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RAILWAY WORKS

IN CONNECTION WITH AN

ARMY IN THE FIELD:

FORMING THE SECOND DIVISION OF THE AUSTRIAN GUIDE TO RAILWAYS.

VIENNA, 1872.

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PART I.

DEMOLITION OF RAILWAYS.

CHAPTER I.

§ 1.

Introductory Remarks.

In order to deprive an adversary of the use of a line of railway for purposes of traffic—or, in other words, to render the line unserviceable—either the entire line, or only portions of it, may have to be temporarily made useless, or utterly destroyed, according to circumstances. In every case, the withdrawal of all unnecessary rolling-stock should be the first measure adopted. Simultaneously with this, all reserves of railway plant, and the most important tools, &c., should be removed from the stations, as well as all individuals entrusted with the technical working of the railway; the signals, first the electric, and then the visual, should be destroyed.

The simplest means of rendering the actual line impracticable is the removal of the permanent way, and when this is done throughout a considerable length it is one of the most effectual means of delaying an enemy. The restoration of the permanent way generally occasions considerable delay, and when it has been removed from a great length of railway, the enemy cannot at once bring up the necessary material for the restoration of the line, but is compelled to collect it first of all at stations, often far distant, and thence to bring it on to the point required. It is most important that the separate component parts of the permanent way should be withdrawn entire, in order that they may be secured for future use.

Wooden sleepers should, therefore, only be cut up or burnt, when their removal is impossible; and only in such a case should the enemy be deprived of the rails and their fastenings, by sinking them in the nearest water, burying them in the ground, &c. If the formation level as well as the permanent way be destroyed, the most lasting interruption to the traffic is attained.

It may, however, happen, that by demolishing individual portions of the railway, such as bridges, viaducts, &c., the object in view may be more quickly or more thoroughly attained than by destroying the permanent way.

If stations occur on the line, they must, in order to effectually interrupt the traffic, be rendered useless to the enemy, at least, in the first instance.

This can only be accomplished by the removal of such plant about the station as is the most important and the most difficult to replace—such as water-pipes, sidings, point-levers, points, &c.

In the following pages it will be shown how the various parts of a railway may generally be made unserviceable.

CHAPTER II.

Main Works.

§ 2.

Embankments.

Embankments may be made unserviceable either by erecting barricades across them, or by cutting through them transversely. The former method is so simple, that no further remark need be made upon it; the effect produced can never be anything but slight. The embankment should only be cut through when the removal of the permanent way alone is considered to form too slight an obstacle, or when no more suitable object for destruction is found on the line. But since a railway embankment may serve as a dam in the event of an inundation, or as a protection against sudden and destructive floods, the causing of a breach on friendly territory would appear to be in no case advisable: and even in an enemy's country, embankments should only be broken through when by this means an extremely important end, attainable in no other way, is to be arrived at, and when there is no possibility of their being of any service in connection with the positions and movements of friendly troops. The partial destruction, therefore, of embankments should only be ordered by the general commanding-in-chief, who alone is in a position to judge of all the circumstances in connection therewith.

The highest portions of an embankment should be chosen for demolition; and also, if possible, such points as are unapproachable from both sides—as, for instance, where the line runs through a marsh; for in such a case, the simultaneous restoration of several destroyed portions becomes almost impossible. The demolition may be effected either by blowing up, or by forming a gap by manual labour. The latter plan is to be preferred when it is possible to work at several places at once; each cut should be at least 10 feet or 12 feet deep, and and from 30 feet to 36 feet long. The excavated material is, with high embankments, thrown over the slopes, but with lower ones it is scattered about. If the embankment is carried along the side of a river, and is not at the same time a protection against inundations, and a safe escape may be provided for the water flowing through, a length of 5 feet to 6 feet suffices for the opening, if its sides are made vertical, and from 1 feet to 2 feet below the level of the water, because then the water flowing through will wash away by degrees the vertical sides, and the obstacle will become continually broader.

To calculate the labour and time necessary for such work, the following statement may serve as a guide: 56 men, in from 8 to 10 hours, in average soil, can make an opening 30 feet long, 10 deep, and 24 feet wide, supposing the slopes to extend to the full height of the embankment, and the earth to be thrown down over them. This gives, consequently, in 8 working hours 21 cubic feet excavated per man per hour; in 10 working hours, 17 cubic feet.

Note.—The regulation strength of a military detachment of a field railway division is 56 men; in all the following demolitions, the calculations of work done and the distribution of the workmen are made with this understanding.

Cuttings.

Cuttings may have barriers formed across them, or they may be filled up. Barriers made with rolling stock, &c., form, as in the case of embankments, only a very slight obstacle; their employment, however, in deep and long cuttings, appears advisable when there is only a short time at command, or when the adversary is only to be checked for a little while, for the removal of the materials employed is in this case much more difficult than in that of embankments. The kind of barrier to erect, as well as the time, workmen, and material required depend entirely on local circumstances; this point will therefore not be further touched upon.

Cuttings may be filled up either by digging or by blowing in the sides; in most cases, the deepest places are the most favourable. A cutting should be filled up for a length of from 30 feet to 36 feet at least, and to a height of from 4 feet to 6 feet. The data given in the case of embankments as to the calculation of the work will also serve here.

Tunnels.

Tunnels may be rendered impassable either by blowing in, by barricading, or by a combination of the two.

The barricading may be carried out in various ways. Without excluding other possible arrangements, a method of proceeding will here be given, which can generally be carried out. Near the middle of the tunnel, several rails are taken up and formed into a barrier; when possible, grooves are cut out in the sides of the tunnel, and in these the extremities of the piled up rails are placed and tightly wedged. To complete the barricade, a train of (if possible) *loaded* trucks is pushed into the tunnel at a rate of from 35 to 45 miles an hour by one or two engines. When the train approaches the barricade, where the rails have been taken up, the first truck leaves the rails, the others become heaped up on one another, and a formidable barricade is the result. If it is desired to block a tunnel both by barricading and by blowing in, the barricade is formed at the centre, and the tunnel is blown in at each extremity.

Note.—In the Franco-German War of 1870-1871, on the railway from Metz, by Thionville, Montmédi, and Mezières, to Paris, the French blew in the tunnel at Montmédi at each end for a length of 34 feet and 140 feet respectively, and filled the remaining space in the centre with locomotives, trucks, &c.

§ 3.

Bridges in General.

By the destruction of bridges or viaducts, a most serious check may be given to an adversary in a short time, and with but little labour, and this is most especially the case when interruption of communication over a considerable length is effected. But as the restoration of destroyed bridges and viaducts requires some time, their utilisation for one's own purposes will be retarded; they should, therefore, only be destroyed in the following cases:—

(*a*) When there is neither time nor means at disposal to effect the removal of the permanent way, or to offer such other hindrances to the proper working of the bridge as will check the adversary for the time intended. In this case only the largest bridges should be destroyed, those of from 12 feet to 30 feet span being disregarded.

(*b*) When by the removal of the permanent way, and even by forming other hindrances to working, the object in view cannot be attained. In this case even the smallest bridges should be destroyed, especially if many of these occur one after another; because even if their restoration requires no considerable time, the adversary is nevertheless prevented from replacing the permanent way simultaneously at several points thus cut off from each other by the demolitions.

(*c*) When a complete demolition is specially ordered by the Commander-in-Chief. This would probably occur in the case of large bridges, likely to be of importance in the course of operations; the commanding officer (for the reason already given in speaking of embankments) is then the only person in a position to decide on the advisability of a demolition, as well as on its extent.

The means by which bridges may generally be rendered unserviceable are :—

(*a*) The entire or partial removal of the several portions of the construction.

(*b*) Burning.

(*c*) Blowing up.

The material, and partly also the construction of bridges, always admit of one or more of these measures being adopted. If the communication is not to be entirely destroyed, but is, which is most likely, only to be interrupted for a length corresponding to the object in view, the demolition should be most thoroughly carried out at the end of the bridge furthest from the enemy.

§ 4.

Stone Bridges.

These can only be demolished by blowing up.

§ 5.

Wooden Bridges.

Wooden bridges, owing to their usually simple construction, and to the destructible materials of which they are formed, may be rendered unserviceable more readily than any other kind of bridge. If the delay occasioned is intended to be of short duration, it will be sufficient to render only the roadway unserviceable; but if the communication is to be interrupted for a longer time, the supports of the bridge must be entirely or partially demolished after the roadway is destroyed; this is essential in the case of those wooden constructions which rest on stone piers or iron columns. If a considerable interruption of the communication is intended the supports should only be left intact when either their distance apart is so great that the adversary would probably be compelled to erect temporary piers for the restoration of the bridge, or when the necessary time and labour are wanting.

(*a*) *Removal.*—In all wooden constructions with vertical supports, the rails and sleepers are taken up and removed, as on the open line. (§ 8.)

With pile bridges, suspended and trussed bridges, or with combinations of the two last, the side pieces must be taken away, and the longitudinal bearers at the near end of the bridge, together with the sleepers, removed, in order to be loaded into trucks, and then taken to the nearest safe station. But should the necessary rolling stock for this purpose not be at hand, or if time is wanting, these portions of the construction should either be thrown into the water and floated down stream, or towards the near shore, or, if there is no water, they should be sawn in two. However, as this last method occupies considerable time, it is generally more advantageous to burn these portions.

With trussed bridges, after the removal of the longitudinals, the vertical pieces *cc* (*Plate I., figs.* 1, 2, and 3) must be taken down, and afterwards cut through; with bridges on Howe's system, the transoms *k* must be removed or sawn through. But the delay thus occasioned is but slight.

Bridges made after Howe's method may also be taken entirely to pieces; the vertical screw-ties *c* (*Plate I., figs.* 3 and 4) being screwed off, after the removal of the rails, sleepers, and transoms, and the beams *b* being taken away or sawn through, after the removal of the braces *a*. Such a proceeding would, however, require considerable time. It may be thought desirable to destroy or remove merely a portion of the structure, and so cause a weakness in the construction, the extent of which, however, cannot be estimated at the moment of execution. It has, in fact, been practically shown that a Howe bridge, of which a number of braces on one side had been completely smashed by an engine leaving the rails, was perfectly well able to bear all the vibration and work connected with replacing the engine on the rails, without any further injury to the bridge.

But, as a rule, a mere weakening of the structure, whether effected by the removal of certain parts, or by just sawing the bearers through, will have little prospect of success; for a prudent adversary (and such an one must always be assumed) would make use of no bridges which had not first been thoroughly examined. And when once damage of slight importance has been discovered, the bridge may be rendered available for traffic in a short time with the help of struts, props, &c.

The number of workmen required varies according to the nature of the demolition; it can no more be fixed than can the time required.

Rendering wooden bridges, with vertical supports, unserviceable may be effected most quickly, most surely, and with the least expenditure of labour, by the removal of individual portions of the construction. The complete removal of a bridge would generally only be an advantage when it was wished to keep the materials. But in order that this may be possible either the near bank must be completely secured from seizure by the enemy, or the means must exist of sending these materials to a safe place; under all other circumstances the materials must, as far as possible, be destroyed, in order to deprive the enemy of their use; and in effecting this both time and labour would be judiciously expended.

With bridges of boats, the connection lengthwise between the boats must be severed, the anchors in the bed of the river raised, and the cables laid on shore, after which nothing stands in the way of the removal of the boats.

To give some idea of the time necessary for this, it may be noted that the opening of the cut in the railway bridge at Mapau is accomplished in from 7 to 10 minutes.

With flying bridges the boats must be taken away, and the ramps or landing places rendered useless in the manner described for pile bridges.

(*b*) *Burning.*—Notwithstanding the great disadvantage of a demolition by burning, that the limits of the fire cannot be exactly laid down, this, the only sure means adopted up to the present, must be made use of in all those cases in which a lasting and rapid destruction of the communication is contemplated.

The chief condition in the attainment of a satisfactory result in the burning of a bridge is a sufficient draught of air. In order to effect this the ballast must be removed and the woodwork exposed. The inflammable materials—such as straw, brushwood, pitch, tar, petroleum, &c.—are then spread over the different parts of the bridge.

Tarred hoops, or lumps of pitch, may be secured to the piles, &c., care being taken not to press them down too closely to the wood-work; small pieces of touch-wood should be attached to the hoops, &c. The spaces between the piles are filled up with brushwood or straw, the piles themselves being smeared, if possible, with pitch or tar.

Chaldrons filled with petroleum may be hung up under the roadway. Where stone piers occur, stacks of wood should be piled upon them.

Setting fire to the bridge is most simply effected by hand, but Bickford's fuze or hose may also be used. The quantity of the materials necessary for burning a wooden bridge cannot be laid down, as it varies under different circumstances. The nature of the wood, its dryness and age, the season of the year and temperature, the strength and direction of the currents of air, &c., determine, in each particular case, the expenditure of combustibles. A detachment of 56 men under favourable circumstances can prepare for burning 4 sets of piles, or 5 bays, in about 5 hours.

§ 6.

Iron Bridges.

With iron bridges interruption of the railway traffic may be attained by the removal of separate parts of the construction. But this can only be carried out when the connection between the parts is effected by screws. Where rivets are used, on the other hand, as is the case in all new bridges, this proceeding is not practicable, for it is impossible in a short time to break through all the rivets at the points of connection;* in most cases, by the removal of only some of them merely a weakness in the construction would ensue, against causing which a caution has already been given in speaking of wooden bridges. Merely striking off the heads of the rivets is quite useless.

In the following table every kind of iron bridge, with the exception of suspension† and swing bridges, is taken, and, with each particular bridge, those parts which when detached would make the bridge useless for railway traffic are mentioned.

* The truss bridge, 372 feet long, over the March at Kojetin, for example, has over 60,000 rivets.

† The rendering unserviceable of the suspension bridge over the Elbe at Tetschen, near Bodenbach, in the campaign of 1866, was accomplished by taking away the side-pieces, and unscrewing the vertical rods, for which purpose scaffolding had been erected beforehand, and the screws oiled. The unscrewing of the vertical rods was accomplished by 28 men in 35 minutes. This, although only a road-bridge, nevertheless affords some guide in rendering railway suspension bridges unserviceable, as the principle of their construction is the same.

Nature of bridge.			To remove.			How the construction may be further weakened, or entirely taken down.
MATERIAL.	CONSTRUCTION.		Sleepers (after removal of rails).	Transverse girders and binding beams.	Longitudinal girders.	
CAST IRON.	STRAIGHT GIRDERS.	Bridges of beams (*Plate* II. *figs.* 1–5).	With girders of a U-shaped section, unfasten the screw-bolts *x* (*Fig.* 5). With girders of a T- and I-shaped section, take out the screws *z* (*Figs.* 3, 4).		Unfasten the screw-bolts *d* (*Fig.* 3), and remove the distance-pieces *h* (*Figs.* 2, 3).	
		Suspended bridges (*Plate* II. *figs.* 7, 7*a*, *b*, *c*, and 8).	Detach the longitudinal sleepers *o* from the cross-girders *k* by taking out the screw *p*. The sleepers may also be sawn through.	After the removal of the longitudinal sleepers, detach the supports *k* by unscrewing the nuts *n* on the ties *f*.		The ties *f* are set free by unfastening the screw-bolts *e*; the compression booms *a* and struts *b* are separated by taking away the screws *d*, passing through the flanges; the tension booms *h*, by taking away the nuts *z*, are divided into their two parts, and the struts *b* freed from the piers; the bolts passing through the foot-plates *g* are then removed.
		Trussed bridges (*Plate* II. *figs.* 9-11).	Lift the longitudinal sleepers from the chairs *f*.			By undoing the distance-pieces *k*, and the screws *v*, or by removing the horizontal stiffeners, which is effected by undoing the screws in the plate *s*, and the screws *q*.
	ARCHED BRIDGES.	Arch below railway (*Plate* III. *figs.* 1, 2).	Remove the longitudinal sleepers after undoing the screw-bolts *z*, or saw them through (*Fig.* 2).	Remove the binding beams *u* after undoing the screw-bolts *r* (*Fig.* 1).		The vertical rods *p* are detached by undoing the screw-bolts *q* and *s*.
		Arch over railway (*Plate* III. *figs.* 3, 4).	As on the open line.			
	ARCHED RIBS.	Trussed bridges. Arch below or above roadway (*Plate* III. *figs.* 5, 6).	Remove the longitudinal sleepers L after undoing the screw bolts M; or, saw the sleepers through.	Remove the binding beams E after undoing the screw-bolts F.		By removing the screw-bolts D, after which the vertical rods A may be taken out.

Nature of bridge.			To remove.			How the construction may be further weakened, or entirely taken down.
MATERIAL.	CONSTRUCTION.		Sleepers (after removal of rails).	Transverse girders and binding beams.	Longitudinal girders.	
WROUGHT IRON.	STRAIGHT BOOMS.	Plate-girder bridges (*Plate* II. *figs.* 1-4).	As for cast-iron plate-girders, except that the U-shaped section of girder does not occur.		As for plate-girder bridges of cast iron.	
		Box-plate girders (*Plate* III. *figs.* 7-12).	Remove the transverse sleepers *h* (resting on the upper boom), after undoing the screws (*Fig.* 10). Remove the longitudinal sleepers *l* (resting inside the booms), by undoing the screws *m, n, o.* (*Fig.* 7.)			
		Lattice-girder bridges (*Plate* IV., V.).	Remove the longitudinal sleepers *l*, whether the roadway is carried on the upper boom or at the centre, or lower boom, after undoing the screws *m* (*Plate* IV., *figs.* 7, 8; *Plate* V., *fig.* 2). Remove the transverse sleepers *c* by undoing the screws *d*. (*Plate* V., *fig.* 1.)			
WROUGHT AND CAST IRON COMBINED.		Arched Ribs (*Plate* VI. *figs.* 1, 2, 3).	Remove the transverse sleepers *m*, from the blocks to which they are riveted.			With the help of windlasses, the bridge may be raised from its supports, and thrown down.
		Neville's System (*Plate* VI. *figs.* 4, 5).	Remove the longitudinal sleepers *m*, after loosening the screws *q*. Remove the baulks *g*, or saw them in two, or burn them.	Remove the cross-girders *d* after undoing the screws *z* in the chairs *f*; or saw them in two, or burn them.		By undoing the screws *h* and *o*, by which the struts *a* are connected with the booms *b* and the latter with the end pillars *l*; by taking away the distance-pieces R, and the cross-bracing.
		Schiffkorn's System (*Plate* VI. *figs.* 6, 7).	Remove the longitudinal sleepers *v*, after undoing the screws *m*; or cut them through.	Remove the cross-girders *a* after undoing the screws *o'* and *p*.		By taking away the screws *f*, *g* and *z'* by which the booms and cross-pieces *c* are separated from each other, and the former from the end pillars *b*; then remove the circular bars *d* by undoing the screws *n*.

With the help of this table the following facts may be established concerning the degree of unserviceableness to which iron bridges may be reduced by the removal of their individual parts.

(*a*) The permanent way can in all cases be removed; this, in the case of bridges, will cause an enemy more delay than an equal amount of demolition on the open line; because, with the one exception of arched bridges (the arch over the railway), the sleepers must either be fixed by a mechanical contrivance or secured with screws and nails.

(*b*) The transverse girders can only be removed from bridges on Neville's and Schiffkorn's systems. The delay thus caused, judging from the time necessary for restoration, as shown by experience, is considerable.*

(*c*) Where binding beams occur they may always be taken away. By so doing great delay would be caused only in the case of large spans.

(*d*) The removal of longitudinal girders is only possible with bridges of beams. The time required for this is not compensated for by the slight obstacle caused.

(*e*) A further weakening of the construction is only possible where connections by screws occur, but it will never be attended with anything but slight success, unless it is thoroughly effected, which, in most cases, time does not permit.

(*f*) Throwing the bridge bodily down is only practicable with very small spans. To accomplish it there must be extremely powerful windlasses at hand, the bridge must be of small weight, the piers must be without bolts (as in the case of arched wrought iron bridges), and the workmen at the windlass must have a secure foothold on the piers.†

The requisite number of workmen and length of time for removing individual portions cannot, as a rule, be fixed, as the numbers depend on so many different circumstances. For removing rails and sleepers the same numbers apply as for an equal length of permanent way on the open line.

* The campaign of 1866 in Bohemia furnishes the following facts:—

On three Schiffkorn bridges of 124 feet span, on the Turnau-Kraluper railway, the iron cross-girders were removed from a central span, after taking up the permanent way &c.; this was completed at each bridge by 14 men of the Engineer Troop, besides railway labourers, in three hours, while the temporary restoration effected by the Prussians occupied about three days on each of these bridges.

† The removal of the bridge by drawing back the whole construction, which has been sometimes proposed, is, under all circumstances, extremely difficult, and in time of war, utterly impracticable.

CHAPTER III.

Permanent Way.

§ 7.

Extent of the Demolition.

The extent to which the removal of the permanent way is to be carried depends, in this, and in all cases of demolition, on the delay which it is intended to cause the enemy.

With an equal number of workmen the temporary restoration of the permanent way, with the materials at hand, takes about nine times as long as its removal, as will be shown afterwards (§ 22); the amount of demolition to be effected, therefore, can be approximately fixed in every case by the delay intended to be caused.

Under certain circumstances it may be advisable to remove the permanent way only here and there, leaving short lengths intact. By this means a given length of unserviceable roadway is spread over a considerable distance. Although this cannot be done in every case in which a partial removal of the permanent way seems advisable, yet some particular circumstances will now be pointed out, under which this proceeding may be advantageous on a single-line railway.

(*a*) If the material removed is to be conveyed away it is advantageous; because in this case the work of demolition can proceed very quickly, as a certain amount of work (§ 8) may be carried on on that portion of the line subsequently to be taken up, lying behind the removing trucks.

(*b*) It is advantageous, if it is known that the adversary can procure no equally long rails; he is then compelled to employ the rails which he has brought with him; these have to be fitted into the gaps caused by the partial removal of the permanent way, and must consequently be shortened, or else the rails left intact must be taken up, in which much time and labour is expended.

(*c*) If, under the above-mentioned suppositions, many curves occur, it is advantageous; for on account of the rails employed being of unequal length, what is said under (*b*) applies still more forcibly. Curves, being the most difficult portions of a railway to restore, should only be left untouched when there is a prospect of the line being very soon required for use.

No rule can be laid down as to the proper length of permanent way to be left* or removed in the case of a single line; but that the

* The German lines have rails in 18 feet, 21 feet, and 24 feet lengths. The Russian lines have rails of 14 feet and 20 feet lengths.

portion left must not be shorter than the length of the train of trucks is evident.

In the case of a double line, at least one pair of rails must be entirely removed, and the other partially so; otherwise, an adversary might renounce the advantages of a double line for a time, and employ the material from one line of way to complete the partially destroyed one. As a rule, the traffic on a double line of railway is not interrupted for any length of time merely by the removal of the permanent way; for an adversary may employ the material from that portion of the line in his possession in the restoration of the line demolished; it therefore appears advisable, in any case, to ensure success, under such circumstances, by demolishing portions of the main works.

§ 8.

Removal of the Permanent Way.

As mentioned in § 1, the material composing the permanent way may either be torn up and rendered useless on the spot, or it may be taken up and carried away. The choice of the one or the other proceeding depends on the time at command and the labour available. With but little time and many workmen, the former proceeding must be adopted, and the removal of the permanent way can then be effected at several points, and even along the whole line to be destroyed, simultaneously. If, on the other hand, there are only a few workmen available, and the time is not very limited, they must all be fully employed at once which is only practicable when the material is to be entirely, or for the greater part, carried away. In this case, only a certain length of the permanent way, viz. up to the trucks intended for its transport, can be torn up simultaneously; whence the maximum number of workmen that can be employed depends upon this length.

Finally, with very limited time and labour, the mere removal of the permanent way is not sufficient, and other important parts of the line must be demolished (§ 3).

The following table shows the distribution of workmen for the removal of the permanent way without transporting the material, and also their distribution when it is transported, with the special duties of the respective parties; in both cases, it is presumed that the detachment consists of 4 superintendents, 56 skilled workmen, and a sufficient number of labourers (at least 40), and that the rails are of the Vignoles section, and rest on transverse sleepers.

(*a*) *Removal without Transport.*

No. of party.	Nature of work.	Number of Superintendents.	Number of Skilled workmen.	Tools.	Execution.
I.	Removal of ballast.	—	2	A shovel for each man, and a pick, if necessary.	Each man places himself by a rail-length, and clears away the ballast, which probably covers the inside spike nails and fish-plates, so that these may be removed without difficulty. When this work is completed on one rail-length, the party goes on to the next, and so on.
II.	Removal of fish-plates.	1	8	1 screw spanner, and 1 hammer, to each man.	The work of this party begins after No. I. party has left the first rail-length. The party is divided into sets of two men, who station themselves outside the rails, where the unscrewing of the nuts and striking off of the bolts may be continuously effected.
III.	Withdrawal of the spikes.	1	8	4 crow-bars, 4 hammers.	This party begins as soon as No. II. party is about one rail-length ahead. It is divided into sets of two men, one of whom uses the crowbar, and the other the hammer, to draw out the spikes on the inner side of the rails. The hammer is used as a fulcrum for the crowbar, and should only be employed to strike off the spike-heads, when the withdrawal of the spikes is attended with great difficulty; and even then, it is deemed advisable, if possible, to avoid it, as taking up too much time. The most skilful workmen should be selected for this party, as on their work depends the time occupied in the removal of the permanent way.
IV.	Removal of rails.	1	16	4 picks.	This party follows No. III. party, and is divided into two sets of eight men each, who place themselves on the inside of a rail-length. The two men near the ends of the rail are provided with picks, with which they draw the rail inwards, and endeavour to make it lie on the picks, so that it can be well seized by all the eight men; it is then raised on to their outside shoulders, and thrown down the slope, or laid on one side. When this work is finished for the first rail-length, the party advances to the next, and so on.

Removal without Transport—continued.

No. of party.	Nature of work.	Number of Superintendents.	Number of Skilled workmen.	Tools.	Execution.
V.	Lifting up and removal of sleepers.	1	16	1 pick to each man.	This party is so divided, that two men are stationed at an intermediate sleeper, and four men at a sleeper where there is a joint. The men lift up the sleepers with the picks, and drag them on one side, or shoot them down the slope.
VI.	Reserve party.	—	6	As required.	This party gives two men, who are to be provided with hammers, to No. II. party (fish-plate party), to strike off those fish-plate screws, which are very tightly fixed or rusted; these men also collect the bolts and nuts. The remaining men are employed where necessary; but most advantageously in strengthening the spike party (III).
Total.		4	56		

This division of the work might also be applied with chair-rails, except that Parties II. and III. instead of removing fish-plates and withdrawing spikes, would have to knock out the wooden or iron keys, and, if necessary, bore out the former.

The chairs are left on the sleepers. No. IV. Party would then have to lift the rails out of the chairs.

The spare workmen are to occupy themselves on both sides of the railway with preparing the sleepers for burning, with placing the rails removed on the sleepers when stacked in heaps, or with carrying them to places where they can be sunk, or with bending the rails*; for these purposes, the workmen should be suitably divided into parties under their own superintendents.

A rapid removal of the permanent way may be attained under urgent circumstances by the method frequently employed in the American Civil War, by which whole portions of the railway, consisting

* If the rails are laid upon the burning sleepers they become bent, and are thus rendered unserviceable. The simplest method of bending a rail consists in letting it fall down from some little height upon another rail lying on the ground, in such a way that it falls on its side.

of from one to two rail-lengths, together with the attached sleepers are lifted up, and thrown down from the roadway. This method ot demolition of the permanent way will be found most effectual on high embankments, for in this case the rails become thoroughly bent and unserviceable by being thrown down.

In this work, a division of 56 men may be separated into two divisions of 28 men, each division being employed for the removal of a portion of the permanent way equal to one rail-length. Of these 28 men, 8 would be employed for the removal of the ballast, so far as is necessary to enable the rails to be lifted, and 8 more for detaching the fish-plates. Then 12 men lift the rails, carry them to one side, partly laying hold by the sleepers, and partly by the rails, and throw them over the slope. With portions of permanent way consisting of two rail-lengths, 16 men would have to attend to the removal of the ballast, 16 to the removal of the fish-plates, and 24 to lifting up the rails, &c.

(*b*) *Removal with Simultaneous Transport.*

Experiments* have shown that the trucks intended to be loaded with the rails and sleepers must be stationed at a distance of 6 rail-lengths from the starting point of the work, in order that the uninterrupted progress of the work of removal of the permanent way may fit in with the carrying of the material. This arrangement would therefore be adopted with the division of labour following.

* An experiment carried out at Hohenau, 21st September 1868, has shown that the tearing up, carrying, and loading, occupied on an average—

With 3	rail-lengths,	5 minutes
,, 6	,,	7 ,,
,, 7	,,	11 ,,
,, 10	,,	18 ,,

Whence it appears that working with 6 rail-lengths requires proportionately the shortest time.

No. of party.	Nature of work.	Number of		Tools.	Execution.
		Superintendents.	Skilled workmen.		
I.	Removal of ballast.	—	2	As before, in removal without transport.	The work of these parties commences after the train for the removal of the material has been stationed six rail-lengths from the starting point; the work is carried out exactly in the same way as shown in the preceding table.
II.	Removal of fish-plates.	1	8		
III.	Drawing out the spike-nails.	1	8		
IV.	Removal of rails.	1	16		As before, this party takes up the rails as soon as No. III. party has left the first rail-length; they are then carried upon the inside shoulders to the trucks, and loaded on to them, where possible, at the sides.
V.	Raising and removal of sleepers.	1	8		This party merely raises the sleepers from their bed in the ballast; their removal, and the way in which it is effected by the labourers, will be mentioned later.
VI.	Reserve party.	—	6		As described in the previous table. This party can, however, be afterwards used to strengthen the loading-parties.
VII.	Loading party.	—	8		This party, with the help of the Reserve and of labourers, packs the rails and sleepers upon the trucks; these last are so arranged one behind the other, that each truck carrying rails is immediately followed by one carrying the sleepers belonging to them.
Total.		4	56		

The labourers for carrying the sleepers are posted 4 at each intermediate sleeper, and 6 at each sleeper under a joint. From the labourers are also chosen the reinforcement which will probably be necessary for the loading-party; consequently, about 40 labourers in all are required.

When the work on 6 rail-lengths is completed, the train advances this distance, and the demolition is repeated in the manner already described.

When the permanent way is only removed here and there, and the train is standing where the line is intact, Nos. I. and II. parties pass the train and work in front of it. In all other cases, the parties wait to begin their work forward, until the train has taken up its new position.

When the necessity of removing the permanent way for a certain length can be foreseen with certainty, it is very advantageous, some time before the commencement of actual work, to remove the ballasting, and take off the fish-plates, as by this preparatory measure the effective result is increased, without necessitating an interruption to the traffic until the actual demolition is begun.

In calculating the number of trucks (lorries) necessary for the transport of the material of the permanent way, it may be taken as a guide, that one truck has a carrying power of 200 cwt.; it may therefore be loaded with 50 rails, or with the sleepers belonging to that number. Hence may be derived the number of trucks, and also the length of the train, which, besides the necessary open trucks (lorries), must have a truck for tools, one for the men, and a locomotive and tender. A double line of rails should have, when possible, one train for each pair.

§ 9.

Working Power of a Division.

From a trial especially arranged to ascertain the working power of a division of workmen, the following results were deduced, which, however, only hold good during the first hour of work. If, therefore, an equal amount of work is to be attained in each successive hour, there must be a fresh relief every hour.

(*a*) *Removal without transport.*—A division consisting of 4 superintendents and 56 skilled workmen, besides the number of labourers given in § 8, can demolish a length of about 610 feet of permanent way* (29 rail-lengths, each of 21 feet) in about one hour, and remove the material as shown above. In this case, several distinct parties may be arranged at discretion, and the same amount of work obtained

* At Hohenau, 48 thoroughly skilled workmen demolished a length of 29 rails, each of 18 feet (about 520 feet), in 46 minutes, and loaded the rails only on the trucks. Before the commencement of the work, the ballast and two screw-bolts from each fish-plate had been removed.

from each; the result will then be increased proportionally to the number of the parties. Thus, for example, two parties of the above strength will be able to remove about two miles of superstructure in 10 hours.

(*b*) *Removal with simultaneous transport.*—A division consisting of 4 superintendents, 56 skilled workmen, and 40 labourers, can remove a length of 610 feet in $1\frac{1}{2}$ hours, and load the material on trucks. To effect this, the trucks are stationed 6 rail-lengths off, but only a double number of men at the outside can be organised without the parties interfering with each other's work in the limited space. As the working-power in this case is in the proportion of about $1\frac{1}{2}$ to 1 to that in the former, these two united divisions would demolish about 2 miles of permanent way, and load it on the trucks, in about 15 hours.

CHAPTER IV.

Stations, Rolling-stock, Signals.

§ 10.

Points, Crossings, &c.

The simplest means of depriving an adversary of the use of a station in a short time consists in the entire removal of the permanent way. This means can, however, only be employed when not more than 3 or 4 lines of way are found in a station, and when a sufficient amount of time and labour are at disposal. With many lines of way, on the contrary, as is the case in large stations, it is impossible to take up all the rails, and it must then suffice to remove the through lines, or, at all events, the switch-rails and crossings.

It will, however, be in few cases possible to transport all the rails and sleepers removed; but, at any rate, all switch-rails and crossings must be placed out of the reach of the enemy.

As the removal of the permanent way is effected in stations as on the open line (§ 8), only that of switches and crossings will be now described.

(*a*) *Switches or points.*—For these, the work of demolition consists in:—

1. The removal of the switch tongues, after undoing the fastenings.

After this is effected, and the key of the connecting rod is removed, the tongues may be lifted up, together with the point rods.

2. Removal of the stock rails after taking out the screws *a*

(*Plate VII., fig.* 2), the hook-nails, and detaching the fish-plates on the rails at the point of junction.

3. Removal of the arrangement for altering the points, after screwing off the lever or crank arrangement.

4. Raising up the sleeper under the points by the aid of levers or crowbars.

5. Carrying and loading of all material.

If there is not sufficient time to carry away everything, the switch tongues, at least, must be taken.

The removal of a switch may be accomplished by 16 men provided with 6 screw spanners and 12 levers, in 10, or at the most, 15 minutes.

It will, however, be advantageous to remove not only the actual switches, but also the curved rails of the points and, where possible, the rails of the main line as well.

(*b*) *Crossings.*—As the individual parts of crossings, namely tongues, wing-rails, and guard-rails, are usually secured in exactly the same way as the main rails, the principles laid down in § 8 hold good for their removal. The tongues of chilled iron or cast steel are raised up after the removal of the nails, together with the wing-rails belonging thereto, by means of crowbars. Tongues and wing-rails should not be left, as a rule, for the adversary, but should, if possible, be always taken away.

(*c*) *Turn-tables.*—No particular importance is attached to the destruction of turn-tables, as they very seldom serve for the connection of main or through lines, but are only employed on sidings to give a means of access to the rails of engine houses, workshops, &c. Still, should it be desired to render turn-tables unserviceable for a short time, it may be done by removing the central pivot and the turn-table rails. To render it useless for a considerable time could only be effected by blowing up the platform.

(*d*) *Travelling platforms or traversers* may, like the turn-tables, be left untouched, and for the same reasons. Should it be necessary, however, to include them in the demolition, they may be rendered unserviceable by removing the rails on them, and the wheels on which they run, by destroying the girders of the traverser; and, in the case of sunken traversers, by blowing in the sides of the traverser-pit as well.

§ 11.

Water Supply.

The rendering useless of the arrangements connected with water supply deprives an adversary of an indispensable help in the working of a line, and compels him to occupy much time in their restoration. Endeavours must, therefore, be made to destroy as thoroughly as possible all arrangements for the supply of water, particularly as this may be done very simply and quickly.

In the first place, all contrivances connected with the feeding of the water-tanks must be demolished.

The pipes, and especially bends and angle pieces, must be removed, and, when possible, taken away altogether. The piston-rods and pistons must be taken out of the pumps, and the rising pipes screwed off. If there is not sufficient time for this, the pipes must have wedges driven into them. In the case of a steam-pump, the transmission arrangement, as well as the piston, must be taken out of the cylinder. When the filling of the water-tanks has been made impossible, the arrangements for watering the engines must be partially demolished by removing the pipes as before mentioned; in this case this is very easily effected, as leather hose is very often used. The cocks, when all the above-named work has been carried out, may be left intact, for if the feeding of the water-tanks is impossible, and the main to the cocks is interrupted, these will of course not act.

The water-tanks need not be destroyed, for not only are they very easily repaired, but also their demolition can only be effected by blowing up; and by so doing the buildings in their neighbourhood suffer and damage is caused, which the small delay thus occasioned would not justify.

§ 12.

Stations and other Buildings and Fittings.

Buildings are convenient, it is true, for carrying on traffic, but they are not indispensable; the possibility of communication exists without them, and the adversary by their demolition would be prevented from making use of the railway only for so long a time as the removal of the *débris* and rubbish lying upon the line of way would require. The time and labour expended in such a demolition might probably be infinitely better employed in some other way.

Consequently it should be established as a principle, that buildings should only be demolished or blown up, when by so doing other military advantages are gained in addition to the mere interruption of the railway traffic.

In all cases, however, the movable fittings which are found in the buildings, and according to which the latter are designated either as workshops, stores, or fitting shops, should be removed. The different workshop fittings must, therefore, be taken away altogether, and if this is not possible, they must be rendered useless by the removal of important parts. Stationary engines should be made unserviceable by taking out the piston and removing the transmission arrangements; telegraphic apparatus and batteries must be removed. Fuel, permanent way material, and reserve plant, as well as raw material, should be taken away if possible; if not, they must be destroyed or rendered useless. The smaller tools should be taken out of the workshops; but it must never be thought that by this alone the workshops will be made useless, for in most cases an enemy would be well provided with such implements.

Wells may be rendered useless by blowing in their sides, or by filling up; large and important ramps, especially at good stations, should be blown up; on the other hand, small ramps, platforms, and portable weighing machines may in most cases be left intact.

§ 13.

Rolling Stock.

The enemy may be deprived of the use of the rolling stock, either by withdrawing it from the probable range of his operation, or by rendering the locomotives and carriages unserviceable to an extent corresponding with the object in view. Whenever possible, the former plan should be adopted, provided the rolling stock can be spared. Care must be taken beforehand that at the stations appointed to receive the locomotives and carriages, there is a sufficient length of sidings; if necessary, rails must be temporarily laid down along the side of the railway, or even on the roads, to supply any deficiency.

But if it is altogether impossible to remove the rolling stock, the time at disposal should be employed in rendering it useless, at least temporarily.

Of the many methods by which this is attainable, only those will here be mentioned which are easily carried out.

Locomotives may be rendered useless in the following ways:—

(*a*) *By screwing off the injector.*—But if an engine has, in addition to an injector, an ordinary feed pump, or, as is the case with engines of old construction, only a feed pump, the valve in the feed-head must be taken away. For this purpose, the screws *s* (*Plate VIII., fig.* 2) on the cap *d* must first be undone, the cap *d* removed, and then the ball valve inside lifted up by pulleys. By this means the water that is in the boiler will flow back, and it will be impossible to use the locomotive until the ball valve is replaced.

(*b*) *By screwing off a steam dome.*—With engines of recent construction, which very frequently have steam domes made to screw off, this is the simplest and surest means of rendering an engine unserviceable, and it has the advantage that the engine can be got ready for use again almost immediately.

(*c*) *By removing the connecting rods on each side of the engine.*—To do this the wedge *z* (*Plate VIII., figs.* 4 *to* 6) must be removed, and the horizontal bolt *a*, fastening the connecting rod to the cross-head, must be struck out; the connecting rod can then be easily removed.*

Coupling rods may also be removed in this way.

(*d*) *By removing the piston.*—To do this, the screws on the front cap of the steam cylinder are unfastened, the cap *d* (*Plate VIII., figs.* 3 *and* 4) is drawn off, and the most oblique wedge, which effects the connection of the piston-rod with the cross-head, is knocked out; the whole piston can then be drawn out of the cylinder. To facilitate this, it is advisable in the first place to loosen the stuffing-box *h* a little at the back.

The removal of the piston can be almost momentarily effected with a heated boiler, if the connection between the piston-rod and the cross-head is severed by taking out the wedge, and steam is then let in through the openings at the back of the cylinder. The thus loosened piston then presses the cap of the cylinder forcibly out. As in this proceeding the cylinder is generally shattered, it must only be done when no particular regard has to be paid to the saving of material.

(*e*) *By removing the safety-valve.*—The valve becomes useless if either the bar *a* (*Plate VIII., fig.* 1), the safety lever *f*, or the spring balance *f′* is removed. If there is not enough time to remove these individual parts, a blow with a hammer on the cap is sufficient to destroy the whole system.

The most essential parts of the sub-structure of carriages are the axles and wheels. By removing, and at once carrying away the latter, the unserviceableness of the carriages is most completely attained. As this is, however, in very few cases practicable, it appears more advisable to be content with the removal of the springs. For if these are taken away, the body of the carriage falls with its underside directly upon the wheels, and the moving of the carriage is prevented until the springs are restored. To do it, the screw nuts *m* (*Plate VIII., fig.* 7) are removed from the axle-bearers *a*, the bolts or screws *b* are taken out from the bearers of the spring *f*, and the latter is withdrawn. To facilitate the work, the longitudinal bearers of the body of the

* According to experiments made, the removal of a feed-head valve or a connecting rod by two men, provided with a hammer and screw-spanner, lasted, on an average, 3 minutes.

truck may be supported beforehand by means of screw-jacks; after the removal of the springs, the body is let down on to the wheels.

Carriages with wooden frames may be rendered permanently useless by sawing the frames through in one or several places; before doing this the sheet iron, with which the sides of the frames are usually covered, must be cut through. This, however, occupies much time, and the method given when speaking of tunnels (§ 2), of running carriages off the rails, is preferable, especially when many trucks have to be destroyed; by this means, simultaneously with the destruction of the trucks, a barricade is formed, which is chiefly of advantage in cuttings and stations.

§ 14.

Signals.

The poles, levers, and arms of the visual signals, the shunting and stopping signals, as well as all hand signals, must be altogether removed. The wire of the electric signals must be destroyed by cutting and twisting, and by removing some poles. If time permits, the wires should be taken down and rolled up properly. All apparatus and batteries must be taken away.

PART II.

RESTORATION OF RAILWAYS WHICH HAVE BEEN DESTROYED OR RENDERED UNSERVICEABLE.

§ 15.

Introductory Remarks.

In restoring railways which have been destroyed or rendered unserviceable, all constructions and erections are of a temporary character, as it is only intended to make a line fit for traffic with the smallest consumption of time and by the simplest means, for the period that it will probably be required.

The quality of the materials, the nature of the constructions, and their execution, are, in such restorations, only to be so far taken into account as to secure the safe carrying on of the traffic; at the same time all regard for appearance is quite omitted, and convenience is only taken into the question when, by doing so, no greater consumption of time, labour, or materials will be entailed.

There is often, consequently, a great difference between the design and execution of temporary constructions of this kind in the field, and those of permanent constructions erected in time of peace. For example, with permanent constructions, while the permanent way is being prepared, the greatest care is taken to ensure easy running, and to place the sleepers as far apart as possible, and so on; but with field railways, on the other hand, any description of permanent way which leaves no cause for fearing that the trains are likely to run off the rails, is considered to answer all purposes.

In the following pages it will be shown how portions of a railway which have been destroyed or rendered useless may be restored for use in the field; and how far, in such restorations, the method of executing ordinary permanent constructions may be departed from without affecting the safety of the traffic.

CHAPTER I.

Main Works.

§ 16.

Embankments, Cuttings, Tunnels.

Although embankments are not often destroyed, on account of the great consumption of time and labour necessary, their restoration is nevertheless taken into consideration here, as it is quite possible they may sometimes be found demolished.

Filling up, ramming down, and levelling the deficient embankment now appear to be undoubtedly the simplest methods of restoration, and are, when the length and depth to be filled in are not considerable, the most advantageous; but much depends upon local circumstances.

Slight demolitions of embankments are but seldom met with, for as a rule, if an adversary finds himself compelled to destroy an embankment, he will do all he can to create a very considerable obstacle. According as its extent increases so does the restoration by filling up occupy a longer time than that by forming a temporary wooden construction; it is therefore sometimes advantageous to employ the latter method. In cuttings which have been blocked, one line of rails must first be cleared and then the other. If the sides have been blown in, a careful examination must be made, and all movable rubbish removed, so that passing trains may not be endangered by its falling.

Tunnels which have been blocked must be cleared; if, however, they have been destroyed by gunpowder, not only the extent of the explosion, but also the geological nature of the ground above and around, must be narrowly investigated, and the construction of the walls examined. By this means it can be decided whether a simple clearance of the *débris* is sufficient (as, for example, in tunnels through rock without revetements); or whether, and to what extent, it may be necessary to repair the injured walls. Various cases may be met with; they are always, without exception, dangerous, and require excessive precaution. A temporary wooden lining should only be constructed when the existing revetment is very weak ($1\frac{1}{2}$ or 2 feet thick). The uprights, struts, and transoms employed for this purpose must follow the rectilinear normal section of the open line in the clear, and the sheeting must be placed on the outside. Strong revetements show that a considerable side-thrust had to be provided against, and it would in this case be extremely dangerous to undertake a restoration with the limited means of a Field Railway Division. In a case like this, and when an elaborate tunnel-vaulting is damaged at the top, not a moment should be wasted in the endeavour to reconstruct the tunnel temporarily, but, if possible, a temporary line should be laid down, and the tunnel avoided altogether.*

If, however, the hill through which the tunnel passes, is not high, the whole superincumbent mass resting on the destroyed tunnel may be cut away to the necessary slope, and thus a cutting with very high sides may be formed. In 1870, the third German Field Railway Division rendered the tunnel of Armentier, which was blown in for a length of 500 feet, passable in this way; no timber to form framing was to be had, and the hill above the tunnel only had a height of 100 feet. Here, the work was begun at the top, the necessary slopes were given to the cutting, and the sides were partially reveted, for which purpose 80,000 bricks were required.

§ 17.

Temporary Wooden Constructions in General.

Bridges, viaducts, and, to a certain extent also, embankments which have been destroyed, can in time of war, when rapidity of execution is of the first importance, only be replaced by temporary wooden constructions. Extreme simplicity, combined with perfect security, should characterise such a field-construction.

In executing such works, the formulæ founded on experiments made on different railways, and the principles generally laid down in the building of permanent wooden bridges, may be applied in the case of temporary wooden constructions.

As it is supposed that the reader is familiar with the principles of bridge construction, as well as with the technical execution of details, only those matters will be treated of in the following pages which relate

* The attempt of the second Field Railway Division to reconstruct the tunnel at Nanteuil, on the railway from Nancy to Paris, which was blown in during the Franco-German War of 1870–1, forms a very instructive case in point.

This tunnel, about 1,000 yards in length, was blown in by the French by charges loaded in the side walls, so that not only was the masonry of the vaulting and side-walls completely destroyed for a length of about 100 feet, but also the hill above (about 250 feet high) was loosened, and some portions fell into the tunnel, while others slipped over it. As the rebuilding of the destroyed portion could not be thought of, on account of the great consumption of time and insufficient means, the construction of a temporary line in a gallery lined with woodwork was set about. *Plate IX., figs.* 1 *to* 6 show the successive steps of the work. When, at the end of 4 weeks, this was almost completed, considerable displacements were caused by the pressure of layers of the hill, which was of the tertiary formation; various beams of the strong wooden framing were displaced and broken, until at last the complete collapse of the nearly restored portion followed. Hereupon a circuit of the tunnel by means of a field railway was undertaken, and, with the help of 1,000 workmen, was completed in 23 days.

to peculiarities in the construction of railway-bridges in the field. With railway-bridges generally, greater loads comparatively have to be allowed for than with road-bridges; but with temporary field railway-bridges the carrying out of such a construction as will best suit the particular circumstances is all that has to be sought after; for not all constructions, which are executed in time of peace, are applicable for constructions in the field; since, for example, for the formation of groups of piles, trussed and suspended bridges combined, lattice-bridges, &c., the time at disposal is in most cases insufficient. Bridges on piles, trestle-bridges, and, in extreme cases, trusses, may be pointed out as the simplest constructions in field railway-bridging.

In the execution of a structure which is only intended to last during a campaign, there is not the same demand for solidity and durability as in a permanent structure. Consequently, materials of smaller dimentions and of inferior quality will suffice, all complicated joints will be avoided, and cramps, screw-bolts, &c., will be employed instead. The dimensions which are adopted need only be those which will ensure that security which is indispensable. Finally, it must not be overlooked, that a project for the construction of works in the field is not so much dependent on the dimensions (as in the case of permanent works) and on the quality of the materials as on the materials at hand, or those which can be procured in the neighbourhood, which have to be made use of.

Taking the above facts into consideration, and in order, at the same time, to give some guide for cases which frequently occur in war, the two following sections contain:—

Data which are generally absolutely necessary for the calculation of the strength of wooden railway-bridges; and

Rules for the formation of temporary structures in war, as well as some examples, which, with the aid of standard designs, may be adapted to various special cases.

§ 18.

Data for Calculation of Strength.

The calculation of the strength of the bridge must embrace equally that of its superstructure and that of its supports.

The superstructure of a railway-bridge consists of the rails, sleepers, and bearers. The weight of the rails and sleepers may be disregarded, for on every foot run of the length there is only a load of 66 lbs.;* therefore, only calculations as to the strength of the bearers and supports are given.

* As the average length of a locomotive of 25 feet covers about 8 sleepers and

When the baulks are dovetailed,

$$r_1 = \tfrac{3}{4}\, r.$$

Having the preceding formulæ, there can be no difficulty in finding the strength of the bearers, their dimensions being fixed, or, in finding the necessary dimensions, the load being known, as soon as r, the admissible working load, is known. In determining the dimensions numerically, the experiments which have been made in railway-construction, and existing rules, as well as constructions which have been actually executed and tested, may be taken as guides.

The Royal and Imperial private Southern Railway Company has issued fixed rules for the construction of their temporary structures, in which the admissible load is laid down at 120 kilog. per square centimetre, equal to 14·88 cwt. per square inch, or, for round timber, 15 cwt. per square inch.*

On the Emperor Ferdinand's Northern Railway no fixed formulæ have been laid down, but standard designs for different spans have been planned. *Plate IX., figs.* 7 *to* 16, and *Plate X., fig.* 1, show temporary constructions founded on these designs. A calculation made according to what has been said above, and with the help of the formulæ, gave as admissible load from 9 to 11 cwt. per square inch.

In the same way, the greatest load on some of the temporary structures on the Charles Louis Railway was found to be 15 cwt. per square inch.† (*Plate X., figs.* 2 *to* 4, and *Plate XI., fig.* 1.)

If now the temporary arrangements mentioned be taken as a basis for the determination of the admissible load on the square inch, r is found to vary between 9 cwt. and 15 cwt. If the load $r=9$ be taken, in every case the customary limit in the case of permanent bridges is obtained; with thoroughly sound timber and rigid connection, r may be taken at 15 cwt., as the extreme limit.

(*b*) *Calculation of the supports.*—These will consist only of piles, trestles, and simple trussed frames.

For the calculation of the strength of the piles or vertical supports, the very simple experimental rules given in Weiss' *Art of Construction* may be made use of. According to these, there may generally be taken, for vertical timbers, irrespective of their nature, a load of 2 Vienna cwt. on each square inch, provided the height does not exceed thirty diameters. As the height diminishes, the strength increases, so that each square inch of section may be taken to carry,

* To convert kilogs. per square centimetre into Vienna cwt. per square inch, multiply by 0·124.

† In this determination of the admissible load, the supports were neglected, and the clear length ef taken. (*Plate IX., figs.* 7 *to* 16, *Plate X., figs.* 1 *to* 4, and *Plate XI., fig.* 1.)

with a height	25	times the diameter,	3	cwt.
,,	20	,, ,,	4	,,
,,	15	,, ,,	5	,,
,,	10	,, ,,	6	,,

The number of piles or vertical supports which must be used in a simple or complete pile-work, or in a trestle-bridge, is governed partly by the above rules, partly by the load on the piles, and partly by constructional considerations.

It may generally be taken that 3″ vertical timbers $\times 2'' \times 12''$ and 2 struts (which are not taken into account), fixed at a height of 20 feet, are sufficient for one group of piles, if the bridge is only designed to carry one line of rails. The temporary constructions shown in *Plate X., figs.* 1 *to* 4, and *Plate XI., fig.* 1, give more than the necessary safety in this case. Trussed frames are generally only admissible for small spans, when there is plenty of height, and when the footings are good; under these circumstances, they are easily available for the strengthening of pile-constructions. In calculating the strength of the parts of the trussed frame (struts and straining-beams), the load Q which acts at the point of support, and the angle a (*Plate IX., fig.* 15), must, first of all, be ascertained; then the pressure on the strut $Q_1 = \frac{Q}{\cos a}$, and that on the straining beam $Q_2 = Q \tan a$.

In calculating the section necessary, the proceeding is the same as in the case of struts and columns which sustain a thrust in the direction of the axis. For example, for the strut Q_1 it is equal to $r_1\,bh$, where b is the breadth, and h the height of the section, and it is assumed that b is equal to or less than h.

In order to find r, the formula

$$r_1 = \frac{r}{1 + 0{\cdot}00576\left(\frac{l}{b}\right)^2}$$

is used, where, according to the rules for thrusts along struts or compression bars, r is only to be taken as 5·2 cwt.

§ 19.

Rules and their Employment in Special Cases.

As, in the foregoing paragraphs, the construction and calculation of temporary wooden structures erected during a campaign is only generally treated of, it appears advisable to thoroughly consider from a constructive point of view a few cases, which would probably be most likely to occur.

In *Plates IX., figs.* 7 *to* 16, and *X., fig.* 1, several constructions with spans from 6 feet to 60 feet are given, which may serve as guides; in *Plates VI., figs.* 6 *and* 7*a*, *X., figs.* 2 *to* 4, and *XI., figs.* 1 *to* 3, some examples are shown.

If, in a given case, the material which is used in the construction of the standard designs can be procured without loss of time, the execution of the work can be forthwith proceeded with, in accordance with the same. If, however, timber of less dimensions than those given is only at disposal, the length of the girders and their section must be brought into a proper relation with the number of piers or supports; and, similarly, the height of the piers must be varied with the depth of the obstacle, &c., in each particular case. A calculation which thus harmonises local circumstances with the materials at hand, and which must be based upon the principles enunciated in §§ 17 and 18, will always show clearly what standard designs, or combinations of the same, best answer the required purpose. A few examples will show how the given designs may be made use of in the case of destroyed bridges, as regards the material of which they are constructed.

(*a*) *Stone bridges.*—If the piers are only partially damaged by gunpowder, they are still available as foundations for trestles. In the example given in *Plate X., fig.* 4, trestles* in two stages have been erected and strengthened by trussed frames. The clear length $ef = 15$ feet. One rail-length is supported by $1\frac{1}{2}$ bearers; one bearer is formed of two baulks, 13″ by 14″, bolted together. The superimposed weight is therefore similar to that in the construction of the standard design, *Plate IX., fig.* 16; the construction is thus quite safe.

In the case of piers entirely useless (*Plate XI., fig.* 1*b*), or of arches quite blown down (*Plate XI., fig.* 1*a*), when the erection of trestles is impossible, piles must be driven, as shown by the respective figures.

* In the War of 1870–71, the German Field Railway Divisions very frequently made use of trestles in the restoration of stone bridges. The restoration of the demolished bridge over the Marne at Chalifert is shown in *Plate XI., fig.* 2. The explosion had caused a gap of 86 feet; the scattered masonry had filled up the opening to such an extent, that the course of the stream was hindered; by stone-packing, with the interstices filled up with rubbish, a dam, reaching to 16 feet above the water-level, was formed, and there then remained a height of about 30 feet for the construction. There were 11 trestles 8 feet 4 inches apart from centre to centre. The cross-bracings were secured with iron-cramps, while strong nails only were used with the longitudinal bracings. The corbel pieces were connected with the bearers by 2 screw-bolts. As the two sides of the arch unharmed by the explosion were not sufficiently safe to allow the bearers to rest directly upon them, it was necessary to arrange another trestle on the masonry. In a similar manner the temporary bridge of Meaux, at Isles, was constructed for about 84 feet.

Without allowing for the supports *cd*, the clear length $ef = 21$ feet 6 inches. A rail-length is supported by $1\frac{1}{2}$ bearers; a bearer is formed by two baulks, 13″ by 14″, bolted together. The superimposed weight is therefore less than in the construction of the standard design, *Plate IX., fig.* 15.

(*b*) *Bridges of Wood.*—If the piles are not completely destroyed, and are still fit to be used as supports, they must be cut off level, and provided with a cap-sill, on which the new pier may rest. *Plate IX., figs.* 12, 13, *and* 14, and *Plate X., fig.* 1, would serve to explain any constructive details if it is contemplated to make use of the pile foundations as a support for the timbering of the bridge. If, however, the piles are destroyed below water-level, new ones will have to be driven.

If the bed of the opening is dry, and sound stumps of the piles are left which can be cut off level, the formation of the pier may be also effected in the way previously described.*

If the bridge rests on stone piers or iron pile-work, and the superstructure only is destroyed, as many intermediate piers as are necessary must be formed corresponding to the dimensions of the bearers, in addition to the restoration of the superstructure.

If only individual parts of the superstructure are damaged (sawn through, for example), they must either be replaced or supported underneath, according to the nature of the construction.

(*c*) *Iron Bridges.*—If the rails and sleepers have been removed, their places must be supplied by new ones when they are to be had. Deficient iron girders can only be replaced by wooden ones.

If the construction, in the case of suspension bridges, has been weakened by the removal of bolts, king-posts, &c., the missing parts must be supplied as far as possible from the materials at hand. Neville bridges, from which the wooden cross-girders have been removed, may be restored by laying temporary cross-girders in the chairs (*f*), which are made on purpose to receive them (*Plate VI., figs.* 4 *and* 5).

* A method which was adopted in the campaign of 1866, in the temporary restoration of the Altenmarkt Bridge, deserves mention here. The piles of the existing wooden bridge had been burnt down to stumps about 1 foot high. On both sides of the stumps transoms were placed, and secured by means of bolts passed through them. In the opening thus formed, and terminated by the stumps, the vertical timbers were fixed, and the bolts drawn close, by which the cutting off of the ends of the stumps and the cogging of the capping-piece were avoided. The remainder of the work was carried out in the ordinary way. In a similar way, in the campaign of 1870–71, the wooden bridge over the Maine at Châlons, which had been burnt by the French by means of petroleum, was restored by a German Railway Division (composed of French railway officials, and soldiers under the engineer Glaser); the vertical supports of the new bridge were bolted on to the existing foundation-piling *a* (*Plate XI., fig.* 3), at the water line.

Schiffkorn bridges, from which either all or only some iron cross-girders have been removed, may be again made passable if, instead of these girders, timber trusses are fixed, as follows* :—On the bottom boom transoms (a'), 16 feet long and 8 inches square, are laid as close as possible to the joints (*Plate VI., figs.* 6 *and* 7*a*). To effect this, they may be diminished at the ends. On these transoms there comes a timber truss 8″ square. To stiffen the bearers and framing, four longitudinal baulks (b) are halved into the transoms, and struts (c) are fixed. The distance apart of the trusses depends on the strength of the longitudinal bearers; it is, as a rule, 3 feet (i.e. at the same distance apart as the joints), but with bearers 13″ by 14″ it may be 6 feet (i.e. at every other joint).

The calculation given in the note† shows that this construction is

* In the campaign of 1866 the Prussians restored Schiffkorn bridges, which had been destroyed on the Kralup-Turnau Railway, in the following way:—Platforms about 3 feet broad and 15 feet long were formed of planks laid cross-wise over each other upon a plank framing; these were nailed with long nails, two to each cross-bearer; the latter were grasped by the wrought-iron suspension braces of the booms; on these the longitudinal bearers carrying the rails were laid, after wooden bars had been arranged cross-wise to give stiffness in the direction of the length. The platforms were wedged up against the bottom boom, in order to prevent a lateral thrust upon the cast-iron cross-braces.

† The pressure Q of a wheel (of a 6-wheeled engine of 600 cwt.) is 100 cwt.

Taking, as the most unfavourable case, α equal to 40°;

Pressure along the strut $\frac{Q_1}{\cos \alpha} = \frac{100}{0 \cdot 7660} = 132$ cwt.;

Pressure along the straining beam $Q_{11} \tan \alpha = 100\ (0 \cdot 8391) = 189$ cwt.

The safe load of the struts should be $r_1\, b^2 = 132$ cwt.

Whence,

$$r_1 = \frac{r}{1 + 0 \cdot 00576 \left(\frac{1}{b}\right)^2} = 4 \cdot 3 \text{ cwt.}$$

Therefore,

$$r_1\, b^2 = 4 \cdot 3 \times 64 = 275 \cdot 3 \text{ cwt., or more than twice what is required.}$$

The safe load of the straining-beam should be equal to 189 cwt.; but it is

$$r_1 = \frac{5 \cdot 2}{1 + 0 \cdot 00576 \left(\frac{42}{8}\right)^2} = 4 \cdot 4 \text{ cwt.};$$

consequently $r_1\, b^2 = 281$ cwt., or more than sufficient.

Longitudinal Sleepers.

In a clear length of 3 feet, Q = 93 cwt.

The safe load of a sleeper is $\frac{2rbh^2}{31} = 96$ cwt.

With longitudinal sleepers of 13″ × 14″ timber, for a clear length of 6′ Q = 187·5 cwt., and the safe load of such a sleeper is

$$\frac{2rbh^2}{31} = 212 \text{ cwt.}$$

sufficiently secure. Cases may, however, occur in which the restoration of piers is attained more quickly inside the lattice-work which may be left standing (*Plate XI., fig.* 1*b*) ; when, for example, all the transoms of a bay have been removed the bed of the obstacle is dry, &c.

Iron bridges which have been destroyed by blowing down, and in which a partial loosening, sinking, or straining of the iron-work has been effected, must be replaced by a temporary construction, which, if possible, should be formed exactly on the axis of the existing bridge ; or, if this is impracticable on account of the time which would be taken up in clearing away the damaged ironwork, a new axis must be taken. In the latter case, endeavours should be made to effect the junction with the open line by an arc of the greatest possible radius. For this purpose, either the old embankments must be widened by bridge-like constructions, or new embankments must be branched off on a curve.

The time which each of the foregoing restorations would require depends on their extent, the means at command, and on local circumstances. In general, it may be assumed that the restoration of pile-work of the simplest construction, together with the two adjoining bays, may be accomplished in from 10 to 12 hours, the materials being at hand, and other circumstances favourable.

CHAPTER II.

Permanent Way.

§ 20.

General Remarks.

The extent of the restoration of the permanent way must depend upon the time for which it will probably be required. The time, labour and materials at disposal will always decide in how far the work in the field can answer this requirement. But as it is most important to lay down the limits of simplicity of construction (which the temporary construction should not go beyond in time of war) without incurring any risk, each individual element of the permanent way will be treated of in the following pages with this view.

On the formation level only the under ballast *u* (*Plate XII., fig.* 1*b*) is necessary ; all the arrangements for drainage, as well as the intermediate packing, may be omitted.

The description of sleepers depends on the material at hand. If there is any choice, however, the preference should be given to wooden transverse sleepers ; if it is found necessary to make them, they may be given a trapezium-shaped section, and they will answer every purpose, their upper surfaces being trimmed, or merely having rests cut out for the rails.

Sleepers of different heights are no drawback, for the difference of level may be counteracted by the ballast. To facilitate the work, transverse sleepers may be laid 3 feet apart throughout (*Plate XII., fig.* 1); it is sufficient to have the sleepers (*a*) under the rail-joints, and one intermediate sleeper, the places of the others being taken by blocks of wood, the length of each of which is about one-third that of an ordinary transverse sleeper. As, however, this arrangement takes time, on account of the difficulty in laying and under-packing &c., it should only be adopted when the supply of timber is deficient. Longitudinal sleepers (*d*) should be used when possible instead (*Plate XII., figs.* 2 *and* 2*a*); this is most simply effected by using cross-sleepers (*e*), laid under the joints, and having grooves from 3″ to 4″ deep, to receive the longitudinal sleepers. These grooves are absolutely necessary.

The securing of the rails can only be simplified in the case of flat-bottomed ones; by doing away with the bed-plates, by reducing the fish-plate connections from 4 to 2 screw-bolts, and by diminishing the number of nails by one-half. If no fish-plates are to be had, the ordinary number of nails must be retained, and in this case joint-plates (*t*) are desirable (*Plate XII., fig.* 1).

This also applies when block-sleepers are used.

§ 21.

Laying the Permanent Way.

In the following pages, the proceeding which must be adopted when transverse sleepers are used will be more particularly described, as longitudinal sleepers are seldom found to occur, and the work in both cases is much the same.

(*a*) *With flat-bottomed* (*Vignoles'*) *rails*, the work to be done consists in:—

I. Levelling the ballast, laying out the centre line, and running levels.

II. Laying the transverse sleepers; in doing this, it is advantageous to use a lath with the distance apart of the sleepers marked upon it. At the same time, any bed-plates at hand might be laid down.

III. Laying the rails. As soon as about 24 sleepers have been placed, the rails are laid upon them as straight as possible, and separated by about the proper distance. When this has been done for about 3 rail-lengths, there begins,

IV. The screwing on of the fish-plates, for which 2 screw-bolts are used; the space between the rails at the joints, which, in permanent work, differs according to the temperature, here may in all cases be fixed at a quarter of an inch. To maintain this distance, small plates of wood are inserted. When 3 rails have been provided with fish-plates, there follows,

V. The fastening down of one length of rail. To facilitate this work, the respective sleepers are pressed against the rails with the help of a crowbar. As soon as the first rail is fastened to the sleepers, there comes,

VI. The fixing of the gauge, as well as the fastening down of the opposite length of rail, which is secured in the same way as the first, except that a clip-gauge is used. In order to get the rails exactly parallel, it is necessary to lay the clip-gauge over each sleeper. The nailing down of both rails is now continued in this order, until about 150 feet of the permanent way has been laid down; then follows,

VII. The setting of the rails horizontally. This work is accelerated, if only the extreme points of the length of line laid down are made horizontal by means of plummets and cross-sights, and the level adjusted, the intermediate portions being simply corrected by eye. As soon as the whole of the contemplated line is completed, comes

VIII. The adjustment of the entire length, i.e. bringing the track exactly into its true direction. This is done by means of crowbars. Curves require a widening of gauge and raising of the rails, the amount being governed by the radius of the curve. But as this radius is not always known, it suffices to give on an average an increased width of gauge of 1 inch, and to raise the outer rail from 3 to 4 inches above the inner rail. The short rails, which, in permanent work, are employed in these cases, may be entirely dispensed with in temporary restorations, and rails of the ordinary length can be used and cut down to the required length, without inconvenience, whether the joints of both rails are radial or not.*

Level crossings are formed in the usual manner. Wooden blocks are laid inside the rails, and about 2 inches from them, and nailed to the sleepers.

(*b*) *With chair-rails.*—In this case, the work is carried out as follows:—

I. Levelling of the ballast, &c., and } as with Vignoles' rails.
II. Placing the transverse sleepers }

III. Nailing down the chairs along one rail. As soon as the sleepers have been placed for about two rail-lengths, the chairs are secured along a single rail with only one nail.

* On an average the cutting of a rail takes 6 minutes.

IV. Laying down and keying up one rail. As soon as the chairs have been secured on one side for about 4 rail-lengths, the rails are placed in them, and keyed up. After this work is completed along the first rail, then begins,

V. The work along the opposite rail. The chairs are placed on the sleepers, the rails laid in the chairs, keyed up, and gauged, and each chair is fastened with 2 nails; after which the second nail may be driven for the corresponding chair on the opposite rail.

VI. Making the rails horizontal and level } As in the case of
VII. Bringing the line on to its proper axis } Vignoles' rails.

For curves and level crossings, what has been said under the head of Vignoles' rails is applicable in this case. If double chairs are to be had, they should be used for points.

(c) *With mixed rails, sleepers, &c.*—If the employment of mixed materials cannot be avoided, they must be suitably connected, and the difference in section at points of junction must be adjusted proportionately.

As soon as the permanent way has been laid in any one of the ways described, the line may be opened for traffic. The careful maintenance of the line (raising sunken sleepers, packing, tightening fish-plate screws, &c.) will vary in its necessity, according to the length of time occupied in restoration, for the quicker the work, the less solidly and securely will it have been executed in all its details.

§ 22.

Distribution of the Workmen, &c.

In a demolition, a division of workmen was taken to consist of 4 superintendents and 56 men; it now remains to show by examples how the same number of skilled workmen would be able to split up into parties in accord and with the detail of work given in the preceding paragraph, in order so to temporarily restore the permanent way, that no cessation of work occurs, and that the different parts of the work follow each other without interruption. It is assumed here that Vignoles' rails, with transverse sleepers, are used—for in all other cases the method of procedure is much the same—and that a sufficient number of labourers* is available for bringing up the materials. The workmen are distributed in the following manner:—

* For a division of workmen constituted as above, 46 labourers—30 for bringing up sleepers, and 16 for each rail—are, in most cases, sufficient.

No. of party.	Nature of work.	Number of		Tools.	Remarks.
		Superintendents.	Skilled workmen.		
I.	Levelling the ballast; laying out the axis of the line, and arranging the level.	1	6	Pickets, mallets, levels, plummets, cross-sights.	All the labourers, as well as all the working-parties are employed in levelling the ballast; for immediately on the completion of this work, all the rest may be begun.
II.	Laying the sleepers.	—	4	Graduated rods.	The labourers and workmen above named are employed as sleeper- and rail-bearers.
III.	Placing the rails.	—	4		
IV.	Screwing on the fish-plates.	—	8	8 screw-spanners, 8 hammers.	
V.	Boring and nailing for one rail.	—	8	4 drills, 4 mallets, 4 crowbars.	
VI.	Fixing the gauge; boring and nailing for the opposite rail.	1	10	4 drills, 4 mallets, 4 crowbars, 2 gauges.	
VII.	Making both rails horizontal.	1	8	2 levels, 2 plummets, 6 cross-sights, 4 crowbars, 4 cramp-irons.	
VIII.	Final adjustment of the whole line.	1	8	8 hand-spikes, 8 cramp-irons.	Assist No. VII. party, till their own work is ready for them.
	Total.	4	56		

In order to be able to judge approximately the capabilities of a working party of this description, the results arrived at during a change of the permanent way* on the Emperor Ferdinand's Northern Railway, are here given.

The portion of railway in question was about 820 feet long (38 rail-lengths, each 21 feet 6 inches), on which the 150 men employed effected the removal of the old permanent way, and the laying down of the new, within 5 hours.

Before any conclusion can be derived from this special and extraordinary performance, as to the laying down of a temporary line of railway, it must be taken into consideration, that before the commencement of work the packing ballast had been all removed, and that from each fish-plate, 2 bolts had been already taken out, and the new material distributed along the entire length; that further, after the completion of work, the ballast was not replaced, and the staff of workmen was very efficient.

Taking up the permanent way occupied about half an hour; there then remained $4\frac{1}{2}$ hours for laying down the line; 150 men therefore laid 38 rail-lengths in this time; and consequently, under similar circumstances, 56 men would be able to accomplish this amount in about 12 hours, and a length of about 620 feet (29 rail-lengths, each 21 feet 6 inches), taken as in the demolition (§ 8) in 9 hours, supposing that the labourers necessary for bringing up the material were available, the ballasting were made level before the commencement of work, &c.

If this rate of work is compared with that given in § 8, it appears that the permanent way on an equal length of line, with the same number of workmen, takes 9 times longer to restore than to demolish.

If there is a larger number of skilled workmen at disposal, existing circumstances will decide whether the surplus should be employed for strengthening the various parties of the divisions, or whether they should be united into separate divisions. In the latter case, work might be commenced at several points simultaneously.

* Carried out at Krzezowice, 5th September 1868: the condition was that the line should be ready within 5 hours.

CHAPTER III.

Stations, Rolling Stock, Signals.

§ 23.

General Remarks.

Where the permanent way has been destroyed in a station, the restoration of one through line and of a siding, and of the line connecting them must be first undertaken. Additional lines are restored later, and only in so far as traffic and other circumstances may demand. The connection between main lines may be effected for a time by means of switches only, as turn-tables and travelling-platforms cannot be quickly restored when the machinery has been destroyed.

As the rails are laid in stations in the same way as on the open line, the restoration of switches only will be treated of in the following pages.

§ 24.

Points or Switches.

In temporary points, the movable rail is usually the only kind of switch employed, if the stock of ordinary switch arrangements is exhausted.

Before laying the points, they must be, in all cases, traced out.

(*a*) *Tracing.*—If AA^1 and BB^1 (*Plate XII., fig.* 3) are two parallel lines to be connected and the end of the tongue is to be at I, this tongue $b\ a\ c$ will be placed at I with the side $b\ a$ in the direction of the inside rail, and the side $c\ a$ produced till it cuts the other rail $o\ p$ in d; the length $a\ d$ is then laid off along $d\ f$.

This gives the extremity f of the tongue. Inside the angle $f\ d\ a$, the curve $a\ f$ is drawn by eye, and the inner curve $h\ i$ parallel to it; by this means, one switch rail is determined. To lay out the connecting line, the side $a\ c$ of the tongue is produced towards the line $B\ B^1$; and parallel to it a line is drawn from the point h till it cuts the stock rail at a^1. By this means, the second a^1 is obtained, after which the laying out of the second switch rail $a^1 f^1$ may be affected similarly to that of $a\ f$.

If the points to be laid out are for an ordinary siding, instead of for a cross-over line, the proceeding is exactly similar to the former, except that there is no tongue required at the second crossing-point a^1 (*Plate XII., fig* 3).

Supposing that the place at which the points are to be is at II, for example; then in order to find the crossing point at I, a proceeding similar to the first given is adopted. The given tongue is first of all placed at the point II with one branch in the direction of the rail $o\ p$, the other branch is then produced till it cuts the rail *m n* in *x*; the distance *fx* is set off from *x* towards *a*, and this gives the crossing point *a*; the rest of the work is the same as in the first case.

If two similar tongues are not available, the simplest plan is, instead of using the second tongue, to lay down a movable rail D (*Plate XII., fig.* 5), which process will be fully described further on.

Finally, if no tongues are to be had, these must be replaced at the crossing points by movable rails. In order to lay down the switch, it is placed at an angle of 7° with the corresponding rail,* and the subsequent proceeding is as already described.

(*b*) *Method of procedure with ordinary materials.*—After laying out and tracing the points, the actual laying of them, as well as the placing of sleepers, is begun. The latter is commenced at those points at which support is absolutely necessary (*ex. gr.* tongue, crossing points, &c.), and so many intermediate sleepers are added as will bring their distance apart to 3 feet. At the point fixed by the tracing the tongue *a* (*Plate VII., figs.* 3 *and* 4) is now secured to the sleepers, and forms the starting point of the work; it is not finally fastened down until the line of rails has been placed in its exact position.

In order to obtain the proper position for the wing-rails, two straight laths, N and O (*Plate XII., fig.* 4), 2 inches wide, are laid crossing each other exactly at the point of the tongue, the wing-rails are then placed with their ends against the laths, and fastened down to the sleepers. Then the rails are laid with an increased width of gauge of 1 inch in the curve as far as *w* (*Plate VII., fig.* 3), the end of the points, so that the ends of all four rails fall together upon the centre of the sleeper *s*. The different rails must therefore be previously adjusted as regards length, or they must be cut; after which, the final fastening down and placing of the rails follow, as well as the fixing of the guard rails $c\,c^1$.

Simultaneously with the adjustment of the switch tongues, the laying of the points is carried on; it is done in the following order:—

I. Laying the sleepers $r\,r^1$ for the points. (*Plate VII., fig.* 3.)

II. Placing the stock rails *t* and *t*, and connecting them with the adjoining rails by means of fish-plates.

III. Pushing the switch-chairs under and screwing them to the stock rails and sleepers.

IV. Laying in and securing the tongues *z* and z^1.

V. Raising the sleepers supporting the points by means of crow-bars (which requires special attention), as well as the exact adjustment of these sleepers.

* The angle 7° corresponds to a radius of 620 feet; with this angle the breadth *a b* of the tongue, from out to out is $9\frac{1}{2}$ inches. (*Plate XII., fig.* 6.)

VI. Fixing the connecting and point rods v^1 and v.

VII. Fixing the arrangements A for altering the position of the points.

Two superintendents and about 28 men are reqnired, half for laying out the direction of the crossing, and half for the points. For carrying out the work, the same number of workmen is necessary.

(c) *Method of procedure for temporary work.*—The proceedings in this case are nearly the same as those given under (b). The same number of workmen is also requisite.

The ordinary constituent parts of a switch may be replaced by the following temporary arrangements.

Instead of the tongue a movable rail D (*Plate XII., fig.* 5) may be used. For this purpose, flat-bottomed rails may be used, or rails at least 9 feet in length. The movable rail is fastened at the centre *o*, and also at the ends, by spike-nails *h*.

To facilitate the sliding, ground-plates must be laid down under the rails, or in default of these, ordinary fish-plates *l*.

If tongues are available, but the necessary wing-rails belonging to them are wanting, the latter may be formed without much trouble by bending ordinary rails according to a pattern made of laths.

When no constituent part of ordinary switches is procurable, a special arrangement has to be followed.

Instead of the ground-plates *p* (*Plate VII., fig.* 1), ordinary fish-plates may be used. The fastening at the pivoting points A and A^1 is effected at the root, as in the case of tongues of the usual form.

When there is no arrangement for altering the position of the points, the switch rods must be bent, and fixed as required.

§ 25.

Water Supply.

When a station is undergoing restoration, the re-establishment of the arrangements for the supply of water must be commenced simultaneously with the laying of the rails. The locality, and nature of the destruction effected offer the best data for deciding whether the restoration of existing, or the construction of temporary arrangements, is the more advantageous.

(a) *Tanks.*—If these cannot be brought into communication with the new sources of water, they may generally be disregarded. But if the ground on which they stand happens to be favourable for conducting the water, they should certainly be turned to account.

Unimportant damage done to iron tanks may be remedied; thus, small holes in the sides or bottoms may be closed by thin plates of metal rivetted on, or merely by pieces of thin planking: splits and cracks must always be cemented or stopped up.

Where the damage is extensive, repairs of this description are very untrustworthy, and it will therefore be better to make use of a temporary construction, which may either be erected upon the tank, or may supply its place altogether. The simplest form of such construction consists of water butts or vats *a* (*Plate XII., fig.* 7), as nearly as possible of equal height, connected by pipes from 4 to 6 inches at least in diameter, and having a conduit pipe or hose *c* attached, of the same size.

If the buildings connected with the water supply are found demolished, or if it should be necessary to form at any place an elevated position for a tank, a strong combination of trestles will probably answer the purpose (*Plate XII., fig.* 8); but as their erection takes time, it will be found, in most cases, that the simplest method of supporting the planking is by means of stacks of wood. For this purpose, the transverse sleepers which may be in store, or easily obtained at any station, will be found useful (*Plate XII., fig.* 7).

This description of temporary tank, with water tubs, may be erected at any desired point, and even near or between the lines of rail; and in these latter cases, cocks are superfluous, for the filling of the tender may be effected directly from the tubs.

(*b*) *Supplying the tanks.*—In a restored or newly-erected tank, the means of supplying it with water must not be forgotten. Destroyed pipes, leading from sources of water at a higher situation than the tanks, may be replaced either by open ditches or wooden gutters (*Plate XII., fig.* 9).

From sources of water at a lower elevation, the water must be raised by means of either pumps or Archimedean screws.

Permanent pumps, usually worked by steam, would probably be rendered unserviceable by an adversary; the condition to which they have been reduced by the demolition will determine whether their restoration or the substitution of an extemporised arrangement in their place is the more advantageous. It is impossible here to lay down any rules; the decision will be always governed by the consideration of the means at disposal, and other circumstances. But it does not appear superfluous to mention, that when only the main rod, the cylinder, or the valve has been taken away, and the well and rising-pipe are left uninjured, it is for the most part more preferable to effect a restoration than to construct an improvised machine. If, however, the well or rising-pipe has been destroyed, and there is not another in store, the simplest means to adopt is to requisition a complete pump from the nearest village to supply the place of the other. But if the well has been rendered unserviceable, and there is no standing or running water in the neighbourhood, there is nothing else to be done but to clear it out and restore it to its original condition; or, at any rate, to make use of portable Schullhof wells, having first ascertained that the local nature of the soil offers no insuperable obstacle to the driving of the suction-tube of the pump, and that the depth to the water does not exceed the height of this tube (28 feet to 32 feet).

(*c*) *Feeding the Tender.*—For this purpose, water-cranes, usually placed at all watering stations, are very convenient, though not absolutely necessary; if they are found in an unserviceable state their restoration is unimportant, and still more so if the pipe connecting them with the reservoir is damaged. In this case the transition of the water from the reservoir wells or other source to the engines and tenders is most simply effected either by gutters, pipes, or india-rubber hose. The pipes, &c., should always be placed above ground, because they can then be more quickly laid down. The supports which may be necessary should be always 7 feet high at least.

§ 26.

Buildings, &c.

As the majority of the buildings which are found upon railway stations are only for greater convenience in administration, working, and the economical maintenance of *matériel*, they are not absolutely necessary for purposes of traffic. In cases of emergency, and especially in time of war, every thought of convenience and money is laid aside where time and labour can be saved. Hence it follows that everything superfluous may with care be avoided, and only what is necessary brought into a state of efficiency with all possible labour and means. Therefore, when stations are destroyed, no buildings except carriage sheds* should, as a rule, be restored. Care should be taken to construct ramps, and to place in order the necessary wells and drains.

There will be little difficulty in extemporising arrangements to take the place of the ordinary ramps. The masonry revetement may be replaced by planking *a* (*Plate XII.*, *fig.* 10), after which the ramp is formed with earth, or a staging of the simplest kind may be formed with planks.

The height of this ramp must be exactly that of the original; its breadth, however, may be reduced to a minimum; and in an extreme

* In the campaign of 1870-71 a goods shed, capable of containing 1,000 trucks, was erected at the Gonesse station. Large sheds were also built at the station at Mitry. The shape of such temporary sheds resembles that of large huts.

case, in place of the plateau, a very broad ascent (*b*), at least four times the base, may be formed. This last measure is, of course, only admissible when there is sufficient space, otherwise a plateau of the ordinary breadth must be made. Ramps of quite a temporary nature are shown in *Plate XII.*, *figs.* 11, 12; they are principally adapted for getting horses into the trucks.

§ 27.

Rolling Stock.

Locomotives and trucks which have been rendered unserviceable can only be repaired in permanent workshops; individual parts which are wanting may be replaced on the spot by special workmen. Extemporised arrangements are impossible.

§ 28.

Signals.

Directly the restoration of a railway is commenced, the visual signals must be erected, and the electric telegraph placed in operation along the whole line. Electric bell signals and ringing apparatus can be added afterwards.

PART III.

LAYING OUT NEW RAILWAYS.

§ 29.

Introductory Remarks.

In addition to the necessity of depriving an enemy of the use of railways, and of restoring lines which have been demolished, there may also arise the case of entirely new railways having to be laid down for military purposes. The necessity of constructing such railways may, for example, arise under the following circumstances.

(*a*) In order to connect existing railways, or contiguous stations.

(*b*) In order to connect fortified places or detached works, either with each other, or with existing railways.

(*c*) In order to bring rolling-stock from exposed stations into the interior of a fortress, or be able to transport it to a place outside the station to which no railway leads.

(*d*) In order to convert single lines into double ones, or merely to provide sidings.*

(*e*) In order to make stations more convenient for the requirements of a large traffic in troops, by increasing the number of lines.†

(*f*) In order to avoid portions of railway, which, from their situation are more especially exposed to destruction by an enemy, and to construct in their place a more sheltered line of communication.‡

(*g*) In order to avoid tunnels which have been destroyed, and which cannot be temporarily repaired. (*See* Nanteuil Tunnel, *Part II.*, § 16.)

* A case in point is the construction of a second line of rail between Winden and Wendenheim, and also between Weissenburg and Hagenau, by the Bavarian Field Railway Division, in the campaign of 1870–71.

† Rails were laid at the station of Gonesse, on the Oise, by the engineer Glaser, in the campaign of 1870–71.

‡ A line of this description was established between Remilly and Pont-à-Mousson by the German Field Railway Divisions 1 and 4, 1870.

(*h*) In order to establish direct lines of rail to points of strategical importance.*

The construction of railways of this description must naturally be completed in the shortest possible time. Hence it follows that it is not possible to observe all the rules of ordinary railway construction, but everything that is not absolutely indispensable must be omitted, and, as in the case of the restoration of a destroyed line, constructions of an extemporised nature must, as a rule, be only so far made use of when the safe working of the line is ensured for as long as may be required. Sufficient details for the execution of such constructions are given in Part II. Only the laying out of permanent lines will, therefore, be treated of here; it will, however, be shown (§ 36) how the works necessary for permanent lines may be simplified in the laying out of Field Railways.

By the laying out of a railway is understood, in the widest sense, all those preliminary operations which, executed in a definite order, facilitate the preparations for constructions, and after which the work may be undertaken on the ground.

These preliminaries consist of:—

I. General directions.
II. Rough survey and plan.
III. Detailed survey and plan.
IV. Taking cross sections.
V. Detail of levelling.
VI. Details of the whole project.

§ 30.

General Directions (Programm).

The general directions consist of a summary of all those points which serve as a guide to the engineer commanding in the execution of his designs. They embrace usually the following points:—

(*a*) *General statements as to the line.*—Whether there is to be a double or a single line of rail; whether the formation and main works are to be prepared for a double line, the permanent way material of one line of way being reserved until it is wanted; and whether the main works are to be so constructed in the first instance that, in case a second line is required, the existing constructions (bridges, viaducts, and buildings) may be equally made use of.

(*b*) *Gauge.*—Whether any other than the ordinary is to be adopted; and if so, what it is.

(*c*) *Dimensions of the rolling stock.*—Whether the ordinary headway

* Construction of the Bruchthal-Germersheim Railway by the Bavarian Field Railway Division in 1870.

and width in the clear are to be allowed to bridges, or whether special dimensions are to be adopted.

(*d*) *Breadth of embankments at the top*—what dimensions they are to have.

(*e*) *Maximum length of trains*—which will run on the line; this decides the length of stations and sidings, as well as the position of water-cranes, stores, &c.; it influences, too, the gradients and radii of the curves.

(*f*) *Maximum slopes.*—Accurate data on this point for the different conditions of ground.

(*g*) *Minimum radius of curvature.*

(*h*) *Nature of road-crossings*—whether level, or by means of bridges; the former, especially in towns, should be avoided as far as is practicable.

(*i*) *Situation*—distance and list of stations.

(*k*) *Nature of constructions in general*—and directions for the building of constructive works, whether they are to be of masonry, wood, or stone.

§ 31.

Rough Survey and Plan.

After it has been resolved to connect two places or points by a railway, those preliminaries must, in all cases, be gone through, which will decide which is the best line to be chosen, as well with regard to expense as traffic.

These preliminaries become especially important, when the two points to be connected are separated by water-sheds.

The first data for these preliminaries are to be found in any good map, for a single glance at it is sufficient to show approximately the extent and nature of the work to be undertaken. The most important elevations, their distances apart, the existing communications, the river-basins and valleys, will usually indicate the general direction which the line will have to follow.

This preliminary plan, when fixed upon, will be shown on the map in question. Together with this, the peculiarities of the neighbourhood must be carefully examined, and at the same time individual heights should be obtained barometrically. This examination gives a series of points with their relative attitudes, and shows those places where a double line of way is practicable, where stations may be placed, and of what size they should be, where depôts may be formed, and their approximate extent.

Guided by these results, and by the general directions, designs for possible lines may be fixed upon, and from among these the most suitable is chosen.

§ 32.

Detailed Survey and Plan.

As soon as the rough survey has been prepared, it is divided into sections (Betriebstrecken), the length of which depends partly on the rise and fall of the ground, and partly on circumstances connected with the works considered expedient. On these sections, the detailed survey is commenced. This embraces all those proceedings which are necessary before the central line of the railway can be laid down. They are :

(*a*) *The reconnaissance of the country.*—By this is understood the survey and inspection of the country in all directions, in order that a general clear idea of the local peculiarities may be obtained. As exact a description as possible of the local geological condition of the ground should be given, as this has a considerable influence, as well on the nature of the work as on the obtaining of building material. As in such a general inspection, borings and sinkings are out of place, as taking up too much time, and as leading, in only very few cases, to correct results, and being of little use in a general survey, the characteristic indications at hand must form, as far as possible, a sufficient guide. From the nature of the vegetation it may be gathered whether the soil is mainly moist or dry, whether vegetable soil, clay, sand, or rock is present, and from this, whether land-slips or other dangers are probable ; existing quarries, deep wells, and precipices, which show the nature of the beds of stone, are good guides. Similarly, the shape, nature, and size of river-beds should be observed, because from this the rapidity of the stream, in the event of the water rising, may be determined.

Not less important are the statements of the inhabitants in the neighbourhood of the different sections ; they at least suggest in what direction investigations should be made as to the water-level floods, the temporary changes in the course of streams in heavy rain ; the more or less frequent occurrence of such rain ; whether streams ever become dried up, and want of water is to be feared, what places are exposed to accumulations of snow, or sand, &c.

In this examination also the price of labour and material should be inquired into, as well as the possibility of bringing up a large number of workmen. Technically speaking, such a reconnaissance serves also as a rough design ; that is to say, the direction of the line in the section under consideration may be approximately laid down from observation.

(*b*) *Preliminary levelling* (*flying levels*).—As soon as the *reconnaissance* is completed, the actual technical work of levelling may be begun. The object of this preliminary levelling is to obtain the difference of level between the two ends of the line, as well as the heights of a series of intermediate points lying in and near the general direction of the line as decided by the *reconnaissance*. It should give a representation of the ground according to the heights of various points; on this account it is advantageous, before the commencement of the actual levelling, to fix on as many points as possible, such as blocks of stone, corner-stones of buildings, tops of rocks, &c.; on these the heights obtained by the levelling staff may be permanently shown. The actual levelling will be commenced from a point which either falls within the final plan, or is at least very near it. The heights are not to be taken too great, or accurate results will not be obtained; no point, therefore, will be levelled to which is so far distant from the position of the instrument that $\frac{1}{1000}$ Klafter* can no longer be read on the levelling staff with any degree of certainty.

As the process of levelling is here supposed to be understood, it need only be mentioned that in this levelling must be noted the height of the water at the time, the zero points of any water-gauges that may be found, the marks of the highest water level and inundations discovered during the *reconnaissance*, as well as all those points which generally may serve to modify the heights along the line of railway. (*Plate XIII., fig.* 1.)

The results obtained from the levelling must be graphically shown on a section.† On this, the longitudinal section of the contemplated line, observing the conditions laid down in the general directions, and the adjustment of the *remblai* and *déblai*, will be approximately shown. It is, therefore, important to observe at what points the laying out of the line requires special attention, and also whether the direction given can be adhered to or not. In the first case, all preliminary work connected with the levelling for the laying out of the line is completed as soon as the direction of the latter seems in consequence of the ground or other causes to be unalterable. But if another direction for the line appears possible, the development of the design (as indicated under *d* in this section) will probably show which is the most favourable trace. In the second case, however, the development of the line, which must always precede the geo-

* A Klafter is 6·2226 English feet, and is represented by the sign °.

† Brouillon tables are of great practical use in representing these sections; on these, spaces of 50° in length and 1° in height are marked by vertical and horizontal lines. The vertical scale (1″ to 8°) is taken at ten times the horizontal.

metrical work, must be undertaken in order to ascertain and to mark out the central line of the railway.

(*c*) *The triangulation.*—The extent of this plan must be as limited as possible; it will only be increased at places where the line has to be carried through hilly and mountainous country. This must show the principal elevations in the ground, the highest as well as the lowest, and also all those points where there are any striking changes between the relative heights or slopes; the object of this survey is to obtain an accurate plan of the levels of the country. The fixed points determined in the preliminary levelling may here be made use of with advantage. The method of procedure, both for triangulating and for representing the levels, is supposed to be understood. The work is considerably shortened if correct maps are to be had, the levels and fixed points being merely inserted upon them.

(*d*) *Fixing the line by means of trial sections.*—By this expression is understood the determination of the line of intersection of the plane of levels (fixed by the preliminary levelling) with the ground. This is shown on the ground by pickets, and laid down on a plan. The way in which this is done, with the help of a level and of a longitudinal section obtained from the preliminary levelling, will be afterwards shown by means of an example. As a starting-point for the work only such points on the line should be chosen from which it is not possible that the final line will greatly deviate, and which are therefore fixed by local circumstances; or in which slight displacements can produce no important alterations in the line. Such points are: the bridges of a water-shed, or those situations in the direction of the railway which are closely bounded by hills, rocks, ponds, marshes, canals, or other artificial constructions. How far apart and how numerous the trial sections should be, depends on the nature of the ground.

The following example shows the method of taking trial sections: *Plate XIII., fig.* 2, is a contoured plan, the vertical interval between the contours being one Klafter (6 feet)—the longest contour is 51 Klafter, and the highest 56 Klafter—above a given datum. A, $\frac{VN}{1}$, $\frac{VN}{2}$, $\frac{VN}{3}$, ... are points obtained in the preliminary levelling (*Plate XIII., fig.* 2*a*, is a longitudinal section of this levelling), the line of levels falling 1 in 110, by which, at the point A, $\left(\frac{VN}{0}\right)$ the level is found to be 6 feet below the level of the ground. Now in order to obtain a more favourable slope for the final line, a lesser slope is tried, 1 in 130 for example. Let the point A be the starting-point, the ground-height and levelled height of which are known from the preliminary levelling. Under the corresponding heads in the development table are first noted the ground-height and levelled height of the point A, together with the difference between the two; thus, under the head 'Level rises'—'falls'—will be entered the slope (here in the case taken there is a fall of 1 in 130). At the point A, a picket with a sharp point is driven into the ground, and marked $\frac{EL}{0}$, and entered in the table as 0*; the level is then placed with its axis exactly over the point A $\left(\frac{EL}{0}\right)$, and made horizontal; the height of the instrument (say 0·697°) is measured, and entered under the head 'Back reading' in the table. The height of the line of sight of the instrument above the datum is now calculated by adding the height of the instrument to the height of the point A (0·697° + 56° = 56·697°); the result is entered under the head 'Height of line of sight.' If now the levelled height be subtracted from the height of the line of sight, the height of the line of sight above the plane of levels is obtained (56·697°—55° = 1·697°). The person with the levelling-staff places himself as nearly as possible in the direction of the trace, at a distance depending on the formation of the ground, and gives the distance in paces to the engineer. The latter then calculates the height of the line of sight above the line of levels. Suppose this distance is 75 paces =30°; then the difference of height for the slope 1 in 130 is 0·2307°; this, added to the height of the plane of the line of sight above the line of levels at the point A, gives 0·2307° + 1·697° = 1·9277°, or 1·928°. At this height the levelling-staff must be set, and it must then be moved to the right or left (keeping as nearly as possible the same distance off—30°), until the line of sight is directly upon it. As soon as this occurs, a picket $\frac{EL}{1}$ is driven into the ground, the levelling-staff is again held up resting on the top of the picket, and the level directed upon it; the height thus read on the levelling-staff is entered under the head 'Forward reading' for the point $\frac{EL}{1}$ (*ex. gr.* 1·925°). This height, being subtracted from the height of the line of sight at A (56·697), gives the exact height of the top of the picket at the point $\frac{EL}{1}$, which is noted under the head 'Height of picket' (56·697° − 1·925° = 54·772°). Meanwhile the distance of the point $\frac{EL}{0}$ from the point $\frac{EL}{1}$ is accurately measured with the chain, and entered under the head 'Intermediate Distance' (*ex. gr.* 29·8°). If this

* To fix this point with greater security, a second picket is usually driven into the ground from 3″ to 4″ distant from it.

measured distance (29·8°) does not agree with the paced distance (30°), the point $\frac{EL}{1}$ does not lie exactly in the plane of the levels. If now it is calculated how great the difference of height between the points $\frac{EL}{0}$ and $\frac{EL}{1}$ along the levelled plane should be for the accurately measured distance (for 29·8° with a fall of 1 in 130, this is 0·229°), and this is subtracted from the levelled height at the point $\frac{EL}{0}$ (55 − 0·229° = 54·771°), the thus found height for $\frac{EL}{1}$ (54·771) being entered under the head 'Height of the line of levels,' the difference between this calculated line of levels and the height of the picket at the point $\frac{EL}{1}$ is shown (54·772° − 54·771° = 0·001°); the result is then entered under the head 'Difference,' having a + sign if the height of the picket is greater, and a − sign if it is less than the calculated height of the line of levels in this case; therefore the difference is + 0·001°. The instrument is now removed from the point $\frac{EL}{0}$ to $\frac{EL}{1}$, placed exactly over it and made horizontal; the next point $\left(\frac{EL}{2}\right)$ is then determined in the manner just explained,* and so on throughout the whole length of the line completed. It should here be remarked that the difference entered in the table between any two consecutive points may be checked by adding the positive difference to the height of the line of sight, and subtracting the negative from it; by this proceeding the transmission of any small and unavoidable error is prevented.

In addition to the accurate determination of the difference of levels of the various points, the angles which the lines joining the pickets make with one another must be measured; this is done simultaneously with the determination of the points. When the third point $\frac{EL}{2}$ is fixed, the angle at $\frac{EL}{1}$ is measured from this point, and the result entered in the table.†

* In the table it is assumed, for the discovery of the point $\frac{EL}{2}$, that the distance paced and afterwards measured with the chain from $\frac{EL}{1}$ to $\frac{EL}{2}$ amounts to 50°, and that the height of the picket agrees with that of the line of levels.

† Railway engineers are accustomed, in order to prevent errors, to measure all angles, without exception, from left to right; thus the telescope is first brought into

Under the head 'Remarks' in the table, such points are to be noted, as where a line passes near houses, or where, owing to the ground, it could not be laid out without great expense, &c.

When the whole line has been marked out on the ground by means of pickets, and plotted on paper, this broken line, at present useless for the axis of the railway, must be converted into one which is in keeping with the requirements necessary for curves, and which adapts itself as advantageously as possible to the local formation of the ground, with regard to the due equalisation of *remblai* and *déblai*.* (*Plate XIII., fig.* 9.)

The line thus obtained (central line of the railway) will naturally be shorter than the originally plotted line, and will therefore have also a greater slope. But in order that the gradient may in no place exceed the levelled line obtained from the preliminary levelling, a smaller slope is chosen for the determination of the originally plotted line.

The final line consequently, which lies between this line and that obtained from the preliminary levelling, will everywhere remain within the gradient limit, and at the worst can only reach the maximum of the preliminary levelling. From experiment it has been found that the above condition will be complied with, if

the slope of	1 in 100	is decreased to	1 in 130
,,	1 in 150	,,	1 in 175
,,	1 in 200	,,	1 in 220
,,	1 in 300	,,	1 in 315
,,	1 in 500	,,	1 in 510.

the direction of the back station $\frac{EL}{0}$, and the reading on the vernier in this position of the instrument (*ex. gr.* 126° 47′) is entered in the table under the head 'Back angle;' the level is then turned round from left to right until the line of sight is directed upon the staff at the picket $\frac{EL}{2}$. The angle thus given (295° 1′) is entered in the column 'Forward angle;' then, to calculate the proper angle to place in the column 'Angle,' we have $295° 1' - 126° 47' = 168° 14'$.

It often occurs that the vernier of the level passes over the division 360°: in this case, in order to obtain the right angle, 360° must be added to the forward angle, and the back angle subtracted from the sum (*ex. gr.*):—

Back angle = 247° 34′.
Forward angle = 73° 13′.
Angle = $(73° 13' + 360°) - 247° 34' = 185° 39'$.

* For laying out the curves, arcs of different radii are formed of strong cardboard, and on the same scale as the detailed survey. These are fitted on to the plotted line, and moved and adjusted until a continuous line formed of straight and curved portions is found, answering to the above conditions.

§ 33.

Marking out the Central Line of the Railway.

That direction for the railway which has been decided on as the most suitable after a series of trials is now laid out on the ground; the straight lines are transferred and produced until they cut each other, by which are obtained the cutting or angle points, which are marked by poles from 9 feet to 12 feet high. In order to distinguish these angle-point poles, they are provided at the top with two small boards, from 12″ to 15″ long, and 6″ broad, nailed together, and crossing each other at right angles; on these may be marked the number of the angle-point, the size of the angle, or other facts. If on very long straight lines intermediate points are necessary, these are also marked by poles, which, in order to distinguish them from the angle-point poles, have only one board attached. The angle-points (Nos. 1 and 2, *Plate XIII., fig.* 9) are of use, not only for marking out the central line of the railway, but are also of great importance during the whole work of construction; they are the only means by which accuracy is obtained, and they must, therefore, be well secured in the recognised manner.

When the angle-points are fixed, the angles are accurately measured, noted, and the arcs laid down.* The last operation consists in determining points on the curve,† and in laying out the intermediate arcs necessary for the construction.

(*a*) *Marking out the points on the curve.*—If AB and CB (*Plate XIII., fig.* 3) are the straight lines, cutting each other in the point B, n the measured angle, R=DO the known radius of the arc, the point D the commencement of the arc, F its end, and E its middle point, then

$$\text{the angle } m = 180^\circ - n,$$

$$BD = BF = R \tan \frac{m}{2},$$

and,

$$BE = R \left\{ \sec \frac{m}{2} - 1 \right\}.$$

Now in order to lay out these three points D, F, and E upon the ground, the instrument is placed over the angle-point B, and by observing the lines BA, BC, and the line BO, which bisects the angle n, the distances BD, BF, and BE, determined by the above calculation,

* For this purpose Kröhnke's *Handbook for Laying Out Curves* is recommended by railway engineers as being very useful, as it gives constant factors (tangent lengths, arc-distances, &c.) arranged in a tabular form.

† In railway plans these guiding points are designated as BA (commencement), BM (middle), and BE (end).

are plotted; thus the points D, F, and E are obtained, and are marked by pickets. With very long curves it is advantageous to fix more points, *ex. gr.* J and K; these are found as follows:—

$$DG = HF = R \tan \frac{m}{4},$$

$$BG = BD - DG = R\left\{\tan \frac{m}{2} - \tan \frac{m}{4}\right\} = BH,$$

$$GJ = HK - R\left\{\sec \frac{m}{4} - 1\right\}.$$

When these lengths are calculated, the points G and H are immediately fixed by marking out the commencement and end of the curve (D and F) upon the ground. Both these points G and H are then regarded as angle-points, over which the instrument is placed set at the angle

$$DGO = FHO = \left\{90° - \frac{m°}{4}\right\}.$$

By observing along GO or HO, the calculated distance GJ and HK can be plotted.

If the angle-point is inaccessible, or is so situated that no angular or other measurements can be taken from it, the points on the curve must be fixed by the following method.

Two points, G and H (*Plate XIII., fig.* 4), are taken in the lines AB and BC respectively, the distance GH is measured, and also the angles a and b; then in the triangle GBH, the angle c may be calculated, as well as the two sides BG, BH, and the lengths GD and HF.

Thus,

$$\text{the angle } c = 180° - (a + b),$$

$$OD = OF = R,$$

$$BG = \frac{GH \sin a}{\sin c}.$$

$$BH = \frac{GH \sin b}{\sin c}.$$

Again the angle $m = 180° -$ the angle c,

$$BD = BF = R \tan \frac{m}{2},$$

the distance of D, the commencement of the curve from the auxiliary point G:

$$GD = BD - BG = R \tan \frac{m}{2} - \frac{GH \sin b}{\sin c},$$

and the distance of the end of the curve F from the auxiliary point H:

$$HF = BF - BH = R \tan \frac{m}{2} - \frac{GH \sin b}{\sin c}.$$

This distance, being set off from the auxiliary points G and H along the corresponding lines, gives the points of the commencement and end of the curve.

If the auxiliary line cannot be taken from the angle-point, two auxiliary points N and M are taken, in the prolongation of the lines AB and CB, the line MN is measured, as well as the angles p and q; the angle c, and the sides MB and BN, are then calculated in the triangle MBN. Thus

$$\text{the angle } c = 180° - (p + q),$$

$$MB = \frac{MN \sin q}{\sin c},$$

$$BN = \frac{MN \sin p}{\sin c};$$

the centre-point angle

$$m = 180° - c,$$

and the line

$$BD = BF = R \tan \frac{m}{2}.$$

Again,

$$ND = NB + BD,$$

and

$$MF = MB + BF.$$

In the triangle MNF the sides MN and MF, and the included angle p, are known; in the triangle NMD, the sides MN and ND, with the included angle q, are known; therefore in the first triangle, the angle w, and in the second, the angle v can be calculated; thus

$$\tan w = \frac{MF \sin p}{MN - MF \cos p},$$

and

$$\tan v = \frac{ND \sin q}{MN - ND \cos q}.$$

If these two angles are calculated, they can be laid out with the instrument at the points M and N of the auxiliary line; the points D and F give the commencement and end of the curve.

(*b*) *Marking out the intermediate points on the curve.*—For this purpose the following methods are usually employed.

I. The method already described, viz. by a continued bisection of the angle at the centre-point, until the necessary number of intermediate points has been obtained.

II. By means of abscissæ and ordinates.

If AB and BC (*Plate XIII., fig.* 5) are the directions of the straight portions of the line; A the commencement of the curve; AHC the curve which has to be laid out; $AO = R$, its radius; $AD = a$, an abscissa taken; and $DE = x$, the co-ordinate to be calculated: then

$$x = R \mp \sqrt{R^2 - a^2};$$

or,

$$x = \frac{a^2}{2R}, \text{ nearly.}$$

With this formula, the curve may be laid out from any tangent whatever.

III. By means of a theodolite. If A (*Plate XIII., fig.* 6) is the commencement of the curve to be laid out, $AO=R$ the radius; AC the tangents (the directions of the straight portions of the line), AB, BD, DE, EF, &c., chords of known and equal length; then the angles CAB, BAD, DAE, EAF are equal, and each is equal to $\frac{AOB}{2}$;

or,

$$n = \frac{m}{2}.$$

Each chord

$$= 2R \sin \frac{m}{2} = 2R \sin n,$$

and

$$\sin n = \frac{AB}{2R}.$$

From this formula, AB and R being known, the angle n may be found by the help of a trigonometrical table, and the curve may then be easily laid out.

Now in order to lay out a curve according to this method on the ground, a theodolite is placed over the starting-point of the curve, and directed along the tangent AC; it is then turned round to the amount of the calculated angle n, the length of the chord (10° at most) taken is plotted along this line of sight, and thus the first point B of the curve is found. The instrument is then turned round to the angle $2n$, the length of the chord (10°) is measured on from the first point B of the curve, the instrument is accurately directed along AD, and thus the second point D of the curve is found. In this way, as many points of the curve as possible are observed from one station.

If the instrument has to be moved, it is placed over the last point determined in the curve F, directed on its former position A, and from this along the direction of the tangent FN; the latter is obtained by turning the instrument round through an angle the same number of times n as there have been points fixed on the curve from the first position (*ex. gr.*, here through an angle $4n$); the other points are then found in the manner already described.

IV. The curve may be laid out by trial; from the point A (*Plate XIII., fig.* 7), any length A*b* is taken, and from *b* a perpendicular of any length is let fall, and the point 1 is marked by a picket. To determine a second point on the curve, the line A1*c* is drawn, and 1*c* is made equal to A*b*, and the perpendicular *c*2 equal to *b*1; then 2 is the point required. The line 12*d* is now drawn, 2*d* is made equal to 1*c*, and *d*3 equal to *c*2; thus a third point of the curve is obtained, and so on, till the point B is reached. With a little practice, the proper length at which to set off the perpendicular may be obtained at the second trial. In very thickly-wooded districts, this method of laying out a curve is often the only one possible.

§ 34.

Subdividing for Cross Sections, and Levelling the Line.

By subdividing is understood the splitting up of the final trace for the line into equal sections, usually about 250 feet or 300 feet long, and which are called station-lengths, profile-lengths, or profiles.

The points of division are marked in the field by pickets, which are numbered consecutively with Roman figures, and have the corresponding picket-level marked. At the same time, all points on the line at which the ground changes its slope, or at which work has to be executed, must be marked with pickets. These points are marked with consecutive letters of the alphabet, and in such a way that after each profile-picket a fresh alphabet begins. Cross sections are now taken at all the points indicated by the subdividing. (*Plate XIII., figs.* 8 *and* 9.)

As soon as a sufficiently long portion of the line has been subdivided, and the pickets showing the changes of slope in the ground, &c. are marked, the detailed levelling in the exact direction of the centre of the line is taken. Properly speaking, this is only to limit the points fixed in the subdivisions. From the results of this levelling the longitudinal sections and the cross sections are drawn, and lastly the correct and final levelling for the line to be constructed is laid out on the plan.*

* The choice of the scale is entirely at the discretion of the engineer. The scale for the verticals is generally ten times that for the horizontals. The size of the scale should, as a rule, be such that heights up to about one-twentieth Klafter may be measured off.

The following scales have been found suitable :—

For longitudinal sections :—	Horizontal	1″ =	250 feet.
,, ,,	Verticals	1″ =	25 feet.
For cross sections	. . . .	1″ =	12 feet.

After the completion of these preliminaries, the entire line is inspected, and all those points at which constructions—such as culverts, bridges, viaducts, arrangements for crossing of roads or rivers, retaining walls, &c. have to be executed, are shown with their principal dimensions on the longitudinal section; those points, too, must be ascertained at which it is proposed to erect signal boxes.

§ 35.

Working-drawings, &c.

The last operation before the commencement of the actual work of construction, and at the same time the most difficult, requiring, as it does, perfect knowledge in almost every particular of engineering work, is the execution of the working-drawings, &c. Generally a design to be worked out must embrace—

I. Complete longitudinal and transverse sections.

II. A map of the neighbourhood with the direction of the line shown upon it.

III. Fully worked out designs, with estimates of cost for the permanent way, formation, and all such works as bridges, viaducts, retaining-walls, tunnels, &c. and masonry work.*

IV. Calculations of the earth-and-rock-movement with cost.

V. Accurate specifications for the rolling stock, and arrangements for the working of the line, such as signals, telegraphic communication, the building of offices, waiting rooms, workshops, &c.

VI. A calculation of the amount of compensation for ground and houses, as well as the insurance against fire of all inflammable, covered-in buildings situated within a distance of 60 yards from the centre of the line.

VII. Estimate for various works, such as drainage, fences, planting, &c.

VIII. Estimate of interest on the capital, cost of management, and other outlays during the construction.

§ 36.

Special Proceedings in Laying out Field Railways.

Field railways, as a rule, are only of small extent. In laying them out, all difficult work is to be avoided as much as possible, such as the formation of deep or long cuttings, throwing up high embankments, blasting of rocks, large constructive works, &c.; marshes and ponds should be avoided.

* Masonry work is generally shown, like the cross sections, on the scale of 1 inch to 12 feet.

With regard to the gradients, one will generally be guided by the description of rolling stock to be used on the line, but it will generally be found that the gradients on existing lines may be exceeded; thus, on level ground, the gradient may be 1 in 120; in hilly country, 1 in 80; and in mountainous country, 1 in 40. It is the same in the case of the radii of curvature, which may be taken at $284{\cdot}5^{m}$ on level ground, $189{\cdot}6^{m}$ in hilly country, and $158{\cdot}7^{m}$ in mountainous country.

If the locomotives at disposal are of suitable construction, the radius of curvature may be diminished on all ground to $151{\cdot}73^{m}$, and likewise short lengths, i.e. up to 1000 yards, may have a gradient of 1 in 60, and longer ones a gradient of 1 in 70; it is, however, advisable, where possible, not to have the smallest radii of curvature and the steepest gradients occurring simultaneously at one and the same place.

In all cases, even in the most favourable, the following works must be completed before the commencement of the actual construction, viz.:

I. The reconnaissance of the line;

II. The setting out of the final centre line of the railway; and

III. Its subdivision and levelling.