, and the side lengths consist of bars of the same depth and $\frac{9}{16}$ in. thick.

The joint *f* is formed of four joint plates, 1 ft. 2 in. by $4\frac{1}{2}$ in., the two central ones being $\frac{1}{2}$ in. thick, and the external ones $\frac{7}{16}$ in. thick, as shown in Figs. 14 and 15. Washers or thin plates are introduced to make up the thickness of the thinner bars, and the whole is united by four $\frac{7}{8}$ in. rivets. The bars cannot, therefore, separate without shearing two $\frac{7}{8}$ in. rivets, each in four places; so that the area of shearing section amounts to $4\frac{3}{4}$ square inches, being more than the effective area of section of the thinner bars, and less than that of the thicker ones, after allowing for the diminution of the area caused by the rivet holes. The force required to shear a given section of iron has been ascertained to be the same, or nearly so, as that required to tear it asunder; so that the joint would be rather stronger than the thinner bars, even if mere pins were used in place of rivets. In a riveted joint of this nature, however, the friction of the plates upon one another, which is caused by their being tightly bound together by the rivets, adds materially to the strength; so that, in fact, the central joint is of about the same strength as the $\frac{3}{4}$ in. bars which it connects.

It is worthy of notice that the external plates double the strength of the joint, by rendering it necessary for each rivet to be sheared in four places instead of in two.

The standards or struts *g* are of cast-iron, and are shown in Figs. 16 and 17. They are similar to those of the 48 ft. trusses, but are $\frac{1}{2}$ in. thick in place of $\frac{3}{8}$ in. The end standards K are also of cast-iron, and are shown in Figs. 18 and 19. They are similar to those of the 48 ft. trusses, but are provided with an inch hole just above the bottom rail, for the purpose of receiving a bolt to fix the truss to the column.

The diagonal L is a flat wrought-iron bar, $4\frac{1}{2}$ in. wide and $\frac{3}{4}$ in. thick, and is secured at each end by a $1\frac{1}{4}$ in. rivet. Iron washers are introduced to fill up the space of one inch between the top and bottom rails. M is a flat bar 4 in. by $\frac{11}{16}$ in., and secured at each end by a $1\frac{1}{8}$ in. rivet. N is 4 in. by $\frac{1}{2}$ in., and secured by inch rivets. O is 4 in. by $\frac{5}{16}$ in., and secured by $\frac{7}{8}$ in. rivets. The diagonals P are of wood, from $\frac{3}{8}$ in. to $\frac{3}{4}$ in. thick, and 4 in. wide, except the end ones, which are $4\frac{1}{2}$ in. wide; they are secured by $\frac{3}{8}$ in. rivets at each end, and by wood screws passing through the iron diagonals at their centres. These wooden diagonals are merely introduced to preserve the symmetry of the appearance of the truss.

The 72 ft. trusses are intersected by diagonal bracing at six different places, as shown in the plan, Plate III. This bracing is shown in detail at Figs. 20, 21, 22, and 23, Plate XI. Fig. 20 is a plan of the bottom rail of the truss; *i i* are the diagonal braces of $\frac{7}{8}$ in. round iron. Fig. 21 shows the method of adjusting the braces by screws, and Figs. 22 and 23 show the junction at the centre of the cross. Horizontal diagonal bracing of similar strength is used in the 24 ft. bays across the ends of the Transept, above the Gallery, and also at the east and west ends of the Nave or Central Avenue.

Wrought-iron trusses, 72 ft. long and 6 ft. deep, are employed to carry the lead flats and the arched roof of the Transept across the Nave, with two 24 ft. wrought-iron trusses between each pair, the positions of which will be seen on Plate III. The details of these will be given in describing the Transept.

GLASS ROOF.

Plate XII. shows the details of the glass roof.

Fig. 1 is a section through the roof and Paxton gutters, with elevation of parts of the main gutters on 24 ft. and 48 ft. trusses.

A A are the Paxton gutters, resting upon the plates B on the main gutters C, which are supported on the 24 ft. cast-iron girders D, and 48 ft. wrought-iron trusses E, to which they are secured by bolts and nuts at intervals of 8 ft. on the cast-iron girders, and at intervals of 4 ft. on the wrought-iron trusses. The Paxton gutters carry the sash-bars F, which are notched into them and into the ridge G.

Fig. 3 is an elevation of the Paxton gutter A, which is trussed and cambered by means of the rod H and the two struts I I. The rod H passes through a cast-iron shoe J at each end, where it is secured by a nut.

Fig. 4 is an elevation on a larger scale of the end of the gutter, and Fig. 5 is a section of the same. Fig. 6 is a view of the under side of the shoe J.

The gutter A consists of a single piece of timber, 5 in. wide and 6 in. deep. A groove, 3 in. wide and $2\frac{1}{2}$ in. deep, is formed in its upper surface, and the edges are bevilled off, as shown in Fig. 5. Two small grooves, $\frac{1}{2}$ in. wide, are formed in the sides of the piece of wood, as shown in Fig. 5. These small grooves serve to receive the moisture which condenses on the interior of the glass, while the large groove receives the rain which falls on the exterior. These grooves are all formed at one operation, by means of circular cutters revolving at a high velocity, and arranged in a machine through which the piece of timber is passed.

The gutters are cut off to the proper length of 24 ft., by means of a circular saw mounted in a moveable frame, by which it is made to descend upon the gutter. In the centre of the saw, two quadrantal cutters are fixed, which form a semicylindrical cutting or groove of 3 in. diameter in the end of the gutter. This cutting serves to deliver the rain water into the main gutter. Two small diagonal grooves conduct the condensed water from the side grooves into the main gutter.

The depth of the Paxton gutter is reduced from 6 in. to 5 in. for a distance of 11 in. from the end; and the shoe, the base of which is 6 in. long, 3 in. wide, and $\frac{5}{8}$ in. thick, is let into it, as shown in Fig. 5, and by the dotted lines in Fig. 4. The end of the shoe spreads out to a depth of 2 in. and a width of 5 in. at the lower part, so as to distribute its pressure upon the wood. It has a projecting inclined flange, $\frac{5}{8}$ in. thick, with a hole $1\frac{1}{16}$ in. diameter to receive the end of the tie-rod H. The shoe J is secured to the gutter by a $\frac{5}{8}$ in. bolt at *a*. This bolt passes through a small curved plate K, which is let into the bottom of the gutter. A $\frac{1}{2}$ in. bolt L also passes through this plate, through the Paxton gutter and one side of the main gutter, and through the top flange of the cast-iron girder, as shown at L in Fig. 1, or through a wrought-iron plate, riveted to the top of the wrought-iron truss, where it is secured by a nut. The heads of these bolts are countersunk into the plate K.

The tie-rods H are of round iron, $\frac{13}{16}$ in. diameter, and are enlarged at the ends to 1 in. diameter, where they are screwed and fitted with nuts. These nuts are screwed up until the gutter A is cambered up $2\frac{1}{2}$ in. in the centre, so that the water which falls into it may run freely each way from the centre. The struts I are cast iron, and are shown in Figs. 7 and 8. They are of the cross or stancheon section, $3\frac{1}{2}$ in. wide each way at top, and 1 in. wide at bottom; the substance of metal is $\frac{5}{16}$ in. The upper part is made with a flat table or plate, 4 in. diameter, on which is a projection or tenon, 2 in. wide × $1\frac{1}{2}$ in. long, which is morticed into the gutter A. The lower part of the strut is formed into a saddle or fork, which rests upon the tie-rod H. The Paxton gutters which pass over the columns and the wood trusses before described are not provided with truss-rods H, but are supported and cambered by two struts which stand upon the wooden truss. One of these struts is shown in Fig. 9. It is similar to that shown in Figs. 7 and 8, with the exception of the lower part, terminating in a plate or foot 2 in. square. The upper edge of the gutter A is notched, as shown in Figs. 3, 4, 5, 7, and 10, to receive the sash-bars.

Fig. 10 is an enlarged section of the Paxton gutter and glass roof. A is the gutter, G the ridge, made of a piece of wood 3 in. square, with the sides shaped as shown in the drawing, and notched to receive the sash-bars F, which are secured by a single nail at each end, driven through a hole drilled diagonally through the bar. The ridges G are united at their ends by two $\frac{1}{2}$ in. dowels, 3 in. long, shown at *c c*.

The sash-bars are 1 in. wide, $1\frac{3}{8}$ in. deep, and furnished with a groove on each side $\frac{3}{16}$ in. wide and $\frac{5}{16}$ in. deep, to receive the glass. The fillet on one side is reduced in width $\frac{1}{8}$ in., as shown in the section, for the purpose of facilitating the operation of glazing, as explained elsewhere. Three stronger bars are introduced in every 24 ft., their width being $2\frac{1}{2}$ in. Their positions are shown by the wide notches in the gutter A, Fig. 3. The sash-bars are all of the same length, and the ridge is consequently cambered like the gutters.

Fig. 2, Plate XII., is a section, showing the junction of roof over one-story building with the front of two-story building and gallery floor.

A is the gutter, having the deep groove at top, and only one side groove. B is a cast-iron bracket and shoe, carrying the end of the gutter. C is the main gutter. N is a curved channel, which conveys the water from the gutter A into the main gutter C. O is the gallery floor, and P one of the transverse 24 ft. cast-iron girders which support it. Q is a section of one of the longitudinal 24 ft. cast-iron girders supporting the side of gallery. R is the vertical sash forming the side of the second tier, and S is the sill.

The rain water which runs down the vertical sash R falls from the sill S into the gutter A, and thence passes through the channel N into the main gutter, as will be more fully explained in reference to Plate XIII., Figs. 12, 13, and 14.

A similar arrangement occurs at the junction of the roof over the two-story building with the side of that which rises three stories.

The glass employed in the roof is sheet glass, blown in cylinders about 10 in. in diameter and

49 in. long, which are split down one side and opened out into flat sheets. Each sheet is cut into three strips or panes, 49 in. long and 10 in. wide. The glass is made of the thickness of $\frac{1}{13}$ in., and weighs 16 oz., or one pound per square foot.

The roof is glazed in the following manner:—a number of sash-bars are prepared with the grooves filled with putty, and the ridge piece is raised into its place and supported by the broad sash-bars. A sheet of glass is then pushed into the groove of one of these broad sash-bars, and another bar is then pressed upon its edge and brought into its place and secured by a nail at each end. The sheet of glass is then pushed up into the groove in the ridge, and the putty is smoothed with a knife. Another pane is then inserted, and so on until the workman arrives at the next broad sash-bar, which he lifts out of its place and introduces the pane of glass as before, the ridge being supported in the meantime by the bars already inserted. A provision is made, however, by which the glass can be introduced without removing the sash-bar, which is particularly useful in case of a pane being accidentally broken after the glazing is completed. By referring to Fig. 10, Plate XII., it will be seen that the fillet is partially removed on one side of the bar, so that if one edge of the glass be slipped into the groove in the next bar, its other edge can be brought down past the fillet on to the shoulder; the glass is then slipped back a little so as to enter the groove, and it is thus secured at both ends. This method of glazing with grooved sash-bars has been proved, by many years' experience at Chatsworth and elsewhere, to be much superior to the ordinary method of fixing the glass on sash-bars made with a simple shoulder on each side. A smaller quantity of putty is used, and, being confined in the groove, it is not liable to crack and break away, as is the case in the ordinary method.

MAIN GUTTERS AND RAIN-WATER CONNECTIONS.

Plate XIII. shows the construction of the main gutters and the various rain-water connections.

Fig. 1 is a longitudinal section of one of the main gutters of the roof over the nave, which is supported by the 72 ft. wrought-iron trusses shown in Plate XI. These trusses are cambered up 5 in. in the centre, and the gutter follows the camber of the truss, so that the water flows both ways from the centre. Fig. 2 is a transverse section of this gutter, which is 6 in. deep and $5\frac{1}{4}$ in. wide inside; it consists of two side boards, C and D, $1\frac{3}{8}$ in. thick and 6 in. deep, tongued into a plank E, $2\frac{1}{2}$ in. thick and 1 ft. 2 in. wide, to which they are secured by $\frac{1}{2}$ in. bolts passing also through the top rail of the truss. The joints are made good with white lead. The plank E adds considerably to the stiffness of the upper rail of the 72 ft. truss.

Fig. 3 is a longitudinal section, and Fig. 4 is a transverse section of the main gutter on one of the 48 ft. wrought-iron trusses. These gutters deliver the whole of the water at one end.

The side boards C and D are $1\frac{3}{8}$ in. thick and $7\frac{1}{8}$ in. deep, tongued and bolted to a plank E, $1\frac{3}{8}$ in. thick and 9 in. wide.

A false bottom F is tongued into the side boards C and D. This false bottom lies in contact with the bottom plank E at one end, and follows its camber to the centre of the truss, rising $1\frac{1}{2}$ in. in that length. It then leaves the bottom E, and rises $\frac{3}{8}$ in. in 8 ft. until it reaches the end. The total rise is, therefore, $2\frac{5}{8}$ in.

Fig. 5 is a longitudinal section of one of the main gutters over 24 ft. span. This is similar to the preceding; but the false bottom F falls $\frac{3}{8}$ in. in 8 ft. throughout its length, and delivers all the water at one end.

The water is thus conducted down the inner row of columns in each of the three tiers, and passes through the outlets shown in Plate VIII., Figs. 3, 5, and 7, into the drains by which it is conveyed away.

The ends of the Paxton gutters A meet and are supported on shoes or plates B, which rest on the main gutters, into which they deliver the water. One of these plates is shown in plan in Fig. 6, with one of the gutters A resting upon it, the other being removed to show the plate.

Fig. 7 is a section through the line *c c* in Fig. 6, and Fig. 8 is a section through the line *d d* in Fig. 6.

This plate is $8\frac{3}{4}$ in. long, $5\frac{3}{4}$ in. wide, and $\frac{3}{8}$ in. thick. It slopes downwards towards the centre line of the main gutter, so as to follow the inclination of the ends of the Paxton gutters. It is formed with a projecting ledge on the upper surface, $\frac{3}{8}$ in. wide, and the same in height on each side, and $\frac{5}{8}$ in. wide at each end, where the top is made flat to fit a notch in the under side of the Paxton gutter. On the lower surface at each end is a projecting beading, $\frac{3}{8}$ in. wide and $\frac{3}{8}$ in. deep, and a beading is also formed round a hole, 3 in. diameter, made through the centre of the plate. The semi-cylindrical cuttings in the end of each gutter form, by their junction, a cylindrical passage for the water, which thus drops through the plate B into the main gutter. The two small diagonal grooves in the end of each Paxton gutter conduct the condensed water from the small side grooves into the vertical passage. Any water which may escape between the two gutters falls on the plate B, which conveys it into the main gutter.

Figs. 9, 10, and 11 show the method of delivering the water into the columns. Fig. 9 is a plan. Fig. 10 is a section through the line *a a*, and Fig. 11 a section through *b b* in Fig. 9. A is the

Paxton gutter. T is a cast-iron shoe fixed to the main gutter over 48 ft. span. U is a cast-iron shoe fixed to the gutter over 24 ft. span. These shoes are secured by a $\frac{5}{8}$ in. bolt and nut through each side of the gutter, and two wood screws in the bottom F, and two others in the top edges of the sides of the main gutter.

The Paxton gutters A meet on the top of the shoe T, which is of a similar form to the top of the plate B, shown in Figs. 6, 7, and 8. They are fixed by $\frac{1}{2}$ in. bolts passed through lugs V, on each side of the shoe T. The bottom of each shoe is formed with a turned down lip to deliver the water into the connecting piece W, which forms the top of the column. The passage thus formed in the shoe T is made much larger than that in the shoe U, on account of its having to deliver the water from double the area of roof.

Similar shoes are employed to deliver the water from the 72 ft. and 24 ft. spans of the roof of the third tier.

Fig. 12 is a plan of the mode of conveying the water from the Paxton gutters, round the outer columns X of the upper stories of the building, into the main gutters. Fig. 13 is a side elevation of the same, and Fig. 14 is a section through the line *g g* in Fig. 12. B N B is an iron casting of rather peculiar form, which partially encircles the column X, and rests on the connecting piece W. The parts B B are formed into shoes to receive the ends of the Paxton gutters A. The water passes through the semicircular passages *i i* into the covered channels N, and thence through the aperture *j* into the main gutter. *n n* are two small channels which convey the condensed water from the small grooves of the Paxton gutters into the main gutter. The general thickness of metal in this casting is $\frac{3}{8}$ and $\frac{5}{16}$ in.

Fig. 15 is a plan, and Fig. 16 a vertical section on the line *f f*, of the mode of delivering the water from the main gutters of 48 ft. roof, on the north side of the building, into the external columns. T is a circular cast-iron plate, $\frac{5}{16}$ in. thick and 7 in. diameter, with a hole 4 in. square in the centre, surrounded by a lip on the lower edge. The plate is also surrounded with a lip on its lower surface, and it is fixed to the false bottom F of the gutter by six wood screws, and to the column by two $\frac{1}{2}$ in. pins.

Fig. 17 is a plan, and Fig. 18 a section, of the connection for conveying the water into the external columns at the ends of the building, and also at the sides of the Transept. A cast-iron plate T, very similar to that shown in Figs. 15 and 16, is fixed by wood screws to the bottom of the outside gutter.

The whole of the gutters are of deal. Being exposed to the alternating effects of heat and moisture, the timber requires to be well seasoned; but, from the difficulty of obtaining so large a quantity of timber in so short a time, some lots were employed which were not sufficiently seasoned, and the consequence has been that some of the gutters have proved leaky.

GALLERIES.

Plate XIV. shows the construction of the Galleries.

Fig. 1 is a transverse section, and Fig. 2 a longitudinal section. A B are the longitudinal cast-iron girders, and C the transverse girders. The longitudinal or side girders A B, support two trussed joists, each formed of two battens D D, 7 in. × $2\frac{1}{2}$ in., placed 2 in. apart, and trussed by a round iron rod E, $1\frac{3}{8}$ in. diameter, and two cast-iron struts F. These joists are shown in detail on a larger scale in Figs. 3, 4, 5, 6, 7, 8. Fig. 3 is a longitudinal section between the two battens D, and through the shoe G. Fig. 4 is an elevation of a portion of the joist. Fig. 5 is a transverse section through the centre of the joist. Fig. 6 is a sectional plan of the strut F at the line *a a* in Fig. 4. Fig. 7 is a front elevation, and Fig. 8 a plan of the shoe G, by which the tie-rod E is attached to the ends of the battens D. H H are wooden binders, 9 in. deep and 4 in. wide, passing under the trussed joists D and common joists I, into which they are notched half an inch, and supported at their ends by the transverse girders C, by means of $\frac{3}{4}$ in. bolts and nuts, passing through a piece of wood J, $4\frac{1}{2}$ in. deep by 4 in. wide, which rests upon the girder C, as shown in Fig. 2.

The binder H, together with the brackets K K, Figs. 4 and 5, rests upon the cast-iron strut or standard F, under which passes the tie-rod E. The strut F is prevented from being accidentally displaced by means of projections morticed into the timber, and a $\frac{1}{2}$ in. bolt passing through the binder H, and through a small wrought-iron saddle L, where it is secured by a nut. The saddle L rests upon the battens D D. By this arrangement the joists D D and the binders H H are supported at four points in each square of 24 ft. by the struts F, as well as being supported at their extremities by the girders. The common joists I I are supported at their extremities by the longitudinal girders A B, and at two intermediate points by the binders H H. The flooring boards R are laid upon the trussed joists D and common joists I I, and run in a longitudinal direction. In this manner the weight of the whole gallery is distributed as equally as possible on the longitudinal and transverse cast-iron trellis girders; as it will be found that the two longitudinal trellis girders carry between them two-thirds of the weight of a bay, and the two transverse girders the remaining third, their load being made equal to that of the longitudinal girders by the portion of the adjoining bays of 24 ft. square, which they have also to support. Each of these girders was proved by placing 15 tons equally divided on the two vertical parts *b b*, so that this proof is equivalent to 45 tons on the square of 24 ft., or 175 lbs. per square foot. The tie-rods E are $1\frac{3}{8}$ in. diameter, and are enlarged at their ends to $1\frac{3}{4}$ in. diameter, and screwed to receive the nuts M. The shoe G rests upon a piece of wood N, $1\frac{3}{8}$ in. thick, placed on the cast-iron girder, and is secured by $\frac{1}{2}$ in. bolts O. The top of the shoe has two lugs, P P, for receiving bolts to fix the standards of the Gallery railing, a portion of which is shown in Fig. 2. The flooring boards R are 1 in. thick, and are tongued with hoop iron 1 in. wide, as shown in Figs. 3 and 4. The surface of the Gallery floor is 22 ft. 11 in. above the ground floor.

In Plate XIV. are also shown the ornamental octagon bands and bases of the columns.

Fig. 9 is an elevation, and Fig. 10 a plan of the octagon bands on the columns in the interior of the building. A is the column. B is the connecting piece which supports the girders. C C are two light iron castings, $\frac{3}{16}$ in. thick, which embrace the column, and are united by two small screws *d d* on each side, passing through the castings, and entering a small strap of wrought iron *e* on the interior of the casting. Notches are formed at the sides of the castings, where the girders pass through them.

Fig. 11 is an elevation, and Fig. 12 a plan of the octagon bases of the columns in the interior of the building. C C are two light iron castings, $\frac{3}{16}$ in. thick, which join at the angles in such a manner that three sides of the octagon are in one casting, and five sides in the other. They are united by two $\frac{3}{8}$ in. bolts and nuts *d d*, passing through flanges *e e*, whose position is shown in the plan, Fig. 12, and in Fig. 13, which is a view of the joint. The flange *e* is set back $\frac{1}{16}$ in. from the plane of the joint, and has a small projection or chipping piece at *b*, which projects $\frac{1}{16}$ in., so as to lie in the plane of the joint.

STAIRCASES.

Access to the Galleries is obtained by twelve staircases, whose positions are shown in the plans Plates I. and II., and, on a larger scale, in Plate XV.

It will be seen by the plans and section that these staircases consist of two parallel flights 8 ft. wide, with a space of 8 ft. between them, leading to a landing 24 ft. long and 8 ft. wide, from opposite sides of which two flights of stairs lead to the Galleries. The staircase is covered by a cross gallery, 48 ft. long and 24 ft. wide, which unites the two main galleries, and in which two spaces or well-holes of 8 ft. wide by 16 ft. long are formed to receive the upper flights of stairs. By this arrangement there are two passages of 8 ft. wide at every part. The above dimensions are merely given to explain the manner in which the two 24 ft. bays of the building are divided out and occupied by the staircase. Owing to the space occupied by the columns, balustrade, &c., the actual width from centre to centre of the strings of the stairs is only 7 ft. 1 in., and the actual clear passage between the balusters is reduced to 6 ft. $10\frac{1}{4}$ in.

The landing is supported by eight small cast-iron columns, of similar section to the columns which support the building, but of smaller diameter. These columns are united by cast-iron girders running along the sides of the landing. Four cast-iron strings of I section are bolted to these columns and to the floor, to carry the lower flights of stairs, and two similar cast-iron strings are bolted to each girder at the side of the landing, and to cast-iron trellis girders *b*, under the gallery floor, for carrying the upper flights. An elevation and section of one of these trellis girders, drawn to a larger scale, is shown in the Plate. It is of the strongest section shown in Plate X., and the vertical struts are widened to receive the strings which rest upon projecting snugs cast upon the girders, to which they are each secured by four bolts and nuts. A series of standards, with open triangular frames at bottom, are bolted on the upper edges of the strings, for the purpose of receiving the treads and risers of the stairs, which are of elm. There are twenty-one steps in each flight. The columns on each side of the staircase are strengthened by diagonal bracing in both tiers, and the strings of the staircase also form strong diagonal struts, and contribute to the lateral stiffness of the building.

The details of the various parts of the staircase are shown in Plates XVI. and XVII. Fig. 1, Plate XVI., is an elevation of the cast-iron string for the upper flights of stairs, showing also a section of the same, and a portion of the stairs and balustrade. The top flange of the string A is $4\frac{1}{2}$ in. wide and $\frac{1}{2}$ in. thick, and parallel from end to end. The vertical web is $\frac{1}{2}$ in. thick at top and $\frac{5}{8}$ in. thick at bottom, and the bottom flange is $\frac{3}{4}$ in. thick and 7 in. wide in the centre, and tapered to 3 in. wide at the ends. The total depth of the string is 1 ft., and its extreme length is about 22 ft. 10 in. It is provided with a flange at the upper end, $\frac{3}{4}$ in. thick, 1 ft. 2 in. deep, and $5\frac{1}{2}$ in. wide, shaped to fit against the side of the gallery girder B, the elevation and section of which are shown in Plate XV. The string rests upon the snug of this girder, with the intervention of a wood packing $\frac{1}{2}$ in. thick, and a similar packing, $\frac{3}{8}$ in. thick, is introduced between the end of the string and the girder, which are united by four $\frac{7}{8}$ in. bolts. Fig. 2 is an elevation of the end of the string, showing the positions of the four 1 in. holes for receiving the bolts. The lower end of the string A is provided with a flange of the form shown in Fig. 3, 5 in. wide, 8 in. deep, and $\frac{3}{4}$ in. thick. It is secured by four $\frac{3}{4}$ in. bolts to the cast-iron girder C, which supports one side of the landing, with the intervention of a wood packing $\frac{1}{2}$ in. thick. The girder C is 8 in. deep; the bottom flange is 4 in. wide and $\frac{5}{8}$ in. thick; the top flange is 2 in. wide and $\frac{1}{2}$ in. thick; the vertical web is $\frac{1}{2}$ in. thick at top and $\frac{5}{8}$ in. thick at bottom. A plan of this girder is shown in Plate XVII., Fig 1. Fig. 2 is an elevation, and Fig. 3 a section. It is 8 in. deep and 23 ft. $1\frac{3}{4}$ in. long.

The bottom flange is cast with a broad foot at each end and two intermediate ones. These feet are $6\frac{3}{4}$ in. wide and the same in length, and project $\frac{1}{4}$ in. below the bottom of the girder. They are formed with four $\frac{7}{8}$ in. holes, $4\frac{3}{4}$ in. from centre to centre, through which pass the $\frac{3}{4}$ in. bolts which secure them to the small columns. The centre of each foot is in the centre line of the column. The distance between the two intermediate columns is 8 ft. 5 in. from centre to centre, and that between the end columns and the intermediate ones is 7 ft. 1 in., that being the distance from centre to centre of the strings of the lower flights of stairs, which are bolted to the columns. The strings of the upper flight are also placed at a distance of 7 ft. 1 in. from centre to centre, and are bolted to the vertical web of the girder at two places between the intermediate columns, where the web is thickened and furnished with four $\frac{7}{8}$ in. holes at each place, as shown in Figs. 1 and 2. Four $\frac{3}{4}$ in. holes are formed through the web at each end for securing two transverse cast-iron bearers, shown in Figs. 4, 5, and 6.

The top flange of the girder is 2 in. wide and $\frac{1}{2}$ in. thick: it spreads out at the ends to form a base of $6\frac{1}{2}$ in. square, for receiving the post or standard, shown in Figs. 5 and 6; and it is also widened half an inch at two intermediate parts, and provided with two $\frac{5}{8}$ in. holes at each place. These were intended for fixing a standard to carry the return of the handrail, which was, however, replaced by three cast-iron balusters of the form shown in Plate XVI., Fig. 12.

The columns which support the landing are of similar form to those which support the building, but their external diameter is only 5 in., and their thickness of metal $\frac{1}{2}$ in. In Plate XVI., Fig. 4 is an elevation, Fig. 5 a side elevation, and Fig. 6 a sectional plan, of one of the columns. Their total height is 13 ft. 1 in., of which 10 ft. 8 in. is above the floor and 2 ft. 5 in. below. The bottom of the column D terminates in a base plate, 1 ft. 3 in. diameter, $\frac{5}{8}$ in. thick in the centre, and $\frac{1}{2}$ in. thick at the edges, which rests on the foundation. The top of the column is furnished with a flange of the form shown in the plan Fig. 7, $6\frac{3}{4}$ in. wide and the same in breadth, and $1\frac{1}{4}$ in. thick. Four $\frac{7}{8}$ in. bolt holes are made through the flange, at a distance of $4\frac{3}{4}$ in. from centre to centre. The girder C which carries the side of the landing is bolted to the flange by four $\frac{5}{8}$ in. bolts.

E is one of the cast-iron transverse bearers at the end of the landing, which is bolted to the girder C by four $\frac{5}{8}$ in. bolts, with the intervention of a wood packing $\frac{3}{8}$ in. thick. This bearer is shown separately in Plate XVII., Figs. 4, 5, and 6. Fig. 4 is a plan, Fig. 5 is an elevation, and Fig. 6 a vertical section at the part marked *b b* in the elevation. This bearer is 8 in. deep and 7 ft. $10\frac{1}{4}$ in. long. The bottom flange is 3 in. wide and from $\frac{3}{4}$ in. to $\frac{5}{8}$ in. thick. The top flange is 2 in. wide and $\frac{1}{2}$ in. thick, and the vertical web is $\frac{1}{2}$ in. thick at top and $\frac{5}{8}$ in. at bottom. The ends of the bearer are of such a form as to enter between the flanges of the girders which carry the two sides of the landing, and they are terminated by flanges 5 in. wide, $6\frac{1}{4}$ in. deep, and $\frac{5}{8}$ in. thick, with four $\frac{3}{4}$ in. holes for receiving the $\frac{5}{8}$ in. bolts, by which they are secured to the girders. The bearer has a small projection on the under side at each end, which rests on the top of the column.

Two $\frac{3}{4}$ in. holes were formed in the vertical web in the centre of the bearer, for securing it to the main columns of the building, but they are not used, as the staircase is sufficiently firm without this additional support.

The upper part of each of the four columns at one side of the landing is provided with four $\frac{7}{8}$ in. horizontal holes for receiving $\frac{3}{4}$ in. bolts, by which the string F of the lower flight of stairs is attached to the column, with the intervention of a wood packing $\frac{3}{8}$ in. thick, as shown in Plate XVI., Fig. 4. The end of the string rests upon a small snug cast on the column, with the intervention of a $\frac{1}{4}$ in. wood packing.

Figs. 8, 9, and 10, Plate XVI., show one of the strings which support the lower flights of stairs, and which are similar in section to those which support the upper flights. Fig. 8 is an elevation. Fig. 9 is an elevation of the flange at the end of the string. Fig. 10 is a plan of the under side of a portion of the bottom flange, showing how it narrows in at the end. The end flange is 1 ft. 3 in. deep, 2 in. wide at bottom, $2\frac{3}{4}$ in. wide at top, and $\frac{7}{8}$ in. thick. It is furnished with four $\frac{7}{8}$ in. bolt-holes, to correspond with those in the column. The lower end of the string is provided with a horizontal flange 1 ft. $7\frac{1}{2}$ in. long, 4 in. wide, and $\frac{3}{4}$ in. thick, which rests upon the ground floor. Fig. 11 is a horizontal section through the string at the line *g g* in Fig. 8, showing this flange with four $\frac{7}{8}$ in. bolt-holes, by which it is secured to the floor.

On the top flange of each string is a series of vertical standards G H, cast open, and formed with triangular frames at bottom, which rest upon the flanges to which they are each bolted by three $\frac{1}{2}$ in. bolts and nuts. These bolts pass through holes $\frac{5}{8}$ in. wide and $\frac{7}{8}$ in. long, as shown in Fig. 1, Plate XVI., and in Fig. 13, which is a plan of a portion of the top flange of the string.

The holes in the foot of the standard are $\frac{5}{8}$ in. in diameter, and in the positions shown in the section taken through the line *e e* in Fig. 1. The general thickness of metal in the standard is $\frac{1}{4}$ in. and $\frac{3}{8}$ in., and the forms of the various parts are shown in the elevation and in the small sections. The standards are notched into the end of the step I, which is supported on the flange of the triangular foot, the form of which is seen in the section through the line *d d*. The end of the step is made good by a returned nosing. The step is 1 ft. 2 in. wide and $1\frac{1}{2}$ in. thick. The riser K is $7\frac{1}{2}$ in. deep by $1\frac{1}{4}$ in. thick, and is fixed by screws to the vertical side of the triangular foot of the standard. The step is tongued into the riser.

On the top of the standard is fixed by screws a hand-rail L, of the form shown in section in Plate XVII., Fig. 10. It consists of a flat strip of wood 2 in. by $\frac{3}{4}$ in., surmounted by a cylindrical wooden rail $2\frac{3}{4}$ in. diameter, on the lower side of which a flat is cut to bear upon the first strip of wood. Each standard has two small projections, which are let into the lower strip.

The landing is floored with $1\frac{1}{4}$ in. boards tongued with hoop-iron, and supported on wooden joists 7 in. deep and $2\frac{1}{2}$ in. thick, which rest upon the girders C C. At the angles of the landing are cast-iron standards M, of the form and dimensions shown in Plate XVII., in which Fig. 7 is an elevation, and Fig. 8 a plan. Their outside diameter is 5 in., and the thickness of metal is $\frac{3}{8}$ in. Their total height is 3 ft. $7\frac{3}{8}$ in. They are formed with loose caps, fixed on by screws. They are bolted to the girders C, shown in Figs. 1, 2, and 3, Plate XVII., and one of them is shown in its place in Fig. 4, Plate XVI. They are also used at the angles of the well-holes in the cross gallery, as shown in Plate XV.

GALLERY RAILING.

In Plate XVII. is shown the construction of the Railing along the fronts of the Galleries, and round the landings and well-holes of the staircases.

Fig. 9 is an elevation of the lower part of the gallery front, showing the plinth of the intermediate standards of the railing. Fig. 10 is a vertical section of the same, and Fig. 11 is a horizontal section through the foot of the standard at the line *c c* in Fig. 9. Fig. 12 shows the same with the plinth removed. N is the standard, which is of cast iron, and of a similar pattern to those used for the staircases, but the top and bottom are horizontal in lieu of being inclined, and the sides are $\frac{1}{2}$ in. thick and spread out from a width of $1\frac{3}{4}$ in. at top to a width of 5 in. at bottom. The form of the foot is shown in Figs. 10 and 11; it is let into the gallery floor, and secured by two $\frac{5}{8}$ in. bolts and nuts. A light cast-iron plinth, O, is let into the sill P, and secured to the standard by a single small screw. The railing R is cast in short lengths, and the junctions are made by the diamond-shaped bosses S being cast on one length, and notched to receive the angles of the next length. The railing is secured at top and bottom by wood screws entering the hand-rail L and the plinth T.

TRANSEPT.

Plate XVIII. Fig. 1 is a transverse section of one half of the arched roof of the Transept, taken through the lead flat at the north or south end.

Fig. 2 is a transverse section of part of the Transept roof and lead flat over the 72-ft. span in centre.

Fig. 3 is a longitudinal section of a portion of the roof, showing one bay supported by a 24-ft. cast-iron girder D, and a portion of an adjoining bay, supported on the strong 72-ft. truss E.

A A are the strong arched wooden ribs, which form the main support of the roof. B B are lighter intermediate wooden ribs, which are supported by wooden purlins C C.

The ribs A rest upon the columns, with the exception of two which are carried over the nave by the deep 72-ft. trusses E.

The intermediate ribs B are placed over the 24-ft. cast-iron girders D, and the 72-ft. truss E.

The ribs A and B carry the sash-bars F, which are placed in a diagonal position, and fixed to the ridges G.

This diagonal position of the bars is adopted for the purpose of delivering the water in the direction of the flow of the gutters, which are formed on the outer surfaces of the ribs A and B.

The whole roof is strengthened by a system of diagonal bracing H H, consisting of six crosses in each bay. A short pillar, or strut I, made of elm, is placed at the intersection of each cross, to connect the bracing to the purlins.

The space J below the glass roof is fitted with iron louvres, similar to those used in other parts of the building.

Fig 4 is an enlarged section of one of the main ribs A, drawn to a scale of 2 in. to the foot, and Fig. 5 is a side view of a portion of the same, and a part of the lead flat, drawn to a scale of $\frac{1}{2}$ in. to a foot. The rib A is formed of three thicknesses of timber cut to the proper curve, and bolted together. The central piece *e* is 4 in. thick, and consists of separate pieces $13\frac{5}{8}$ in. wide, and about 9 ft. 6 in. long. One side of these is left straight, and the other is cut to a curve of 37-ft. radius. The angle formed on the interior of the rib by the junction of these pieces is filled by a short piece *f*, 4 in. thick and 3 ft. 4 in. long. To this central piece are spiked two side pieces 2 in. thick, which are cut out of planks, with scarcely any waste of material, in the following manner. The plank is divided into two pieces, *h* and *i*, by a curved cut, the radius of which is 37 ft. The position of the two pieces is now reversed by bringing the two straight edges together, as shown in

Fig. 5. The internal edge is then brought to its proper radius by a very slight amount of trimming. The side pieces *h i* thus made are placed so as to break joint with the central 4 in. piece *e*, to which they are firmly nailed or spiked. A piece of timber *j*, 7 in. wide and 2 in. thick, is nailed to the intrados of the arch thus formed, and two boards, *k* and *l*, 1 in. thick and 11 in. wide, are nailed to the extrados. A flat bar of iron, 2 in. wide and $\frac{3}{8}$ in. thick, is placed upon these boards, and another bar, $3\frac{1}{4}$ in. wide and $\frac{3}{8}$ in. thick, is placed upon the piece *j*, and $\frac{5}{8}$ in. round iron bolts are passed through the whole at intervals of 2 ft., and secured by nuts. The piece *j* has its corners rounded, so that the intrados of the arched rib corresponds in form with the cast-iron columns. In this way a strong arched rib is formed of a general section of 1 ft. 6 in. deep by 8 in. wide, and 74 ft. 4 in. diameter on the extrados, and the grain of the wood is at every part in the direction of the strain, or nearly so. The lower ends of the ribs are fitted into the tops of the columns, shown in Plate VIII., Figs. 9 and 10. They are secured to the columns by a wrought-iron strap, 3 in. by $\frac{1}{2}$ in., passing round the front of the column, as shown in Plate XIX., Fig. 1. The ends of the strap terminate in $1\frac{1}{8}$ in. bolts, passing through a timber L, 7 in. square, which lies at the back of the ribs, and also through a $\frac{1}{4}$ in. plate behind the timber, where they are secured by nuts. These straps are used for the ribs springing from the columns next to those at the junction of the Nave with the Transept, and also for the ribs nearest the two ends of the Transept, which are marked *b b* in Fig. 2, which is a plan of one-half of the lead flat; the other ribs, *a a*, are fixed in a similar manner with straps 3 in. by $\frac{1}{4}$ in.

The two ribs which are supported by the 72-ft. wrought-iron trusses over the Nave, cannot, of course, be fixed to the columns. They are, therefore, strengthened at each side by a T iron strut *z*, Figs. 2 and 5, Plate XVIII., $3\frac{1}{2}$ in. by $3\frac{1}{2}$ in., and $\frac{3}{8}$ in. thick. The upper end of the strut is thickened by a wrought-iron plate riveted to it, and it is fixed to the strap on the back of the rib by $\frac{3}{4}$ in. screws. The lower end of the strut is bedded in a wooden block 1 ft. 4 in. wide, and secured by screws.

One of the intermediate ribs B is shown in section in Fig. 6. It is 4 in. deep and 3 in. wide, and carries two boards, *k l*, 11 in. wide and 1 in. thick. Two strips of wood, *m m*, are attached to the edges of these boards, so as to form the internal gutters for the reception of the condensed moisture from the under surface of the glass. Similar strips of wood are attached to the main ribs, as shown in Fig. 4.

The sash-bars F are notched into the boards *l*, Figs. 4 and 6, and also into the ridge G, Fig. 4, which is formed of three pieces of wood, each $1\frac{1}{8}$ in. thick, and of the respective widths of 2 in., 3 in., and 4 in. The ridge is secured to the purlins C C^2 and C^4 at the points marked *b b b* in Fig. 1, by means of a ½ in. bolt, as shown in Fig. 7, and partly shown in Fig. 4. A small wrought-iron plate *n*, 3¼ in. long, 1 in. wide, and ¼ in. thick, is let into the top of the ridge G. Two ⅜ in. wrought-iron bolts, with countersunk heads, pass through this plate, and through a similar plate *o*, ½ in. thick and 1¼ in. wide, on the under side of the ridge, where they are secured by two nuts. A ½ in. bolt, *p*, is passed through a small plate *q*, which is mortised into the purlin C^4, and the end of the bolt is screwed into the plate *o*, and secured by a washer or set-nut ⅛ in. thick.

The ridge G does not form a complete semicircle, but is divided at the summit of the arch, where a path 2 ft. wide is made and covered with lead, as shown in Fig. 1. The end sash-bars are 3 in. wide and 1⅜ in. thick, and have only one groove, as shown in the enlarged section, Fig. 8.

The purlins are supported by two cast-iron brackets at each end, bolted to them and to the arched ribs. Fig. 9 is a side view of the brackets K K, with portions of the rib A and purlin C. Fig. 10 is a front view of the brackets, with a section of the purlin and side view of a portion of the rib A. Fig. 11 is a plan of the under side of the bracket. Their general thickness of metal is ⅝ in., and they are each secured to the rib A by two ¾ in. bolts and nuts, which at the same time secure the corresponding bracket on the opposite side of the rib. Each bracket has a projection 3 in. by 1 in., which is let into the purlin, which is further secured by a ⅝ in. bolt passing through it and through the two brackets. The brackets are strengthened by being cast with a rib. Wooden blocks or brackets are added under the purlins, as shown in Fig. 3. The first purlin C is 8 in. by 6¼ in., and the semicircular arch springs at 2¼ in. below its upper surface. The other purlins are all 4½ in. thick, but increase in depth towards the crown of the arch. C^1 and C^2 are 9 in. deep. C^3 is 10 in., C^4 is 11½ in., C^5 and C^6 are 13½ in. The light intermediate ribs B are notched into the purlins.

The diagonal bracing H H consists of ¾ in. round iron rods, each of which is forged with an eye at one end, and is screwed at the other end. The eyes are secured to the main ribs by the same bolts and nuts which fix the brackets for carrying the purlins; and the screwed ends, which are 1 in. diameter, enter a central adjustment-plate L, shown in Figs. 12, 13, and 14. Fig. 12 is a side view of the plate L and the elm strut I. Fig. 13 is a front view, and Fig. 14 a section, of the plate. The rods H are adjusted in this plate by means of nuts. The plate L and strut I are secured to the purlin by a ⅝ in. bolt passing through them all. The lengths of the struts I diminish as they approach the crown of the arch, the lower one being 9⅝ in., the middle one 8⅝ in., and the upper one 5⅛ in. This diminution of length is to allow for the increasing depth of the purlins as they approach the top.

Before proceeding to describe the lead flat on each side of the Transept roof, we shall explain the construction of the four wrought-iron trusses which carry the lead flat and arched roof across the Nave.

These trusses are 72 ft. long and 6 ft. deep, and are of two different strengths. The two stronger ones are placed under the arched ribs of the roof, while the two lighter ones are placed under the opposite edges of the lead flats. These trusses are shown in Plates XX. and XX *a*.

Fig. 1 is an elevation of one-half of one of the strong trusses. The elevation of the light truss is the same, except that there is no provision at its ends for distributing the weight upon two columns, as is the case with the strong trusses.

The top rail G consists of two angle-irons $4\frac{1}{2}$ in. deep, $3\frac{1}{2}$ in. wide, and $\frac{3}{8}$ in. thick, with a plate 9 in. wide and $\frac{3}{8}$ in. thick, riveted on the top. A space of 2 in. is left between the angle-irons. The angle-irons are in five lengths, and are connected at *t t* by eight $\frac{3}{4}$ in. rivets passing through them and through a plate or plates introduced between them.

The top plate is in seven lengths, and is connected at *uu* by twelve $\frac{1}{2}$ in. rivets passing through the plate, and also through the two angle-irons, and a $\frac{3}{8}$ in. joint-plate 9 in. square, as shown in the enlarged plan, Fig. 2. The top plate is fixed to the angle-irons by $\frac{1}{2}$ in. rivets, of which there are twenty in every 8 ft., and the rivets are countersunk into the top plate.

The bottom rail H consists of two flat wrought-iron bars 6 in. deep, with a space of 2 in. between them. It is in four lengths, jointed at *c c c*, as shown on a larger scale in Figs. 3 and 4. The bars forming the two central lengths are $\frac{7}{8}$ in. thick, and those forming the side lengths are $\frac{5}{8}$ in. thick. The joint is made by six 1 in. rivets passing through two wrought-iron joint-plates 6 in. by 1 ft. 6 in. and $\frac{15}{16}$ in. thick. The space of 2 in. between the bars is filled up by three wrought-iron plates 6 in. by 1 ft. 5 in. Plates of $\frac{1}{4}$ in. thick are introduced with the $\frac{5}{8}$ in. bars, to make up the thickness of the central bars, as shown in Fig. 4.

The end standards A are of cast iron, and are shown in Figs. 5, 6, and 7. Fig. 5 is a front view. Fig. 6 is an elevation of the side next the column, and Fig. 7 is an elevation of the opposite side, with sections of the top and bottom rails.

These standards are $3\frac{1}{4}$ in. wide, 4 in. deep, and 1 in. thick, of a T form of section, and provided with a rib or chipping-piece $\frac{3}{4}$ in. wide and $\frac{1}{2}$ in. deep, which comes in contact with the side of the column. Six $1\frac{1}{8}$ in. bolts secure the standard to the column. The standard is 2 in. thick at top and bottom, where it receives the top and bottom rails. The top rail is secured by a $1\frac{3}{8}$ in. rivet, and the bottom rail by a $1\frac{3}{8}$ in. bolt and nut. Two sockets are formed in the middle, to receive the diagonals I and J. The diagonal I, being exposed to compression, is not made of flat bars, but of four angle-irons $2\frac{1}{4}$ in. by $2\frac{1}{4}$ in., and $\frac{7}{16}$ in. thick, riveted together in pairs, with $\frac{1}{2}$ in. rivets. The two pairs of angle-irons are placed $\frac{1}{2}$ in. apart, and riveted together with $\frac{1}{2}$ in. rivets and small distance-pieces. Portions of this diagonal are shown in Figs. 5, 8, and 9. The lower end of the diagonal is secured in the upper socket of the standard A by a $1\frac{1}{8}$ in. rivet, the space between and on each side of the angle-irons being filled up with wrought-iron plates. The upper end of the diagonal enters between the angle-irons of the top rail, where it is secured by three $\frac{7}{8}$ in. rivets, the thicknesses being made up by three $\frac{3}{8}$ in. plates of the form shown in Fig. 10.

The diagonal J is formed of two bars $4\frac{1}{2}$ in. × $\frac{1}{2}$ in., and is secured at each end by a $1\frac{3}{8}$ in. rivet. The ends are thickened by short plates riveted to them at each end by two $\frac{3}{4}$ in. rivets, by which means the loss of strength in the diagonal is merely that due to a $\frac{3}{4}$ in. rivet-hole, instead of being that due to the $1\frac{3}{8}$ in. rivet-hole.

The diagonal K is formed of two bars $4\frac{1}{2}$ in. deep and 1 in. thick, and is fixed at each end by a 2 in. bolt and nut. The other diagonals, being exposed to much less strain, are formed of single bars $4\frac{1}{2}$ in. deep and $\frac{1}{4}$ in. thick, and are secured at each end by a 1 in. rivet. Fig. 11 is an enlarged elevation of a portion of the top rail G, with the top of one of the standards B, showing the mode of fixing the diagonals; small square washers, or plates of wrought iron, are introduced to fill up the space of 2 in. between the two bars of the rail. The rivets are each 9 in. from the centre line of the standard.

The standards B and C are shown separately in Figs. 12, 13, and 14. Fig. 12 is a front elevation, which is the same for both B and C. Fig. 13 is a side view of the standard B, showing sections of the top and bottom rails and diagonals. Fig. 14 is a similar view of the standard C, which differs from B in being bowed out in the middle to admit of the passage of the strong diagonal K. Each standard consists of four angle-irons $2\frac{1}{4}$ in. by $2\frac{1}{4}$ in., and $\frac{1}{4}$ in. thick, riveted together in pairs, and the two pairs riveted together with six small cast-iron distance-pieces between them, one of which is shown separately in Fig. 15. The rivets employed to fix the distance-pieces, and to unite the angle-irons, are $\frac{1}{2}$ in. diameter, and the ends of the standards are secured to the top and bottom rails by 1 in. rivets. Four $\frac{1}{4}$ in. wrought-iron plates, of the form shown in Fig. 16, and two smaller ones $2\frac{3}{4}$ in. square, are introduced at the top of each standard B, to fill up the 2 in. space between the angle-irons of the top rail G, as shown in Fig. 13. Four $\frac{1}{4}$ in. plates, of the form shown in Fig. 17, are employed at the bottom of the standard B, with two smaller ones, as also shown in Fig. 13. Similar plates are used with the standard C, but only two of each are employed, and the small plates are $\frac{1}{2}$ in. thick instead of $\frac{1}{4}$ in., as shown in Fig. 14.

Fig. 18 is a front elevation, and Fig. 19 a side view, of the standard D, which is of cast iron, and over which is placed one of the main arched ribs of the Transept roof. Fig. 20 is a horizontal section at the line *c c* in Figs. 18 and 19. The width in the centre is 6 in. each way, and the substance of metal is from $\frac{3}{4}$ in. to $\frac{7}{8}$ in. The base, which rests upon the bars of the bottom rail, is 1 ft. 6 in. long by 4 in. wide, and the top is 1 ft. 6 in. by 3 in. Triangular projections 2 in. thick enter the top and bottom rails, where they are secured by 1 in. rivets. In the centre of the standard is a socket $\frac{3}{4}$ in. wide, through which pass the two light diagonals, $4\frac{1}{2}$ in. by $\frac{1}{4}$ in. In one side of the strut are two $\frac{9}{16}$ in. holes for receiving the bolts, by which the 24-ft. wrought-iron trusses are fixed, as will be presently described.

The main strength of the truss consists in the top and bottom rails G and H, the diagonals I J and K, the first wrought-iron standard B, and the cast-iron standards D. These parts alone are sufficient to support the main arched ribs and the 24 ft. wrought-iron trusses which rest upon the standards D. The other diagonals and standards serve to support the light intermediate arched ribs, and to preserve the symmetry of the appearance of the truss.

The truss is secured to the column L by six $1\frac{1}{8}$ in. bolts and nuts, but the column is relieved of the whole, or great part, of the weight of the truss by means of the plates M, which transfer the weight to the additional column N. Fig. 21 is a front view, and Fig. 22 a side view, of the plates M, with portions of the truss and columns L N. Fig. 23 is a horizontal section on the line *d d* in Fig. 21, and Fig. 24 is a section on the line *e e* in Fig. 21. The plates M M are of such a form as to fit the sides of the end standard A, and take a bearing under the socket in the centre. They are fixed to the truss by the $1\frac{3}{8}$ in. bolt, which connects the bottom rail to the standard A, and by two other 1 in. bolts. The plates are 1 in. thick, 1 ft. 5 in. wide at bottom, and 5 in. wide at top; they are 1 ft. high on the side next the truss, and 2 ft. $7\frac{3}{4}$ in. high on the side next the column. The bottom of each plate spreads out into two feet, each of which is $3\frac{3}{8}$ in. by $2\frac{3}{4}$ in. These feet rest on the top of the column N, with the intervention of two pairs of wrought-iron keys, by driving which the weight of the truss is taken off the column L, and transferred to the column N. The two columns are tied together by means of wrought-iron straps *i i*, 2 in. by $\frac{1}{2}$ in., and plates *k k*, 2 in. by $\frac{1}{2}$ in., which are tightened up by gibs and keys. A wood block is introduced between the two columns, to preserve the proper distance between them. In Fig. 1 is shown the mode of connecting these columns at the lower junctions, on a level with the girders. Fig. 25 is a plan of the connecting plate *g*. Fig. 26 is a plan of the ornamental octagon bands, and Fig. 27 is a plan of the octagon bases. The plate *g*, which is $\frac{1}{2}$ in. thick, is secured by the bolts and nuts which unite the columns to their connecting-pieces. The spaces between the octagon bands and bases are filled by blocks of wood, of the forms shown in the Figures.

As we have already mentioned, the strong 72 ft. trusses, above described, are placed under the arched ribs of the roof of the Transept, where it crosses the Nave. Other trusses of similar length and depth, but of lighter scantlings, are placed under the opposite edges of the lead flats. The elevation of these trusses is the same as that of the stronger ones, and is shown in Fig. 1, Plate XX.

The top rail G is similar to that of the strong truss, but the angle-irons are only $\frac{5}{16}$ in. thick instead of $\frac{3}{8}$ in., and the top plate is $\frac{1}{4}$ in. thick instead of $\frac{3}{8}$ in. The two bars of the bottom rail H are each $\frac{7}{16}$ in. thick in the middle of the truss, and $\frac{5}{16}$ in. thick at the ends, being only one-half the strength of those of the strong truss; $\frac{7}{8}$ in. rivets are used at the joints. The diagonal I is of four angle-irons $\frac{1}{4}$ in. thick. The diagonal J is of two bars, each $\frac{5}{16}$ in. thick. The diagonal K is of two bars, each $\frac{9}{16}$ in. thick. The small plates, or washers, used to fill up the space of 2 in. between the bars of the top and bottom rails, consequently vary in thickness, to make up for the reduced thickness of these diagonals. The other diagonals are $4\frac{1}{2}$ in. by $\frac{1}{4}$ in., as in the strong truss, and in other respects the dimensions are the same. The additional columns N, and plates M, are not employed for these trusses.

Fig. 28 is an elevation of one of the 24 ft. wrought-iron trusses, which are supported by the deep 72 ft. trusses. These trusses are 3 ft. deep.

The top rail P consists of two angle-irons 4 in. deep, 2 in. wide, and $\frac{1}{4}$ in. thick, placed 1 in. apart. The bottom rail Q is in three lengths. The central part consists of two flat bars $4\frac{1}{2}$ in. deep, and $\frac{3}{8}$ in. thick, placed $1\frac{1}{4}$ in. apart. The ends consist of two flat bars $4\frac{1}{2}$ in. by $\frac{1}{4}$ in. The diagonals R are of single bars 4 in. by $\frac{11}{16}$ in., and are secured by a $1\frac{1}{8}$ in. rivet at each end. The other diagonals are of wood, 4 in. by $\frac{1}{2}$ in., and are secured by $\frac{3}{8}$ in. rivets. The standards S are of cast-iron, and similar in dimensions and form to those used in the 48 ft. trusses, shown in Plate XI. They are secured at each end by $\frac{7}{8}$ in. rivets. Fig. 29 is a plan of the junction of the bars of the bottom rail with the diagonals and cast-iron strut. The wrought-iron diagonal R enters between the two $\frac{1}{4}$ in. bars of the bottom rail, which again enter between the two $\frac{3}{8}$ in. bars, forming the central part of the bottom rail, and the $1\frac{1}{8}$ in. rivet unites them all. Two washers $\frac{1}{8}$ in. thick are introduced with the strut S between the $\frac{3}{8}$ in. bars of the bottom rail, to fill up the space of $1\frac{1}{4}$ in. A washer, or distance-piece, $\frac{3}{4}$ in. thick, is introduced with the wooden diagonal, and secured by the $\frac{3}{8}$ in. rivet. The bottom rail is fixed at each end to the cast-iron standards (D) of the deep 72 ft. trusses, by two $\frac{1}{2}$ in. bolts and nuts. The mode of fixing the top rail to the deep 72 ft. trusses is shewn in plan in Fig. 30, and in elevation in Fig. 31. A $\frac{1}{2}$ in. plate, 5 in. by 10 in., is placed on the upper surface of the top rails of both trusses, and two pieces of angle-iron *h*, of similar strength to those of the top rail (P) of the 24 ft. truss, are placed under it, with the intervention of packing-pieces $\frac{1}{2}$ in. thick. Four $\frac{5}{8}$ in. bolts and nuts connect these pieces to the rail P, and two $\frac{3}{4}$ in. bolts and nuts connect them to the rail G. Two $\frac{9}{16}$ in. bolt-holes are made in the top rail P, over each strut S, as shown in Fig. 30, for the reception of the $\frac{1}{2}$ in. bolts which connect this top rail with the timbers of the lead flat.

LEAD FLATS.

The lead flats rest upon the 24 ft. wrought-iron trusses, and upon 24 ft. cast-iron girders, and are shown in Plate XVIII., Figs. 1, 2, 5, 15, 16, and 17; and the details of the same are shown in Plate XIX. Fig. 2, Plate XIX., is a plan showing the timbers, girders, and diagonal ties, of one half of one of the lead flats. The girders N N, and trusses O, are 24 ft. apart, and support two ranges of trussed joists P P′, which carry the binders Q Q, $6\frac{3}{8}$ in. square. R R are the common joists 6 in. by 2 in., supported by the binders Q, and the girders and trusses N O. The joist R′ is 7 in. by $2\frac{1}{2}$ in. M M′ are two timbers 7 in. square, which run along the edges of the lead flat, and which are also shown in Plate XVIII., Figs. 5 and 15. T is a timber 9 in. wide and 6 in. deep, running along the top of the girders and trusses at the side of the Transept, and U is the front of the gutter $9\frac{1}{2}$ in. deep by 4 in. wide.

The trussed joists P are formed of two pieces 8 in. by $2\frac{1}{2}$ in., and the joists P′ are of two pieces 7 in. by $2\frac{1}{2}$ in., trussed by a $1\frac{3}{8}$ in. wrought-iron rod. Fig. 3 is a plan, and Fig. 4 a section, of one of the joists P′. *u u* are the timbers of the joist 7 in. deep and $2\frac{1}{2}$ in. wide, and *v* is the $1\frac{3}{8}$ in. tie-rod passing through a cast-iron shoe *w* at each end, where it is fixed by a nut. Fig. 5. is a section of the shoe *w* on the line *m m* in Fig. 3. It is $\frac{1}{2}$ in. thick, and of the form shown in the drawing, and is fixed to the timber V, by two $\frac{1}{2}$ in. screws. The shoes, which rest on the intermediate cast-iron girders and wrought-iron trusses, are shown in section in Plate XVIII., Fig. 17.

The tie-rod *v* passes under two cast-iron struts under the binders Q, one of which is shown in Fig. 4, Plate XIX. The block of wood *p*, 1 ft. by 7 in., and $4\frac{1}{2}$ in. thick, is placed between the strut *x* and the binder Q, into which it is notched 1 in. *r r* are two blocks of wood 7 in. wide, $7\frac{7}{8}$ in. high, and $2\frac{7}{8}$ in. thick, placed between the block *p* and the underside of the trussed joists. *o* is another block of wood 8 in. by $6\frac{3}{8}$ in. and $2\frac{1}{2}$ in. thick, placed between the binder Q and the trussed joists *u u*. The strut *x* is fixed by a $\frac{1}{2}$ in. bolt passing through a bent wrought-iron plate 2 in. by $\frac{1}{4}$ in., nailed on the top of the joists.

The binder Q is fixed to the hollow wood columns, on the outside of the building, by two $\frac{1}{2}$ in.

strap-bolts, which are fixed to the binder by a $\frac{1}{2}$ in. bolt. A block of wood *s*, $6\frac{1}{2}$ in. thick, is fitted to the inside of the column under the binder, and a $\frac{5}{8}$ in. bolt passes through both, and through the gutter-front U, which rests on the top of the column. The gutter-front U is connected at the corner of the building to the timber V, $6\frac{1}{2}$ in. wide by $8\frac{1}{2}$ in. deep, by means of a wrought-iron knee $1\frac{3}{4}$ in. by $\frac{5}{8}$ in., fixed by three $\frac{1}{2}$ in. bolts and a $\frac{1}{2}$ in. wood screw. A circular block of wood *t*, $2\frac{1}{2}$ in. thick, is fitted to the interior of the cast-iron column, and screwed to the bottom of the gutter-front U.

Fig. 6 is an elevation of the gutter-front U, with part of the ornamental casting below it, and the tops of the corner cast-iron column, and one of the hollow wooden columns marked *g*, in Fig. 2.

Fig. 7 is an elevation of parts of the end of the lead flat, and its junction with the Transept.

Fig. 8 is a plan of the part marked *n n* in Fig. 2, showing the junction of the lead flat with the front of the Transept. The timber V is supported under the trussed joists by solid wooden columns W, at the front of the Transept. The timber V is united to the timber X, 8 in. wide and $8\frac{1}{2}$ in. deep, by a $\frac{1}{2}$ in. cast-iron plate *x*, and two $\frac{5}{8}$ in. bolts and nuts. Another similar bolt fixes the plate to the cast-iron column Y. This plate *x* is more particularly shown in Plate XXIII., Figs. 2, 5, 6, and 7. The timber T buts up against the plate *x*. The timbers M and M′ are bolted to the timber V by $\frac{5}{8}$ in. bolts. The common joists R R, Fig. 2, are supported by pieces of wood, which are laid on the binders Q Q, and which are $3\frac{3}{8}$ in. thicker at the ends next the Transept than at the ends next the gutter, as shown in Figs. 1, 2, 5, 15 and 16, Plate XVIII. The last Fig. shows the method of jointing the joists, which is effected by means of a piece of hoop-iron $\frac{1}{8}$ in. thick, turned down at the ends, and fixed by four nails. The boarding, which is $1\frac{1}{4}$ in. thick, is laid upon the trussed joists and common joists, and covered with sheet-lead in the usual manner of laying a lead flat, and the slope of $3\frac{3}{8}$ in. causes all the water which falls on the lead flat and on the arched roof of the Transept to flow into the gutter at the outer edge of the lead flat. The gutter is 1 ft. $8\frac{1}{2}$ in. wide, and has a gentle slope towards the columns *e e* and *e′*, Fig. 2, Plate XIX., which serve as rain-water outlets.

Fig. 9 is a plan of the mode of fixing the gutter-front to the columns *e e*. The two portions of the gutter-front are united by a cast-iron plate let into them, and fixed by two $\frac{1}{2}$ in. bolts with countersunk heads. This plate is furnished with a projecting piece at bottom, which enters the column, to which it is secured by two $\frac{3}{8}$ in. bolts.

Fig. 10 is a plan, and Fig. 11 a section, of the mode of fixing the gutter-front to the iron columns *fff* in Fig. 2, where there are no rain-water outlets. A wooden block is turned to fit the inside of the column, and the two lengths of the gutter-front are notched on to it, and secured by two $\frac{1}{2}$ in. bolts in each.

The whole of the lead flat is stiffened by diagonal bracing, as shown in Fig. 2, the bars *c c* being 4 in. by $\frac{1}{2}$ in., and the bars *d d* 4 in. by $\frac{1}{4}$ in. The mode of fixing the braces is shown in Fig. 1. A wrought-iron plate 4 in. by $\frac{1}{4}$ in. and 1 ft. $7\frac{1}{2}$ in. long, with its ends turned up, is let into the bottom of each of the timbers M M′, and secured with two $\frac{5}{8}$ in. bolts and nuts. The diagonal *c* is fixed at each end by a $1\frac{1}{2}$ in. bolt passing through the timbers and the $\frac{1}{4}$ in. plate.

OUTER WALLS, OR SIDES OF BUILDING.

Plate XXI. Fig. 1 is an exterior elevation of three compartments of the outer wall or side of the building on the ground floor, showing one of the exit doors, with a glass window or sash at the side, and also a compartment of the wooden boarding, with the iron louvres at top and bottom. Fig. 2 is a section through the glass window at the line *a b* in Fig. 1, and Fig. 3 is a section through the boarding at the line *c d* in Fig. 1. Fig. 4 is an interior elevation of the boarding and glass window. The boarding is carried along the sides of the lower tier of the building, except at the entrances, on each side of which glass windows are introduced. A is one of the cast-iron columns which support the building, and which is shown separately in Plate VIII., Fig. 1. It rests upon a mass of concrete 2 ft. 6 in. long by 1 ft. 3 in. wide and 1 ft. thick. These iron columns are 24 ft. apart, and the intermediate space is divided into three 8 ft. compartments by two wooden columns B B, which are built up of three pieces of wood, as shown in Plate XXII., Fig. 14, the external side being of the same form as that of the cast-iron columns. These columns are supported on masses of concrete 1 ft. 6 in. by 1 ft. and 1 ft. thick, and are packed up by folding wedges 1 ft. 6 in. long, 7 in. wide, 2 in. thick at one end, and $\frac{1}{2}$ in. thick at the other end. The boarding which extends along each side of the lower tier of the building is $1\frac{1}{8}$ in. thick, and is placed vertically, and each compartment is supported by three horizontal battens or ledges 7 in. by $1\frac{1}{4}$ in. The boarding is fixed by the ledges in one compartment, being united to those in the next by small cast-iron plates C C, which are also employed to fix the window-frames in a similar manner. These plates are shown in Figs. 23 and 24, Plate XXII., Fig. 23 being an elevation, and Fig. 24 a plan. They are 9 in. long, $2\frac{3}{4}$ in. wide in the centre, and $2\frac{1}{2}$ in. wide at the ends, and are fixed to each ledge by two $\frac{5}{16}$ in. wood screws. A $\frac{1}{2}$ in. screw is passed through a hole in the centre of the plate, and screwed into the cast-iron column A. A board $\frac{5}{8}$ in. thick and 7 in. wide is placed between the column and the plate, and a fillet $\frac{1}{2}$ in. thick and $1\frac{1}{4}$ in. wide is introduced between this board and the external boarding, to complete the junction. The boarding rests upon a sill *q*, 9 in. wide and 4 in. thick, the top of which is 4 ft. 9 in. above the ground floor. The space between this sill and the floor is occupied by eight louvres D, of galvanized sheet-iron. On the top of the boarding is a wall-plate 10 in. wide and $2\frac{3}{8}$ in. thick, above which are five louvres E.

In front of the boarding is an ornamental arch-plate F, of cast-iron, and of the section shown in Fig. 6, Plate XXII., its general thickness being $\frac{5}{16}$ in., and in front of the louvres is another ornamental casting G.

Fig. 5, Plate XXI., is a vertical section, and Fig. 6 is an interior elevation, of one bay of the front of the second tier of the building above the gallery floor. No boarding is used in the second and third tiers, the whole being glazed. Above the windows are five louvres, similar to those at the top of the front of the lower tier of the building.

Plate XXII., Fig. 1, is a section on an enlarged scale of portions of the front of the building, with a side elevation of a portion of one of the iron columns A, and also one of the standards used for carrying the flagstaffs. Fig. 2 is an elevation of a portion of the front of the building, showing one of the wooden columns B. Fig. 3 is a side elevation of the top of the standard. Fig. 4 is a plan of the same. Fig. 5 is a front elevation of one of the staples for holding the flagstaff. Fig. 6 is a section of the circular rib of the arch-plate. Fig. 7 is a sectional plan of one of the wooden columns at *a a* in Fig. 2, looking upwards.

A is the iron column. F the arch-plate, which is cast with small lugs, by means of which it is secured to the columns by $\frac{3}{8}$ in. screws, as shown in Fig. 7. Above the arch-plate is the casting G, also shown in Plate XXI., Fig. 1. It is cast hollow, of a general thickness of $\frac{5}{16}$ in., and is secured by lugs and $\frac{3}{8}$ in. screws to the arch-plate and to the columns. H is a wall-plate, 10 in. wide by $2\frac{3}{8}$ in. thick, on which is fixed a strip of wood $2\frac{1}{2}$ in. wide by $\frac{5}{8}$ in. thick, against which the lower louvre-board shuts. I is a portion of the case for the louvres, which consists of two jambs and a head, all $5\frac{1}{2}$ in. wide and $\frac{7}{8}$ in. thick. J is a lining $\frac{5}{8}$ in. thick, which conceals the case of the louvres.

K is a portion of one of the transverse cast-iron girders, on which is fixed the main gutter L. M is a $\frac{7}{8}$ in. board forming the external face, and N is a $\frac{5}{8}$ in. board forming the internal face. Above these is fixed the plank O $11\frac{3}{4}$ in. wide and $2\frac{1}{4}$ in. thick, to the external edge of which is fixed a rounded piece of wood to support an ornamental cornice P, of sheet-zinc. Q is a cast-iron cap $\frac{3}{16}$ in. thick, which conceals the top of the column A, and is provided with a recess at the top to receive the foot of the flagstaff. R is a board $10\frac{1}{4}$ in. wide and $1\frac{1}{8}$ in. thick, to which the cornice is fastened, and which also carries the finials S. These finials are of cast iron $\frac{1}{8}$ in. thick, with a flange

$\frac{5}{8}$ in. wide round the edge. T is a board $5\frac{1}{4}$ in. wide and $1\frac{1}{8}$ in. thick, placed at a distance of $3\frac{5}{8}$ in. from the board R, and serving to carry the sash-bars U of the glass roof. The top of the board T is curved down $2\frac{1}{2}$ in. at each end towards the main gutters L; and the board V, which forms the bottom of the external gutter, also slopes down in the same direction. The water from this external gutter is delivered into the main gutter L, through a hole in the plank O, as shown in Plate XIII., Fig. 5. W is a strip of wood nailed to the board T, and forming a channel for the moisture condensed on the under surface of the glass. This channel follows the inclination of the top of the board T. The position of the lowest sash-bar, and the corresponding position of the bottom of the gutter V, are shown by the dotted lines in Fig. 1. X is the standard for supporting the flagstaff. Its height is 4 ft. $1\frac{1}{4}$ in., and the top is shown in Fig. 3, and in sectional plan in Fig. 4. It is made hollow, of $\frac{7}{8}$ in. boards. An iron staple, 3 in. wide and $\frac{3}{16}$ in. thick, is fixed at a height of 1 ft. from the bottom by means of two $\frac{1}{2}$ in. bolts and nuts, and a similar staple is fixed 2 ft. 4 in. above the first. These staples are adapted for receiving a flagstaff $2\frac{1}{4}$ in. in diameter.

In the lower part of Fig. 1 a portion of the window-frame is shown at Y. It is secured by the fillet *y*, and the small plates shown at C C in Plate XXI., Fig. 4. *z* is the glass.

Z is a cast-iron octagon band, which is fixed to the column by a screw, and employed for both iron and wood columns. Fig. 7 is a sectional plan of one of the wood columns at *a a* in Fig. 2, looking upwards, and shows the form of the band Z, which projects 2 in. from the face and $1\frac{1}{2}$ in. from each side of the column.

Fig. 8 is an elevation, showing the termination of the cornice at the external angles, together with the terminal cap to the column there. Fig. 9 is a sectional plan at *b b* in Fig. 8. Fig. 10 is a vertical section through the cornice at the external angle, showing the mode of passing the water round the corner. Fig. 11 is a plan of the same at *c c* in. Fig. 10.

A is the iron column, Q the cast-iron cap forming two sides of a square at the upper part, and brought into an octagonal form at the lower part. Q′ is the angle of the cornice, which is also of cast iron, $\frac{3}{16}$ in. thick. It is united to the cap by small countersunk bolts and nuts.

k is a shallow cast-iron trough $4\frac{1}{2}$ in. wide and $1\frac{3}{4}$ in. deep inside, which conveys the water from the external side gutter V to the gutter along the end of the building *l*.

Fig. 12 is a sectional plan of the column at the external angle, showing the octagon band. A is the cast-iron column. The band Z forms five sides of the octagon, and is made in two pieces, which are united by two small countersunk screws entering a strip of wrought-iron within the band, which is secured to the column by two $\frac{3}{8}$ in. countersunk screws.

Fig. 13 is a sectional plan of the column at one of the internal angles of the building.

The band z forms one side of an octagon, and is fixed to the column by a $\frac{3}{8}$ in. countersunk screw.

Fig. 14 is a plan, and Fig. 15 an elevation, of a portion of one of the wood columns B, with the octagon band z′ at the level of the sill of the ground-floor windows. These bands correspond with the sockets of the cast-iron columns already described, and shown in Figs. 1 and 2, Plate VIII.

Some of the wooden columns at the ends of the lead flat are solid, as shown in Plate XIX.; others are built up of three pieces, as shown in Fig. 14 and Fig. 7, while others are built up of five pieces, as shown by the dotted lines in Fig. 14. The hollow columns are blocked across where necessary, for fixing the sashes, boarding, &c.

Fig. 16 is a vertical section, showing the mode of fixing the wall-plate O to the hollow wood column B. *m* is a blocking-piece let into the sides of the column. A $\frac{1}{2}$ in. bolt passes through this block, and through the wall-plate O.

Fig. 17 is a plan of the door-frame and part of one of the exit doors, which is shown in elevation in Plate XXI., Fig. 1. Fig. 18 is a vertical section of part of the door, and the head of the door-frame and part of the sash over the door.

The wood columns on each side of the door are solid, as shown in Fig. 17, and are fixed in contact with the door-posts *n*, which are 1 ft. by 6 in. The head of the door-frame *o* is 6 in. square, and a piece $3\frac{1}{8}$ in. by $1\frac{3}{4}$ in. is removed from the lower internal angle to receive the door, which is $2\frac{1}{2}$ in. thick. Above the head *o* is the piece of wood *p*, $4\frac{3}{8}$ in. by $6\frac{1}{4}$ in., which forms the sill for the sash over the door. The door is panelled, as shown in Plate XXI., Fig. 1.

Fig. 19 is a vertical section of the sash-sill and lower part of sash to the ground-floor windows. Fig. 30 is a plan of the sill, and Fig. 29 an interior elevation of the same, showing the mode of uniting the different lengths of the sill at the columns.

The sill *q* is 9 in. wide and 4 in. thick, and is bevilled to throw off the rain-water. It is in 24 ft. lengths, which meet at the iron columns. *g* is a small cast-iron plate, with a central socket and two projecting feathers, which enter the sills. The ends of the plate are furnished with projections $\frac{3}{8}$ in. by $\frac{1}{2}$ in. and 2 in. wide, which are let into the sills, and tie them together. A $\frac{5}{8}$ in. bolt passes through the plate and socket, and is screwed into the cast-iron column. Four small wood screws secure the plate *g* to the sills.

The bottom rail of the sash *r* is $2\frac{3}{8}$ in. thick and $3\frac{3}{8}$ in. deep on the front edge, and $3\frac{1}{8}$ in. deep on the back edge. A groove $\frac{5}{16}$ in. deep is formed in the top edge, to receive the moisture condensed on the interior of the glass. Diagonal holes $\frac{1}{4}$ in. diameter are bored through the rail in the centre of each square of glass, to allow this water to flow out.

Fig. 20 is a section, in detached pieces, of the sashes of the upper windows, showing the mode of fixing them. Fig. 21 is a section of one of the sash-bars. Fig. 22 is a half plan of the strengthening rib in the centre of the sash. Fig. 23 is an elevation, and Fig. 24 a plan, of the joint-plates at *d d* in Fig. 20. Fig. 25 is an elevation, and Fig. 26 a plan, of the plate at *e* in Fig. 20. Fig. 27 is an elevation, and Fig. 28 a plan, of the joint-plate *f* of the sill *s* in Fig. 20.

The sill *s* is 5 in. by 3 in., and is united in a similar manner to the lower sill *q*, and secured to the column by a $\frac{1}{2}$ in. bolt.

The sash-bars are $2\frac{3}{8}$ in. by $\frac{7}{8}$ in., and of the form shown in Fig. 21. The glass is introduced by springing them apart a little. The whole is bound together by three $\frac{3}{8}$ in. bolts, as shown in Figs. 20 and 26.

In the centre of the sash at *e* is a wooden rib $1\frac{3}{8}$ in. thick, and $1\frac{1}{2}$ in. wide at the ends, and 3 in. wide in the centre. A $\frac{1}{2}$ in. tie-rod is laid in a groove at the back of this rib, and secured by a nut at each end to plates of the form shown in Figs. 25 and 26. These nuts are screwed up tight, and a strong support is thus given to the centre of the sash, which is sprung out $\frac{3}{4}$ in. in the middle. The plate is fixed to the sashes by four wood screws, and to the column by a $\frac{1}{2}$ in. screw in the centre.

Plate XXIII., Fig. 1, is a section through the panels and cornice under the window sills, at and above the Gallery floor at the east and west ends of the building, and also at the north and south ends of the Transept, showing a portion of one of the wood columns B, and a section of the breastsummer *t*. Fig. 2 is a similar section, showing one of the iron columns A, and Fig. 3 is an external elevation of the same, showing part of the panels and cornice. Fig. 4 is a sectional plan at *i i* in Fig. 3.

The panels are formed of vertical laths covered with cement. The back of the panel is concealed by $\frac{5}{8}$ in. beaded boarding placed vertically, and flush with the interior face of the column, against which is fixed a board 7 in. wide and $\frac{5}{8}$ in. thick, overlapping the $\frac{5}{8}$ in. boarding. Above the panel is a sill $6\frac{3}{4}$ in. wide, and 3 in. thick, which is jointed and fixed to the iron columns in a similar manner to the sill *s* in Fig. 20., Plate XXII.

The joint-plate of the sill is shown in Fig. 2, Plate XXIII., and also the joint-plate of the breastsummer at *h*. Fig. 5 is an interior elevation, Fig. 6 is a plan, and Fig. 7 a section, of the joint-plate at *h*. It is 1 ft. 10 in. long, $5\frac{3}{8}$ in. wide, and $\frac{1}{2}$ in. thick, with a flange at top and bottom, and two L-shaped projections, which enter the breastsummers. The plate is fixed to the cast-iron column by a $\frac{5}{8}$ in. bolt, with a countersunk head, and each breastsummer is also secured to the plate by a $\frac{5}{8}$ in. bolt.

ENDS OF TRANSEPT.

Plate XXIV., Fig. 1, is an external elevation of part of the north end of the Transept. Plate XXV., Fig. 2, is an internal elevation of the same. Fig. 3 is an external elevation of a portion of the arched roof of the Transept, with the louvres and wheel for working them. Fig. 4 is a section of the same, on the line *u u* in Fig. 2; and Fig. 5 is a plan of the same, on the line *x x* in Fig. 2.

Plate XXVI. contains the detail of the end of the Transept, showing sections, on a larger scale, at the various parts indicated by the small letters in Plates XXIV. and XXV. In these three Plates the figures are numbered consecutively, and similar parts are indicated by similar letters. The following description applies to all three Plates.

Fig. 6, Plate XXVI., is a horizontal section on the line *a a* in Figs. 1 and 2. A is the cast-iron column. B is a wooden column of semi-elliptical section, which joins a cast-iron moulding C, of similar section, which follows the curve of the roof as shown in Fig. 1. Y is a portion of the frame of one of the windows, and Y^1 is a portion of the frame of a narrower window, in front of which is the ornamental frame Y^2. The column B is secured at intervals by $\frac{5}{8}$ in. countersunk bolts, passing through cast-iron plates *s*, which are similar to those shown at C in Figs. 23 and 24, Plate XXII., except that they are lengthened out on one side to receive the $\frac{5}{8}$ in. bolts. The space between the iron column A and the window Y^1 is filled up by blockings concealed behind $\frac{7}{8}$ in. beaded boarding D.

Fig. 7 is a section on the line *b b* in Figs. 1 and 2, showing the panel E^1, which is here substituted for the louvres. This panel is of lath and cement. A^2 is the connecting piece of the cast-iron column, and K is one of the transverse cast-iron girders. B is the semi-elliptical wooden column.

In Fig. 1 B^1 is a second semi-elliptical column, terminating in a cast-iron moulding C^1, and fixed in a similar manner to that already described and shown in Fig. 6.

Fig. 8 is a section on the line *c c* in Figs. 1 and 2, showing the upper part of the panel E^1, and also the wooden panel E^2, and the wooden moulding B^2, which joins the columns B and B^1. H is a timber $12\frac{1}{2}$ in. wide and $6\frac{1}{4}$ in. thick, the bottom of which is 4 in. below the springing line of the arched roof. L is another timber, 8 in. by $8\frac{1}{2}$ in., passing over the panel E^1, and jointed to the timber L^1, Fig. 1, by the plates *t*. The plate *t* is similar to that shown in Plate XXIII., Figs. 5, 6, and 7, but with an additional hole for receiving a bolt for securing the elliptical wooden column.

P is a cornice of sheet zinc, fixed at intervals by means of wooden blocks. P^1 is a cast-iron cap which fits over the zinc cornice, and which is shown in plan in Fig. 9.

Fig. 10 is a section on the line *d d* in Figs. 1 and 2. A^4 is the connecting piece of one of the cast-iron columns A^3 in Fig. 1. K is one of the transverse cast-iron girders, and G is the ornamental casting in front of the louvres E in Fig. 1. I is part of the louvre casing, and J is the lining which conceals it. These parts are similar to those shown in Plate XXII., Figs. 1 and 10. L^1 is a timber $6\frac{1}{2}$ in. by $8\frac{1}{2}$ in., passing over the louvres and jointed by the plates t^1 in Fig. 2, and united to the timbers L by the plates *t*. E^3 is a wooden panel. The timber H diminishes gradually in thickness from the sides to the centre of the Transept end, being $6\frac{1}{4}$ in. thick at the sides, as shown in Fig. 8, and $5\frac{1}{2}$ in. at the centre, as shown in Fig. 10.

Fig. 11 is a section through the line *e e* in Figs. 1 and 2 of the outer ring of the semicircular head of the Transept end. C is a cast-iron semi-elliptical moulding, $\frac{1}{4}$ in. thick. It is fixed by screws to blocks of wood attached at intervals on the face of the ring. M is one of the ornamental cast-iron finials, and N is one of the bars of the glass roof of the Transept.

O is a part of one of the segmental sashes in the semicircular head, and Q is a splay which forms the external frame round the same. This being circular, is made up in three thicknesses. R is the lining which forms the external face of the ring. R^1 is transverse boarding, which forms the inner face of the ring, as shown in Fig. 2. W is one of a series of diagonal braces, shown by dotted lines in Fig. 2, and serving to strengthen the ring. These braces are notched or mortised into the radial ribs S in Figs. 1 and 2, and secured in the manner shown by the dotted lines at *q* in Fig. 2, and on a larger scale in Figs. 17 and 18. U U are two wrought-iron plates $8\frac{1}{2}$ in. long by 3 in. wide, and $\frac{3}{16}$ in. thick. Half an inch at one end of each plate is turned down, and the plates are bent to fit the angles formed by the braces and the radial rib. The turned-down ends of the plates are let into the braces W, while the other ends are fixed by nails to the rib S. V V are two blocks of elm fitted to the plates U U, and the whole is traversed by a $\frac{1}{2}$ in. bolt secured by a nut and washer.

Fig. 12 is a section at *g g* in Fig. 1 of the inner ring of the semicircular head. C^1 is the cast-iron semi-elliptical moulding fixed on the external boarding R^2. R^3 is the internal boarding, fixed in a transverse position, as shown in Fig. 2. O O^1 are the sashes, and Q Q the splays. W^1 is a diagonal brace, shown by the dotted lines in Fig. 2, and united to the radial ribs in the same manner as has been already described in reference to the braces W in the outer ring.

Fig. 13 is a section of one of the radial ribs S at the line *ff* in Figs. 1 and 2. Fig. 14 is a section of the same at the line *h h*. Fig. 15 is a similar section at *i i*, and Fig. 16 a similar section at *k k*. The rib is 1 ft. deep, and tapers in width from $4\frac{1}{4}$ in. at *ff* to $2\frac{1}{4}$ in. at *k k*. The sash-stiles O and the splays Q are also tapered towards the centre of the semicircular head. Fig. 15 also shows the mode of uniting the portions of the semicircular rib T to the radial rib S. Fig. 19 is another view of this junction, which is marked *r* in Fig. 2; and Fig. 20 is a view of one of the wrought-iron plates employed in it. Half of each piece T is notched or morticed $\frac{3}{8}$ in. into the rib S, as shown by the dotted lines, and the whole is secured by two $\frac{1}{2}$ in. bolts traversing the four wrought-iron plates U^1 and the four elm blocks V^1.

Fig. 21 is a section of one of the semicircular ribs T or T^1 at the line *l l* in Figs. 1 and 2. The sashes or compartments O^2 and O^3 have semicircular heads Q^2 and Q^3, as shown in Figs. 1 and 2. These semicircular heads are of cast iron $\frac{5}{16}$ in. thick, and of the sectional form shown in Fig. 21.

The centre of the head of the Transept end is occupied by a series of cast-iron frames X, Figs. 1 and 2, bolted together and attached to the alternate radial ribs by three $\frac{1}{2}$ in. bolts passing through each. The other alternate radial ribs are each secured to the frames X by a single $\frac{1}{2}$ in. bolt. The ribs are still further strengthened and secured by braces or struts Z Z^1 placed between them.

Fig. 22 is a section of one of the cast-iron frames X and the strut Z at the line *m m* in Figs. 1 and 2. Fig. 23 is a section of the cast-iron frame X and radial rib S at the line *n n* in Figs. 1 and 2. Fig. 24 is a similar section at the line *o o*, and Fig. 25 is a section of the frame X and strut Z^1 at the line *p p* in Figs. 1 and 2. O^3, O^4, and O^5 are the sashes.

Fig. 26 is an elevation of the pedestal of one of the detached columns at the entrance at the south end of the Transept. Fig. 27 is a sectional plan of the same at the line *z z* in Fig. 26. A^3 is the cast-iron column. A^5 is the pedestal of cast iron $\frac{1}{2}$ in. thick, made in two pieces, and united by countersunk screws.

Figs. 28 and 29 are parts of a side elevation of the pedestal of one of the semi-elliptical wooden columns B in Fig. 1, and Fig. 30 is a sectional plan of the same. A is the cast-iron column, and A^6 its pedestal. B is the semi-elliptical wooden column, and B^3 its pedestal. These pedestals are shown in the South Elevation, Plate IV.

LOUVRES.

Plate XXVII. shows the detail of the apparatus for opening and closing the louvres.

Fig. 1 is a vertical section through the louvres, at the upper part of each tier of the building.

Fig. 2 is an internal elevation of the same; E E are the louvres of galvanized sheet iron; F is one of the ornamental arch plates, and G is the ornamental casting above it; I is part of the case of the louvres, and J is the lining which conceals it; K is a sill or wall plate, 10 in. by $2\frac{3}{8}$ in., which carries the case of the louvres. A $\frac{1}{2}$ in. pin of the form shown in Figs. 4 and 5, is riveted to the end of each louvre, as shown at *b* in Fig. 1. These pins enter holes in the sides of the case I, and support the louvres which turn upon them. To each louvre E is riveted a piece of hoop iron, L, 1 in. wide, and bent so as to form an eye, through which is passed a $\frac{7}{16}$ in. wooden pin, by which the louvre is moved. These pins enter two wooden bars, M M, which unite them all together, so that all the louvres may be moved simultaneously.

a is a small plate or block, connected by a $\frac{3}{8}$ in. pin to the bars M M. N is a connecting rod, $\frac{5}{8}$ in. diameter, on which the block *a* is fixed by two nuts. The lower end of this connecting rod is forked and attached by a pin to the worm-wheel O, which is driven by an endless screw P. Q is a pulley, keyed on the end of the screw P, and carrying an endless cord or rope R. By pulling this rope, the screw P is caused to revolve and turn the worm-wheel O in either direction, and thus open or close the louvres. The wheel O is cast with a long hollow socket, which turns in the bearing S, which is made in two pieces, and also serves to support the screw P.

Fig. 6 is a side view of the bearing S; Fig. 7 is a front view; and Fig. 8 is a plan of the same; Fig. 9 is a sectional plan of the same, on the line *d d* in Fig. 1. The two halves of the bearing S are slipped on to the socket O^1 of the wheel O, and the screw P is introduced into its place, and the two halves are then bolted together, and fixed to the wall-plate K by four screws. A wooden cleat, shown at *c*, in Figs. 1 and 9, is fixed to the wall-plate K, to support the front of the bearing S.

T T are two lines of 1 in. shafting, which are fixed in the socket O^1 by means of set-screws, and serve to communicate motion to the louvres on each side of those shown in the drawing. A length of 108 ft. on each side of the wheel O is thus set in motion simultaneously. Fig. 10 is a side view, and Fig. 11 is a front view of one of the intermediate bearings S^1 of the shafting T, together with the crank U, which gives motion to the bars M of the intermediate louvres. Fig. 13 is a separate view of the crank U; and Fig. 14 is a view of the connecting rod N^1. The bearing S^1 is fixed to the sill K by four screws. Fig. 12 is a front view of a double bearing S^2 at the junction of the separate lengths of shafting. A crank U is fixed on the end of each length of shafting by means of a set-screw. The two cranks are united by one crank pin, to which is attached the connecting rod N^1. This bearing is fixed to the sill K by six screws.

The above description applies to the upper louvres in each tier, and also to those under the springing of the Transept roof, with this difference, that in the latter the shafting is fixed at the top instead of at the bottom of the louvres, and the bearings are fixed bottom upwards as shown in Figs. 2 and 4, Plate XXV. The wheel Q is also placed on the outside, and protected by a case, as shown in Figs. 3, 4, and 5, in the same Plate. The cord is carried down through holes in the lead flat.

The louvres under the semicircular head of the Transept end are moved like those of the upper tier of the building, of which they are a continuation, as shown in Plate XXV., Fig. 2.

Figs. 18 and 19, Plate XXVII., are parts of a side elevation of the apparatus employed to give motion to the shafting of the lower louvres on the ground floor. T is the shafting carrying the worm-wheel O, which is supported by the bearing S^3. P^1 is an endless screw, working into the wheel O, and turning in a step in the bearing S^3, which is made in two pieces and bolted together, as shown in Figs. 21 and 22, which represent a front view and a plan of the bearing. The bearing is fixed by two long $\frac{3}{8}$ in. screws.

The screw P^1 carries a 3 in. mitre-wheel V, made of gun-metal, and driven by a similar wheel V^1, on the spindle W, which is made square at the end to receive the socket of a moveable handle, by means of which it is turned round. The spindle W and screw spindle P^1, are supported by a cast-iron frame X, 2 in. wide, and $\frac{5}{16}$ in. thick, which is bolted to the wooden column Z by two $\frac{3}{8}$ in. bolts. The wheel O has no immediate connection with the louvres, which are worked by connecting rods and cranks fixed on the shafting T, as shown in Figs. 10, 11, and 12. The bearings for this shafting are shown in Figs. 15, 16, and 17. Figs. 15 and 16 show the side and front views of the single bearing; and Fig. 17 is a front view of the double bearing.

SETTING OUT THE BUILDING AND FIXING THE COLUMNS.

Having now completed the description of the building itself, we may revert to some of the operations involved in its construction. In the first place, it was requisite to set out on the ground the position of the building, and to ascertain the levels of every part. These operations were performed with great accuracy by Mr. Brounger. The centre line of each row of columns was set out by means of a theodolite, and the distance from centre to centre of the columns was measured by means of rods of well-seasoned pine, on which were fixed two pieces of gun-metal, the distance between which was exactly 24 ft. A stake was driven into the ground to mark the position of each column, and a pin was driven into the top of the stake to mark the centre of the column. In proceeding to sink the pit to receive the concrete on which the column was to stand, it was necessary to remove the stake. In order, however, to preserve the centre point, two stakes were driven into the ground at a distance of 6 ft. from the column. One of these stakes was in a line with the row of columns, and the other in a line at right angles to it. A right-angled triangle, formed of three pieces of wood, was laid upon the three stakes, and a saw-kerf in the right angle was fitted to the pin in the stake which marked the centre of the column. Two other pins were driven into the two new stakes at the points marked by two saw-kerves in the two sides of the triangle. Another triangle was prepared, similar to the first, with the exception of the angle, which was cut to fit the sectional form of the column. The centre stake was then pulled out, and a pit sunk to the requisite depth to obtain a good foundation, and filled with concrete to the proper level. The lower portion of the column, with its base plate, was then bedded on the concrete, and its position accurately adjusted by means of the second triangle above-mentioned. Owing to the ground having a slight fall from west to east, the whole building was constructed on an inclination of 1 in. in 24 ft., and the columns deviate from the perpendicular in the same proportion. This inclination is so slight as to be imperceptible to the eye, although it amounts to about 6 ft. in the length of the building.

PROVING GIRDERS AND TRUSSES.

All the cast-iron girders were proved on the spot, by means of a hydraulic press constructed for the purpose. Any defective casting would thus have been at once detected.

Two hydraulic cylinders, with their rams, were fixed, at a distance of 8 ft. apart, in a strong cast-iron beam of a length somewhat greater than that of the girder. At each end of the beam was fixed a vertical pillar or bracket, with a projecting snug at the top, and the girder to be proved was introduced between these pillars in an inverted position, and allowed to rest upon the two rams of the presses. The pumps of the presses being then set in motion, the rams rose and applied the proof pressure to the girder. The pressure was ascertained by means of another ram which was loaded with a lever and weight. The pumps were kept in action until this ram rose and indicated that the required pressure was obtained. The amount of the proof for each of the different strengths of cast-iron girders has been already mentioned in describing them. The girders were proved as they were delivered at the building. Each girder was lifted from the cart in which it arrived by means of a crane, and placed upon a weighing machine. Its weight was noted, and it was then lifted again and placed in the proving machine, and after being proved was again lifted by the crane and placed on one side, in a convenient position for removal.

One of the 48 ft. wrought-iron trusses was proved with a load of ten tons, equally distributed over the upright standards, and one of the 72 ft. wrought-iron trusses was proved in a similar manner with a load of sixteen tons. From the general uniformity of quality in wrought-iron bars, it was considered unnecessary to prove the whole of the wrought-iron trusses. The weights of the 48 ft. and 72 ft. trusses are about 13 cwt. and 35 cwt. respectively. The deep 72 ft. trusses are, of course, heavier.

HOISTING GIRDERS AND TRUSSES.

The girders and trusses were raised by horse power in the following manner:—A pair of "shears," formed of two scaffold poles supported by guy ropes, was erected, and a pair of blocks suspended from it. The rope from the blocks passed through a snatch block, and was carried along in a horizontal direction. One or more horses were harnessed to this rope, and by walking forward in a straight line, raised the girder. By this means a large amount of manual labour was saved.

HOISTING TRANSEPT RIBS.

The semicircular ribs of the Transept roof were connected together in pairs and stiffened by spars attached to them. The pair of ribs was then raised by means of a tackle at each of the four corners. As the width of the ribs was rather greater than the clear space between the girders, it was necessary to raise one side of the pair of ribs higher than the other, so that the whole was lifted in an inclined position until it had passed the upper range of girders. It was then deposited upon planks resting upon rollers, and moved along to its required position, and lowered into its place on the top of the columns by means of screw-jacks.

MANUFACTURE OF THE SASH-BARS.

The sash-bars were cut out of planks by means of a machine containing a number of circular cutters, which formed the grooves and bevilled the edges at the same time. Several bars were cut simultaneously out of each plank, and they were separated as they passed through the machine by a series of circular saws. The ends of the sash-bars were afterwards notched and bevilled by circular saws. The holes at each end for receiving the nails were pierced by means of revolving augers, driven by a steam-engine, the bars being presented to them by hand. The proper angle of the hole was secured by resting the other end of the bar in a notch in a fixed frame or gauge.

The sash-bars were painted in a very simple and expeditious manner. A number of the bars were immersed in a trough of paint, from which they were taken singly and passed through a series of fixed brushes, by which the superfluous paint was brushed *off*, instead of brushing the paint *on* in the ordinary manner.

This and most of the other machines employed in the construction of the building, were designed by Mr. Edward Alfred Cowper, at that time in the employment of Messrs. Fox, Henderson, and Co.

MISCELLANEOUS DETAILS.

The mode of glazing the roof has already been described. To facilitate the operation, a number of small carriages were constructed with wheels to run in the Paxton gutters. Each carriage carried two glaziers, who fixed the glass on each side of one of the ridges. The boxes of glass and the sash-bars and putty were hoisted up and placed on the carriage. As the workmen fixed the sheets of glass, they pushed back the carriage, and thus travelled from the Transept to each end of the building. A somewhat similar carriage was employed in glazing the arched roof of the Transept, being raised and lowered by means of suitable tackle.

The roof was covered with canvas, to reduce the light and heat in the interior of the building. The canvas was nailed to the ridges and allowed to hang down between them. It was in two breadths, with the seam in the centre; the rain which fell upon it passed through the seam and dropped into the Paxton gutter.

The flooring on the ground level was laid with $\frac{1}{2}$ in. spaces between the boards, to allow of the dust falling through when the floor was swept. Machines were provided for sweeping the floor, but were found unnecessary, as the dresses of the female portion of the visitors performed this office in a very satisfactory manner.

The cylindrical hand-rail of the gallery railing was cut out of a rough piece of mahogany by means of a series of cutters fixed to a chuck on a hollow mandril, which was caused to revolve with great rapidity while the piece of wood was pushed through it.

PAXTON'S LATEST IMPROVEMENTS IN ROOFS.

Sir Joseph Paxton * has recently introduced a form of roof which possesses great elegance of appearance, while retaining the general principles of the roofing above described. In this new

* Since the commencement of this work, the honour of knighthood has been conferred upon Mr. Joseph Paxton, Mr. Charles Fox, and Mr. William Cubitt, as an acknowledgment of their services in the cause of the Great Exhibition.

form of roof the glass covering is made to follow the diagonals of the trusses, and thus the whole roof is contained within the depth of the truss.

This will be readily understood by referring to Plate XI., Fig. 1, which is an elevation of the 48 ft. truss. If we suppose the diagonals D F to be removed, together with the diagonals G, in the second 8 ft. compartment from each end, and that the remaining diagonals are made of iron of sufficient strength, and provided either with rebates or wooden sash-bars, for the reception of the glass, we shall obtain a very good idea of this construction. The lower rail is in the form of a gutter, and serves instead of the wooden main gutters above described, and the Paxton gutters rest upon it.

In another form of this improved roofing, the covering is of sheet iron instead of glass, and it is carried in large undulations over and between the diagonal struts. The lower part of the undulation or "valley" serves in lieu of the Paxton gutter, and conveys the water to the main gutter which forms the bottom rail of the truss.

We cannot conclude our description of the Exhibition Building without calling attention to the fact that the tender of Messrs. Fox, Henderson, and Co. was only accepted on the 26th of July, 1850, and that the Exhibition was opened to the public on the 1st of May, 1851, as originally intended. The formal contract was not executed until the 31st of October, 1850; but the contractors had begun to fix the columns on the 26th of September, and had already incurred liabilities to the extent of £50,000. The tender for the original design was £79,800 for the use of the building, or £150,000 for the complete purchase of it, but an additional piece of 936 ft. long and 48 ft. wide was added on the north side, and various other additions were made. The cost of erecting the building in the short space of time allowed for it, also considerably exceeded expectation, so that the actual prime cost of the building amounted to about £200,000, or about £25 per 100 square feet of ground covered.

G. Woodfall and Son, Printers, Angel Court, Skinner Street, London.

Pl. I.

PLAN OF GROUND FLOOR.

C. Downes. Dir.ᵗ

J. R. Jobbins

John Weale 59 High Holborn Augᵗ 30ᵗʰ 1851.

I. J. West. delᵗ

PL. 2.

PLAN OF GALLERIES.

C. Downes Dir.t

John Weale 59 High Holborn Aug.t 30th 1851.

I. J. West. Del.t

J. B. Jobbins.

9 0

11 6

12

PLAN ABOVE GALLERIES.

SCALE

0 10 20 30 40 50 100 150 200 250 300 350 400 450 500 FEET.

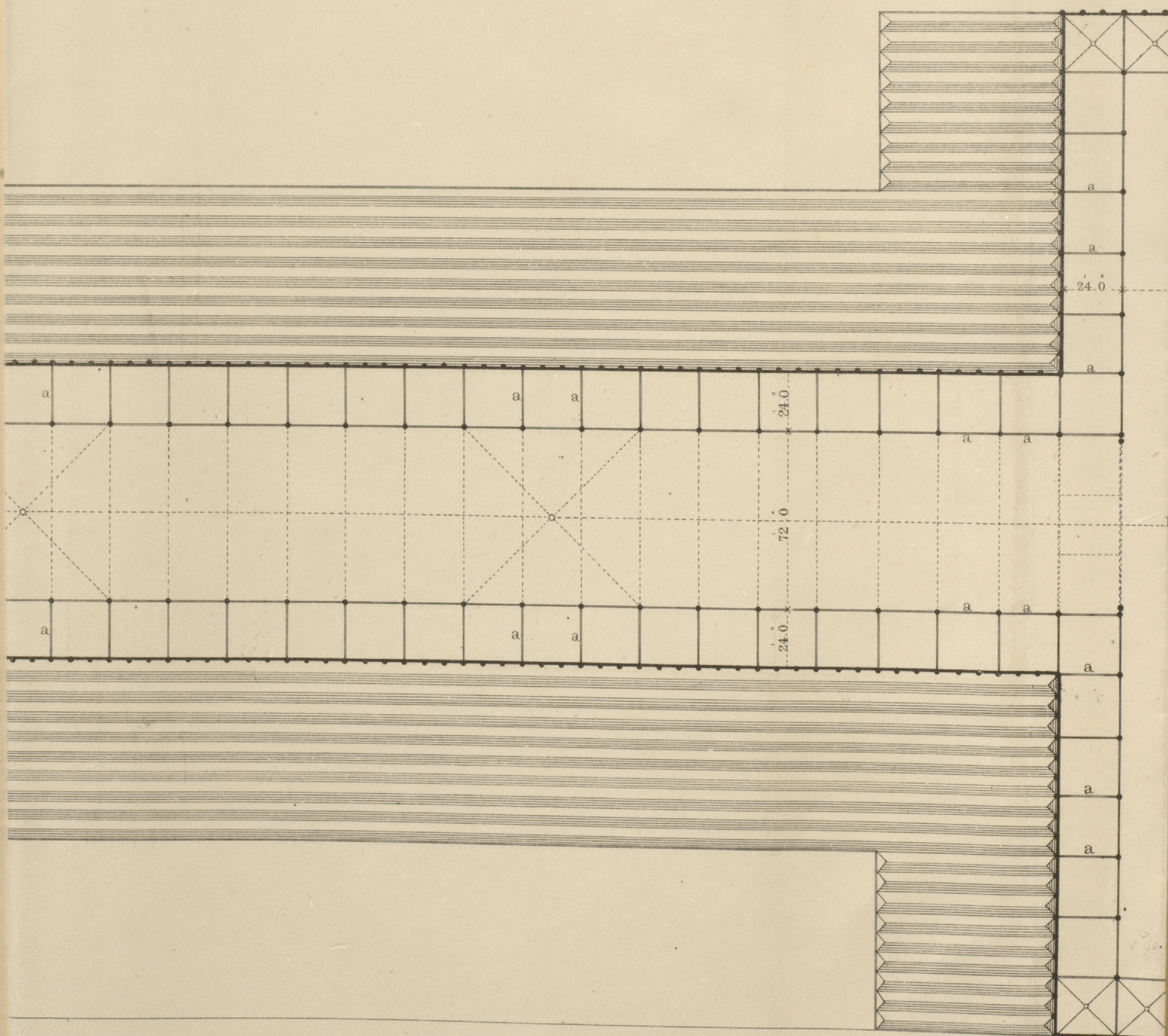
C. Downes Dir.[t]

I. J. West Del.[t]

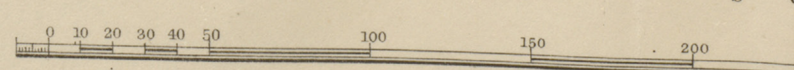
John Weale 59 High Holborn Aug.[t] 30[th] 1851

J. R. Jobbins

PLAN ABOV



S C



C. I

John Weale 59

SOUTH ELEVATION.

SCALE

C. Downes, Dir.t

I. J. West, Del.t

John Weale, 59 High Holborn, Aug.t 30th 1851

J. R. Jobbins.

EAST ELEVATION.

SCALE.

10 8 6 4 2 0 10 20 30 40 50 60 70 80 90 100 FEET

C. Downes, Dr[t]

I. J. West, Del[t]

John Weale, 59 High Holborn, Aug[t] 30[th] 1851.

J. R. Jobbins

TRANSVERSE SECTION ON LINE A.B.

SCALE

C. Downes, del.

John Weale, 59 High Holborn, Jan^y. 1852.

J.R. Jobbins.

Pl. 7.

LONGITUDINAL SECTION ON LINE C. D.

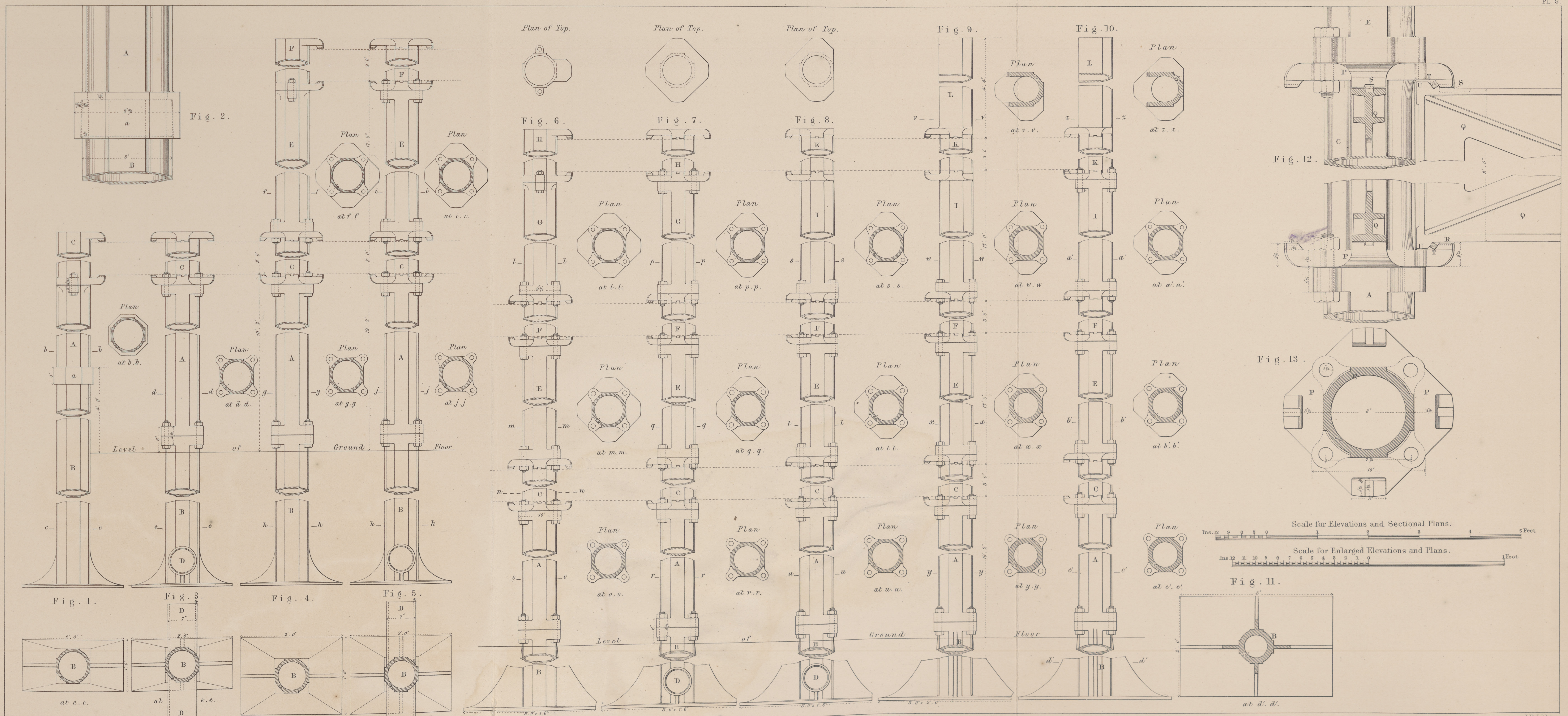
SCALE.

10 5 0 10 20 30 40 50 60 70 80 90 100 Feet

John Weale, 59 High Holborn, Jan.y 1852.

C. Downes, del.

J. R. Jobbins.

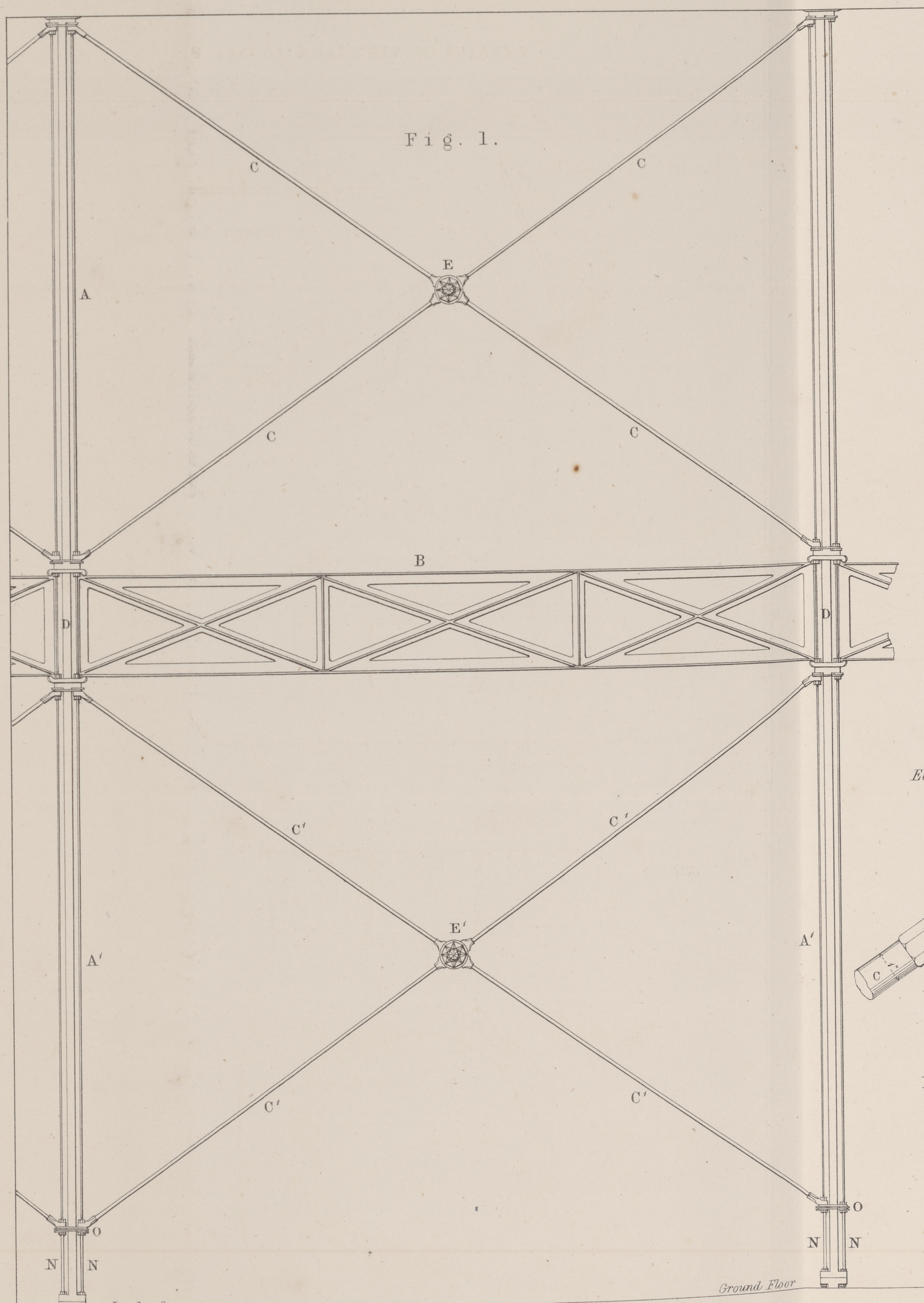


C. Downes, del.

John Weale, 59 High Holborn, Jan.y 1852

J.R. Jobbins

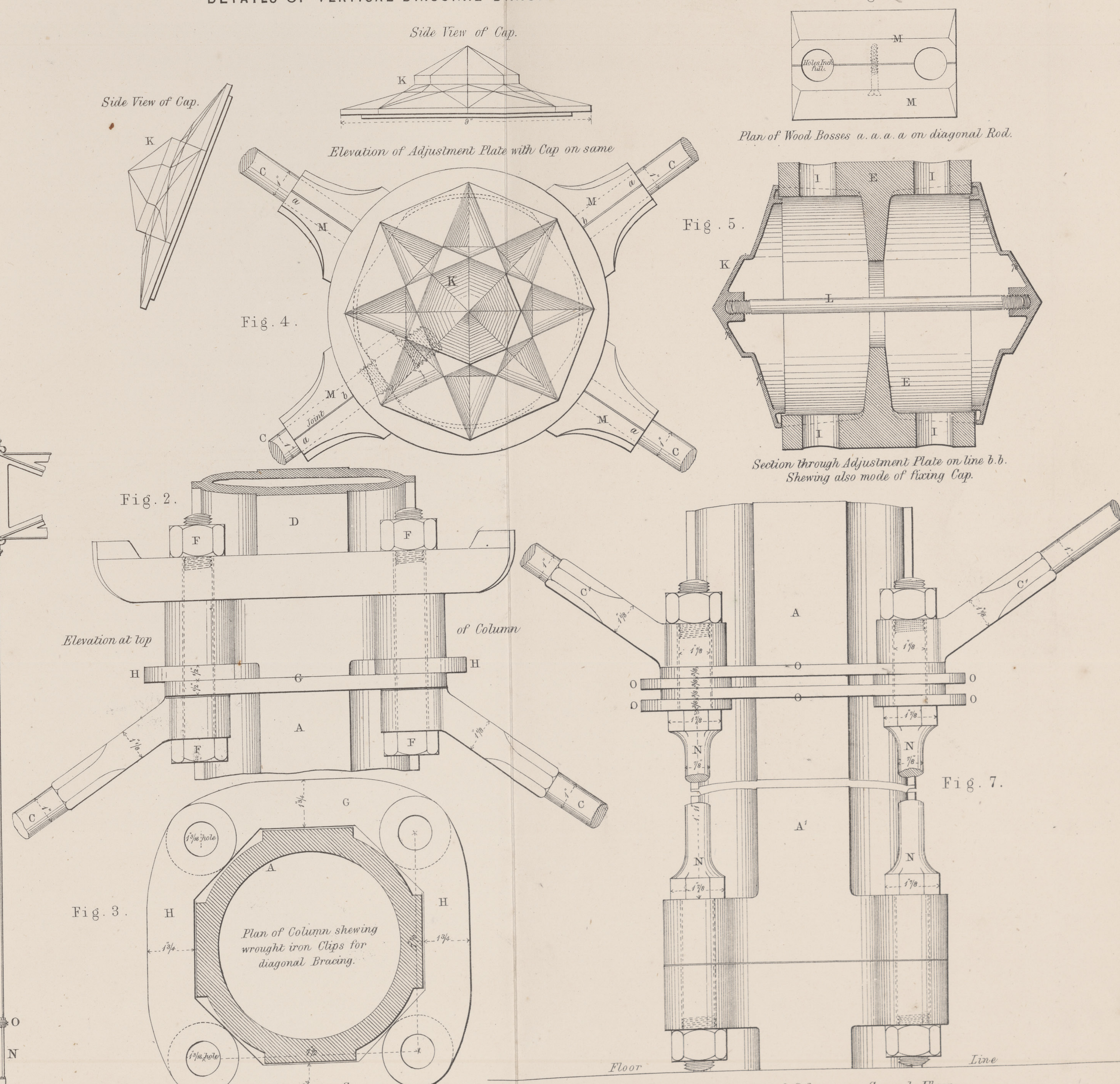
DETAILS OF VERTICAL DIAGONAL BRACING BETWEEN COLUMNS.



Elevation of two Tiers of Columns shewing diagonal Bracing

Scale for Elevation.

10 9 8 7 6 5 4 3 2 1 0 10 20 FEET



Elevation at bottom of Column on Ground Floor

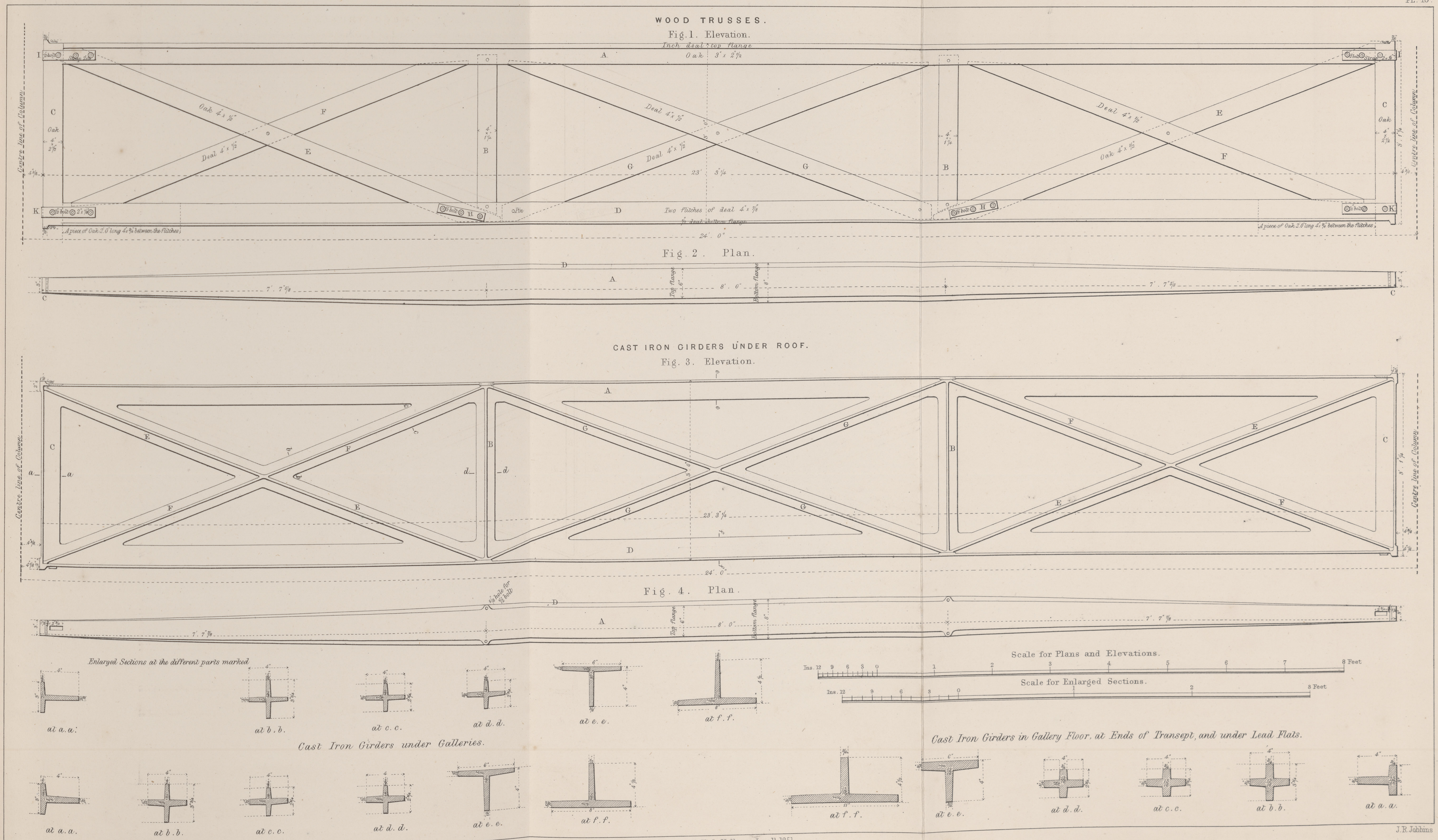
Scale for Details.

INS 12 11 10 9 8 7 6 5 4 3 2 1 0 1 FOOT

C. Downes, del.

John Weale, 59 High Holborn. June 11. 1851.

J. R. Jobbins.



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John Weale, 59 High Holborn, June 11. 1851.

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Pl. 11.

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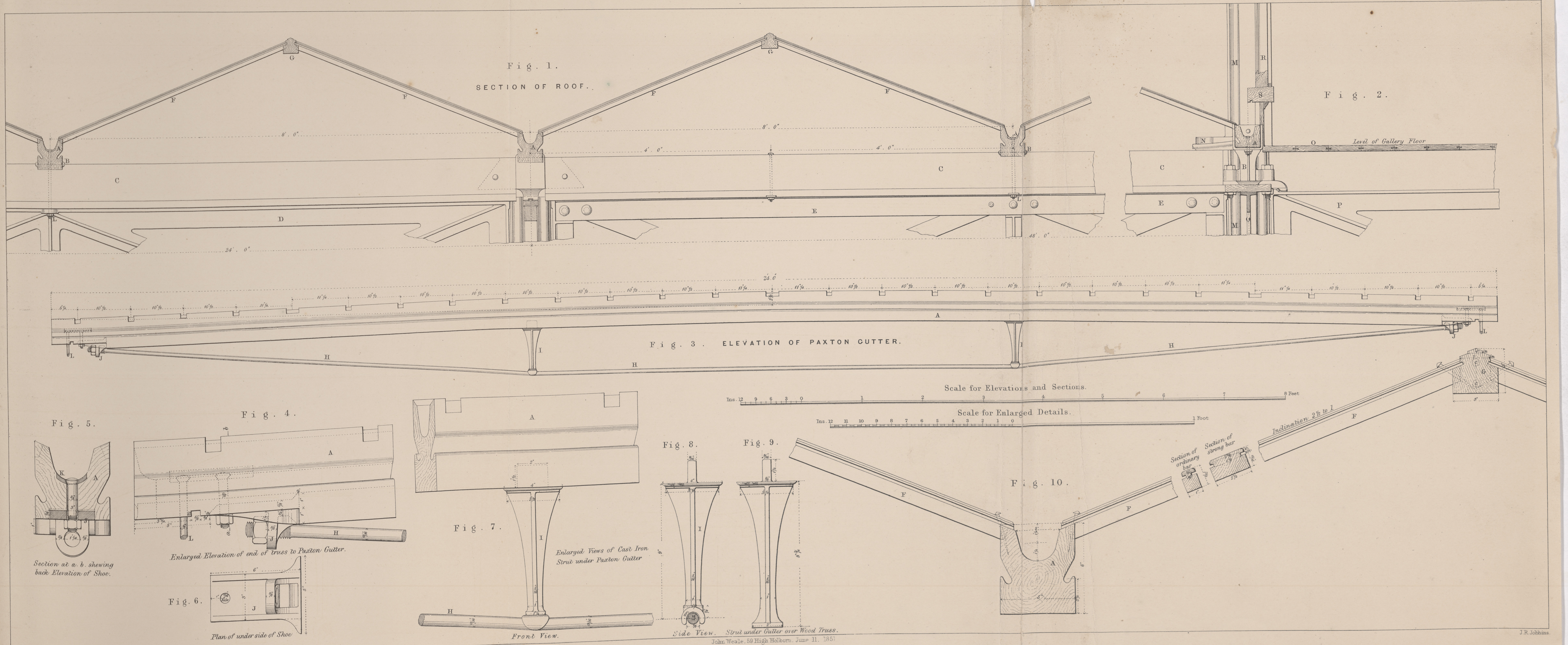

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John Weale, 59 High Holborn, June 11, 1851.

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John Weale, 59 High Holborn, June 11, 1851.

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Pl. 14.

C. Downes, del.t

John Weale 59 High Holborn, June 11, 1851.

J. R. Jobbins

Half Plan of Cross Gallery at Staircases shewing upper Flight of Stairs.

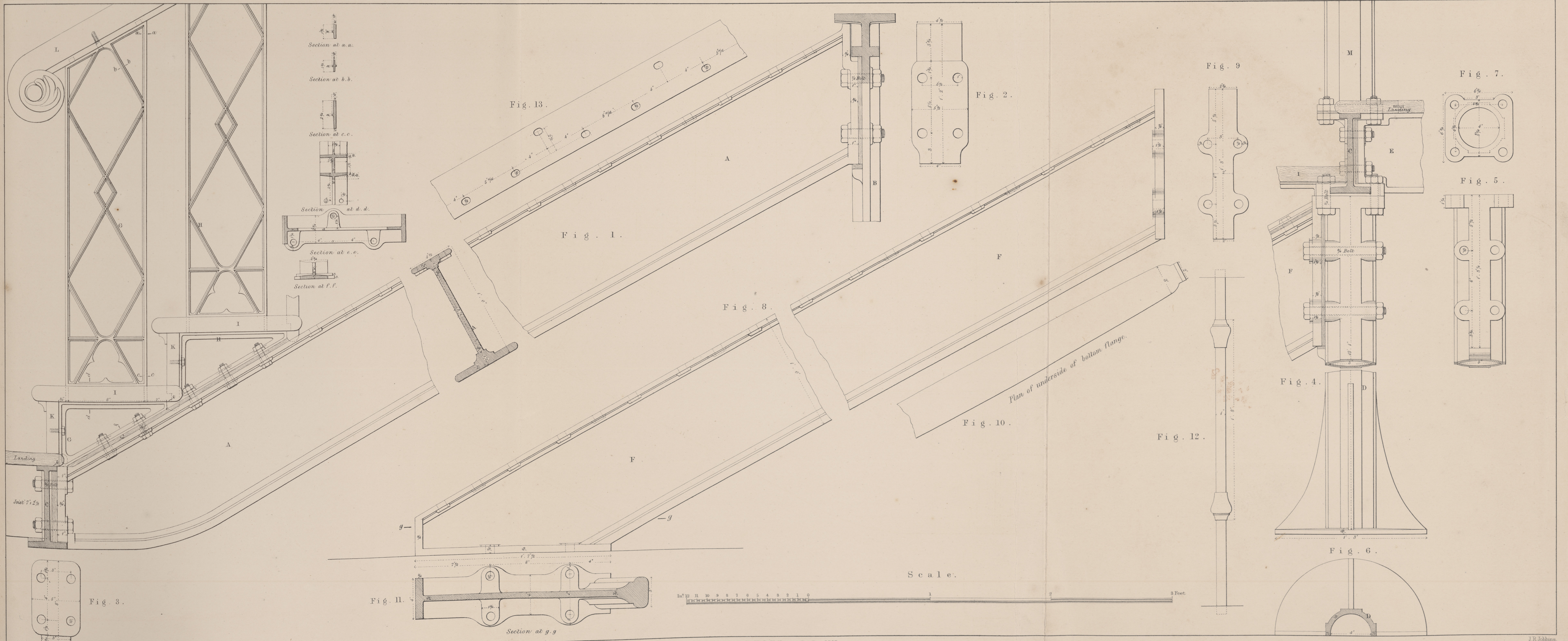
General Plan of Staircases from Ground Floor to Galleries.

Section through Staircase on line a a.

Section at c c.

Elevation of centre of Girder at b b altered to receive Strings of Stairs.

C. Downes del.
John Weale 59 High Holborn Augt 1851.
J.R. Jobbins



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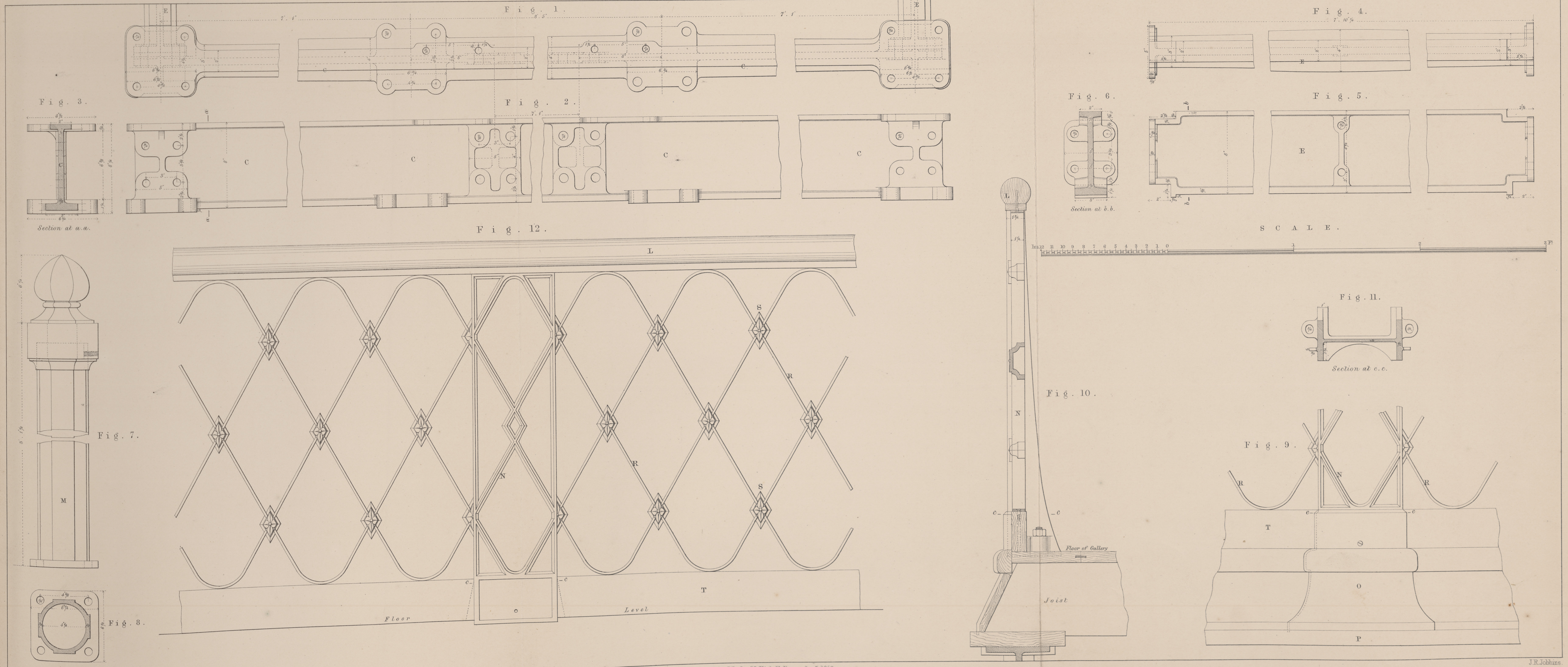
John Weale, 59 High Holborn. Jan^y. 1852
J. R. Jobbins.



John Weale, 59 High Holborn, Jan. 1852.

C. Downes, del.

J. R. Jobbins.

C. Downes, del.

John Weale, 59 High Holborn Jan^y 1852.

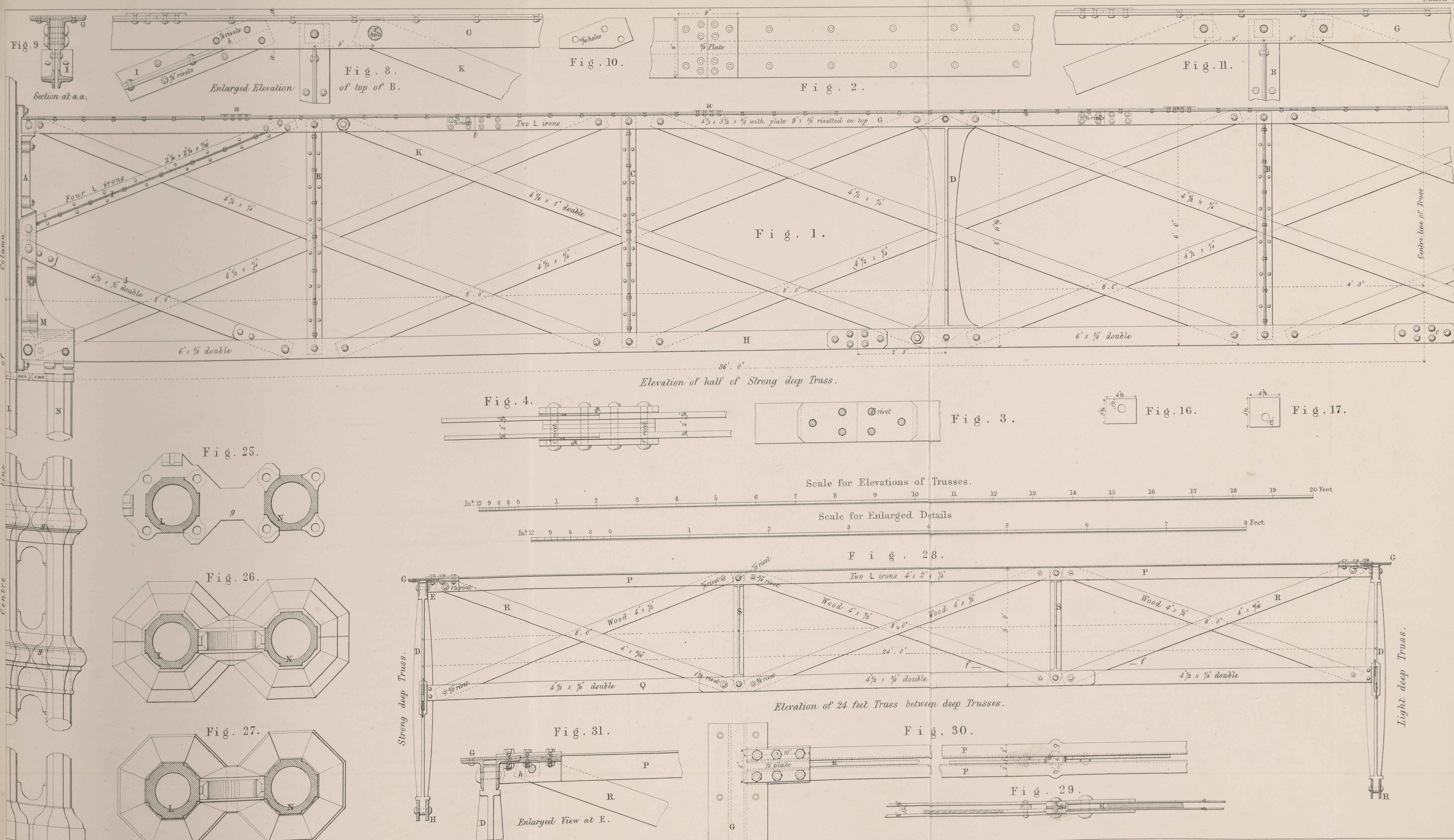
J. R. Jobbins.

Pl. 19

C. Downes, del.

John Weale, 59 High Holborn. April 1852.

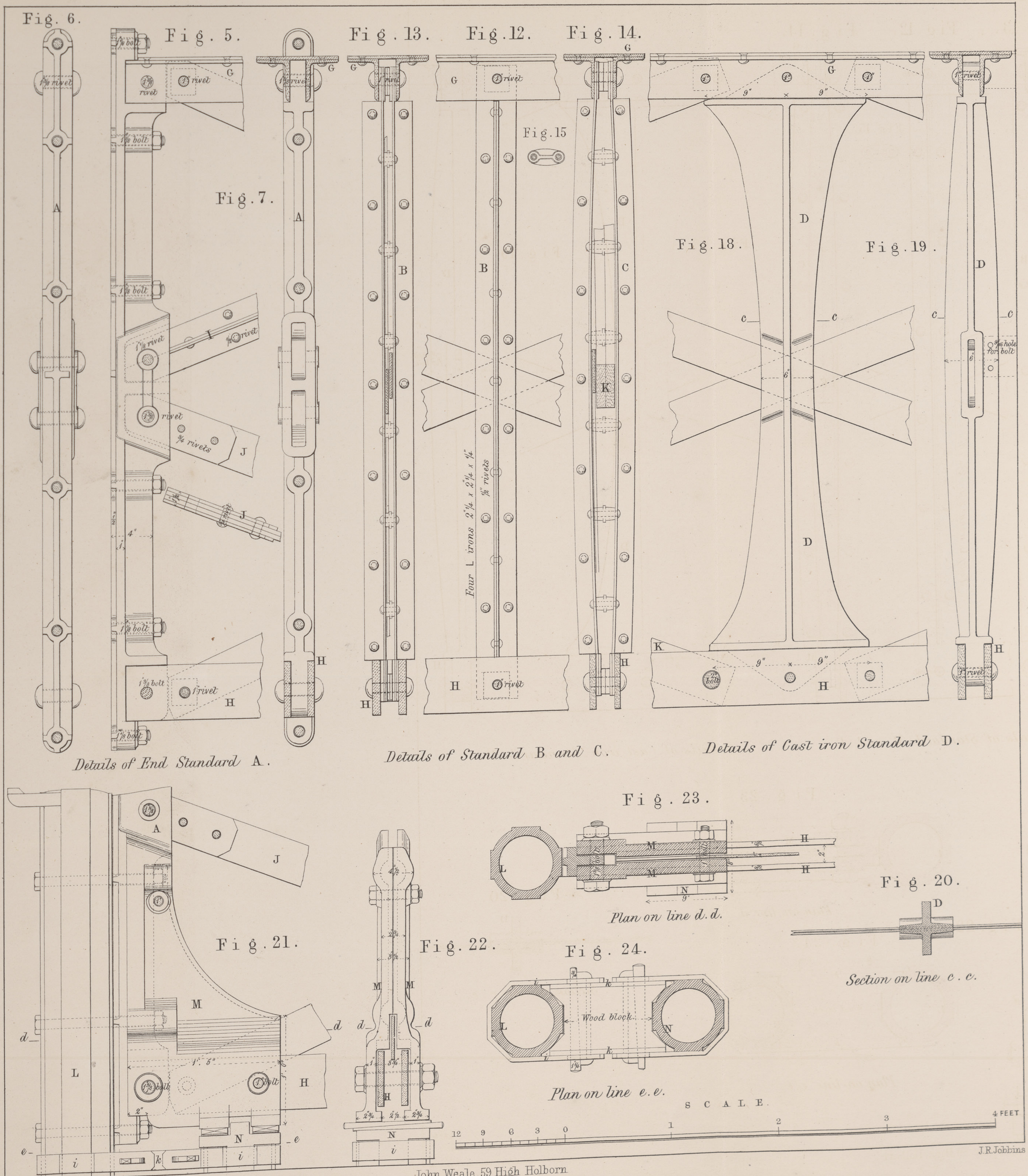
J.R. Jobbins.



C. Downes. del.

John Weale, 59 High Holborn. April 1852.

J.R. Jobbins



C. Downes, del.

John Weale, 59 High Holborn

J.R.Jobbins

Elevation of three Exterior Compartments on the Ground Floor level.

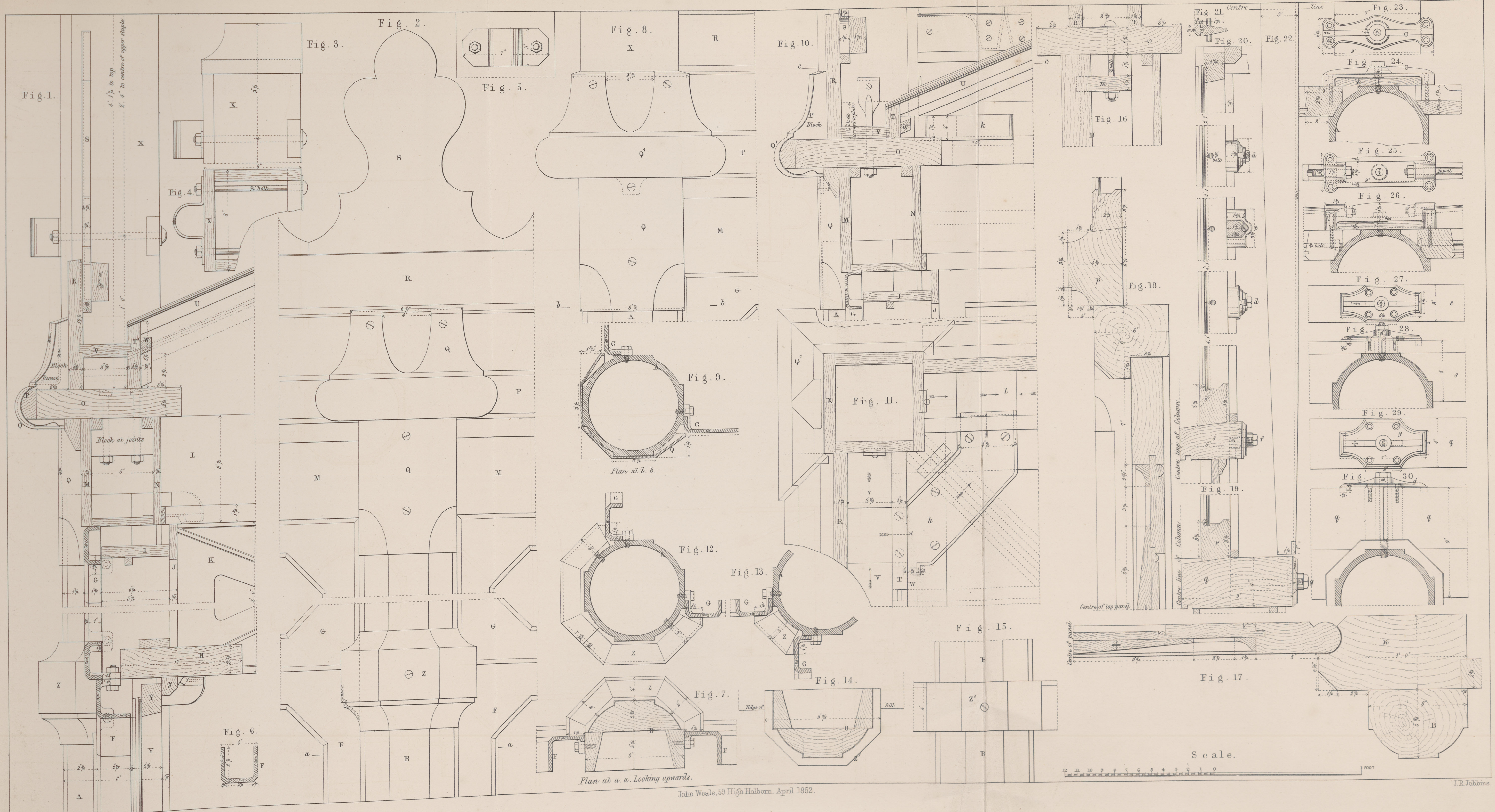
Elevation of two Interior Compartments on the Ground Floor level.

Interior Elevation of One Bay on level of Gallery Floor.
The interior Elevation of the Upper part corresponds with this.

C. Downes, del.

John Weale, 59 High Holborn. April 1852

J.R. Jobbins.

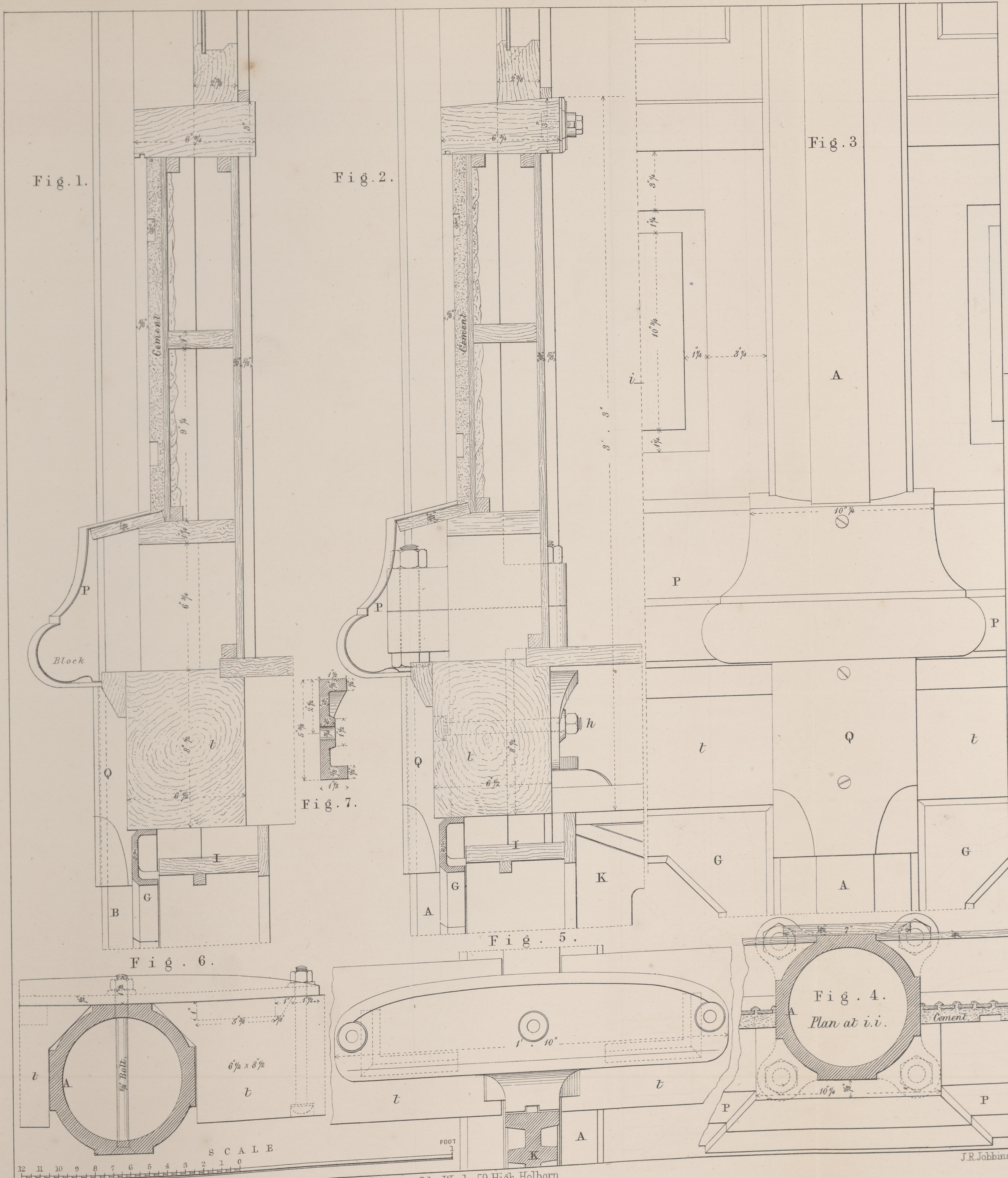


Scale.

C.Downes, del.

John Weale, 59 High Holborn. April 1852.

J.R.Jobbins.

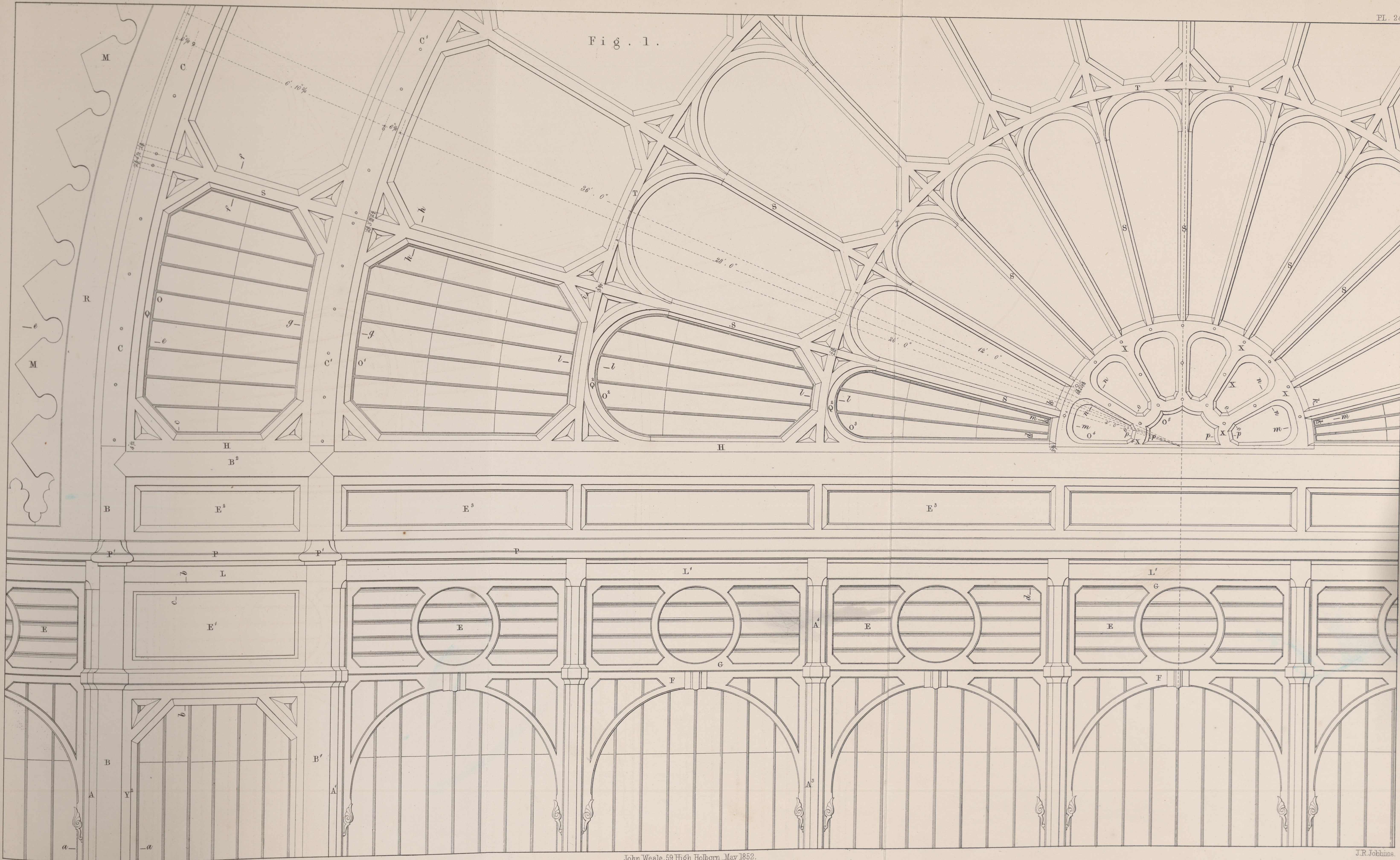


C.Downes, del.

John Weale, 59 High Holborn

J.R.Jobbins.

Fig. 1.



C. Downes, del.

John Weale, 59 High Holborn. May 1852.

J. R. Jobbins.

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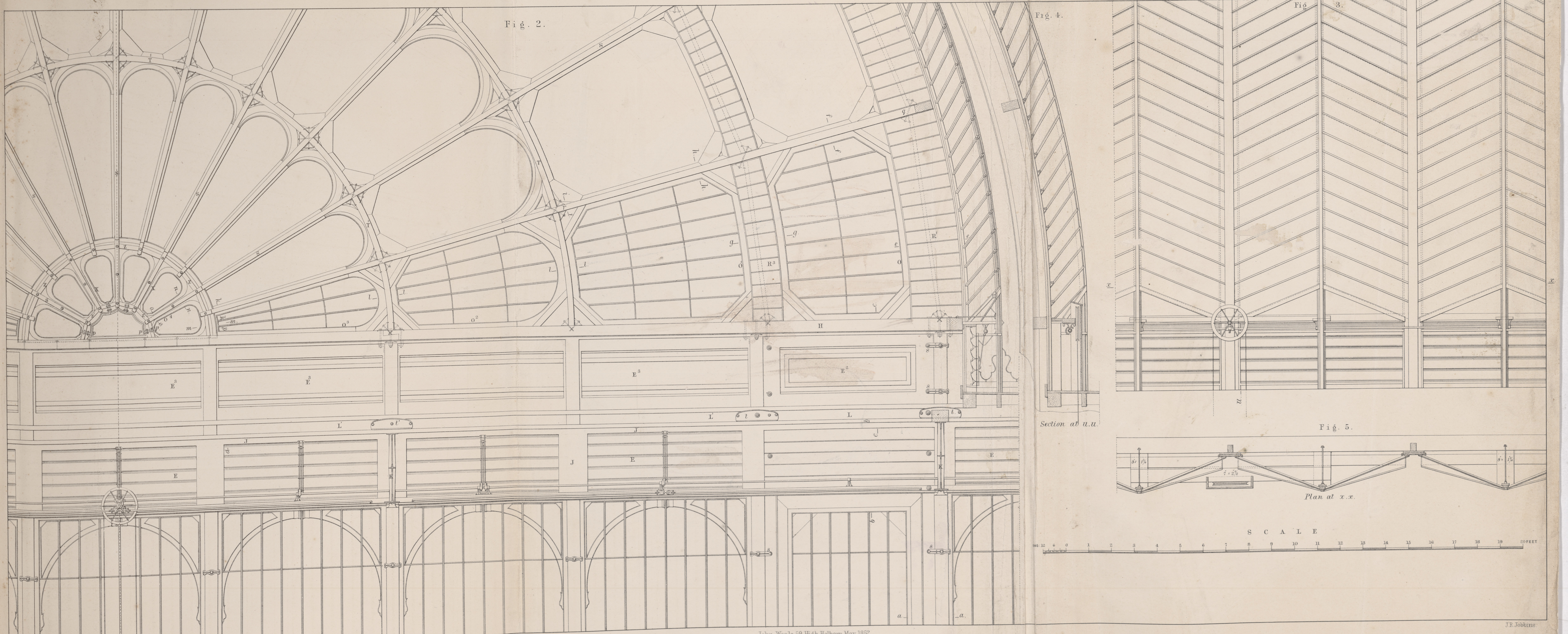
INS. 12 6 0 1 2 3 4 5 6 7 8 9 10 FEET



John Weale 59 High Holborn May. 1852.

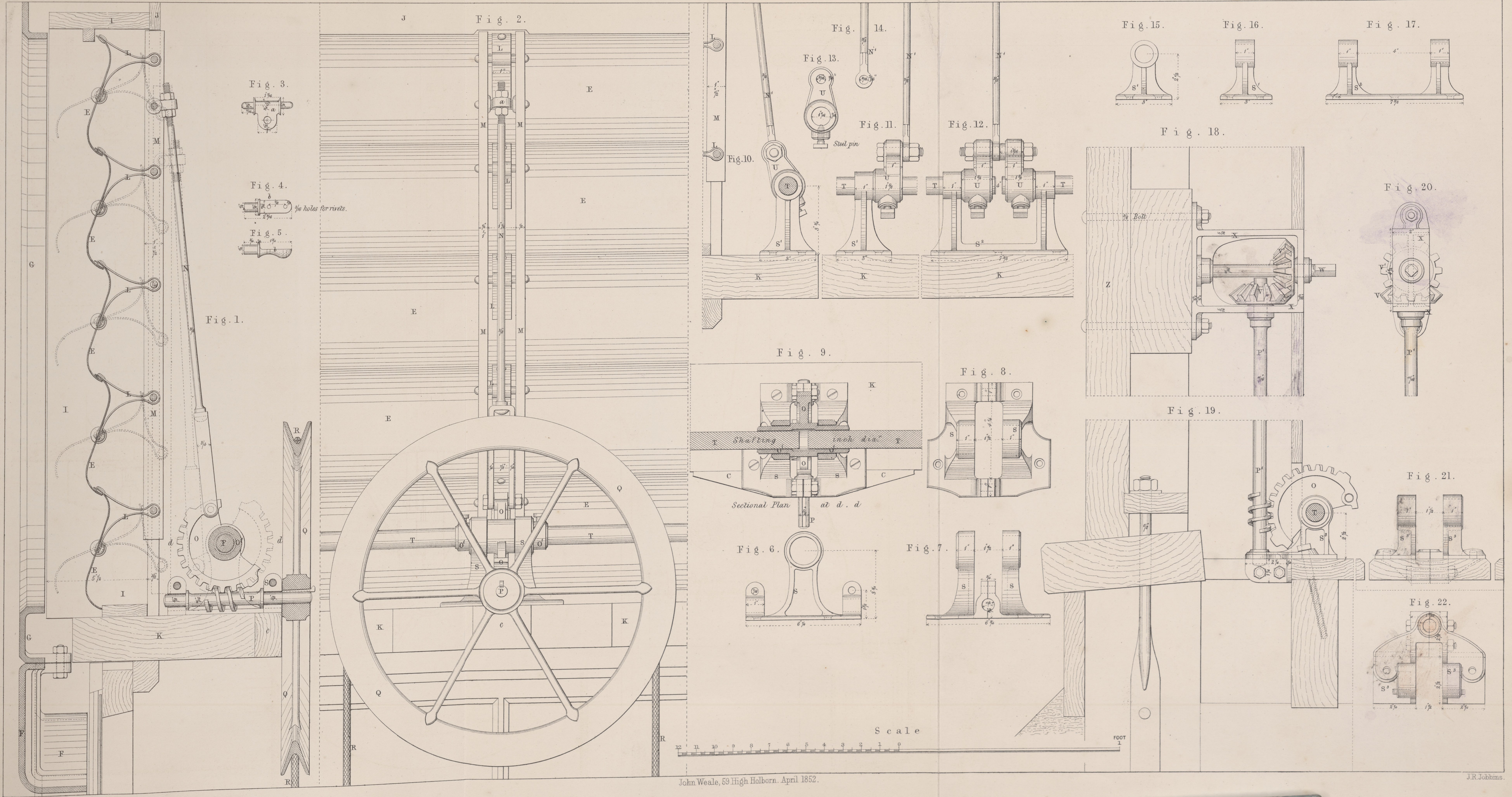
J.B. Jobbins

C. Downes del.

John Weale 59 High Holborn April 1852.

C. Downes delt

J. R. Jobbins.



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