line. This new position will be lower than for the arch ring itself, as the gravity line will be further from the key.

It is not usual, however, to complete the whole structure before removing the centres, as any settlement of the arch ring would render very uncertain the actual distribution of the pressure upon it. To suppose the arch built in this way in order to apply the principle of least resistance to the finished structure, is to introduce a large and unnecessary amount of uncertainty. Now when the gravity line moves further from the key it is evident from the condition of intersection, either that the joint of rupture will take a lower position, or that the point J will move out from the intrados to maintain $L\,J$ at right angles to $C\,D$. To decide between these alternatives we must first examine the question as to how the pressure from the spandrel is transmitted to the back of the arch ring, as it is possible that when the arch ring carries its weight the line $L\,W$ may no longer be vertical. As a limiting direction, the pressure may be everywhere at right angles to the extrados; but this condition can only be realized by taking exceptional precautions with the object of obtaining the "hydrostatic arch," and we cannot therefore suppose it to be the usual case. Again, the pressure may act along inclined lines similar to those given by the pressure of earth. This will be the case for deeply buried culverts and for sewers; but these we cannot now consider, as their stability depends on conditions too far removed from those we have before us. Some Engineers maintain that the pressure of masonry will also act similarly along inclined lines of fracture. It is possible that this may be the case to some extent, especially towards the haunches; but for the central portion of the arch, it is sufficient to adopt the ordinary supposition that each voussoir carries the portion of the load vertically above it. As regards the haunches it is an almost invariable rule to carry up the backing to the level of the joint of rupture as found for the arch ring, before the centres are struck. When this is done the question is much simplified, as the whole of the masonry below that joint can then be taken as forming in reality a part of the abutment. We will assume then that it is only the remainder of the spandrel which is added after the centering is removed; and this has the sanction of the best constructors. When the arch is built in this way, we are not at liberty to suppose that the joint of rupture will take up a lower position than it had in the arch ring, and we are left to the alternative that on the addition of the spandrels the point J moves out from the intrados. We see at the same time the advantage derived from adopting this method of construction.

This also seems the more probable when we compare the form of the spandrel with a form of loading which will make the curve of pressure coincide with the centre line of the arch ring throughout. This form can readily be found by reversing the ordinary graphical process. The centre line of the arch ring is assumed to be the curve of pressure, successive tangents to it are drawn, and a force diagram constructed in which the successive parts represent the weights that have to be applied along the curve. (See Greene's "Arches," Art. 140.) By plotting these parts from the intrados as ordinates, the weight of the arch ring is taken into account, and the area indicated by the ordinates is the loading required. Its form is given in Fig. 6, and on comparing this form as far as the joint of rupture with the usual form of the area representing the weight of the spandrel, the similarity is sufficient to enable us to infer that the addition of the spandrel improves the position of the curve of pressure. This accords with experiment, and with observations on completed structures. It would justify also the practice of increasing the thickness of the arch ring toward the springing; for while this would add nothing to the strength of the arch ring standing alone, it becomes of real service when the structure is completed. There is therefore every reason in favor of the conclusion that when on the addition of the spandrel the gravity line takes up a position further from the key, the joint of rupture will not change its position, but the point J will move out from the intrados. This change, however, will not affect the considerations which led to the determination of the position of K.

For the structure completed as above described, and with unyielding abutments, the following general method of finding the determining points is suggested as harmonizing with the best discussion of the subject as given by different authors:—

The point K will remain at the same position as in the arch ring.

For a semi-circular or elliptical arch the joint of rupture will remain at the same position as in the arch ring, and the point J will be found by drawing from L where T and W intersect, the line $L\,J$ at right angles to $C\,D$. Similarly for a segmental arch, the point J will be determined by drawing $L\,J$ parallel to its former position in the arch ring.

To make the position of the points K and J dependent upon the position of the gravity line as this method does, is much more reasonable than to give them the same arbitrary position for all cases. It also affords a means of ascertaining the most advantageous distribution of weight in the spandrel. As a rule the point J will be only a short distance out from the intrados; but in extreme cases, if there is a large amount of loading over the haunches, the gravity line may be so far