THE ROYAL ENGINEERS JOURNAL.

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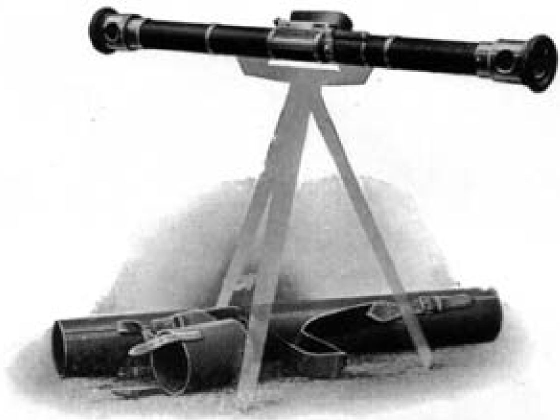


BARR AND STROUD RANGEFINDER, F.Q. TYPE, "INFANTRY," 1 METRE BASE.
FOR USE WITH INFANTRY, CAVALRY, AND MACHINE GUNS.

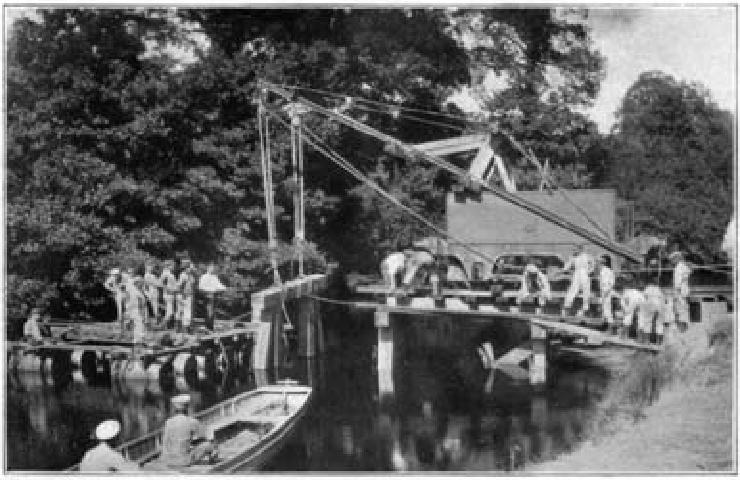
This Rangefinder is constructed largely of Aluminium and is covered externally with brown leather. It is fitted with pads on the ends to prevent damage by rough handling. It is supplied in a strong leather case, as shown, fitted with a shoulder-strap.

The tripod shown in the illustration is not supplied with the instrument, as the Rangefinder is so constructed that it can be used with ease without a stand.

Approximate uncertainty of observation:—

5 yards at 1,000 yards.
40 yards at 3,000 yards.
170 yards at 6,000 yards.

Barr & Stroud Rangefinder


Laying Trestles with an Improvised Crane.


The Bridge completed.

HEAVY TRESTLE BRIDGING ON THE RIVER MONNOW AT PWLHOLM

A HEAVY TRESTLE RAILWAY BRIDGE

CONSTRUCTED BY THE ROYAL MONMOUTHSHIRE R.E. (MILITIA).

By LT.-COL. C. M. CROMPTON-ROBERTS, R.M.R.E. (M.).

As it had been decided that the two Railway Companies (Nos. 3 and 5) of the Royal Monmouthshire Royal Engineers (Militia) were to spend the last fortnight of their 1906 annual training at Whitehill, Hants, for work on the Woolmer Instructional Railway under the direction of Major F. Fuller, R.E., O.C. Railway Companies, R.E., the officers commanding these two Companies, Lieut.-Colonel C. M. Crompton-Roberts and Lieut.-Colonel H. E. M. Lindsay, in making out the annual programme of fieldworks to be carried out by them, determined to devote rather more time than usual, while at Monmouth, to the construction of heavy trestle bridging.

Accordingly stock was taken of all the available timber and other materials at Pwlholm, and Lieuts. J. H. Bradney (No. 5 Co.) and F. B. Jarvis (No. 3 Co.) were directed to take sections of the River Monnow at "Bridgehead," and to send in a report as to the feasibility of constructing a Heavy Trestle Railway Bridge at this spot.

They made three sections and reported the distance from bank to bank at the most favourable site to be 100 feet, the banks to be shelving steeply and muddy, showing a certain amount of probable sinkage; but that the main portion of the river bed was fairly level with a hard gravelly bottom, and that the greatest depth of water was 11 ft. 4 in.

It was then decided to construct a heavy trestle railway bridge of 10 bays of 10 ft. each, with eleven trestles including the two shore transoms, for which baulks 12 in. × 12 in. were used. Detail drawings of the bridge and of each trestle were got out, from the information furnished in the report, while the Railway Companies were at Ross for their annual musketry course.

The trestles next the shore on either side of the river were placed on footings of courses of sandbags; it was found practicable to construct these footings as the water was comparatively shallow at these points.

It was decided to rest the seven centre trestles with their groundsills on the river bottom, as, owing to the depth of water, it was not considered necessary and scarcely feasible to construct crib piers in these positions.

To enable these heavy trestles to be placed in position more easily, a locomotive tender (on charge as "wood and water wagon, one") was converted into a species of travelling crane (under the supervision of Major Talbot, R.G.A. (M.), who was attached to No. 3 Company during the training) by having two 30-ft. bull-headed rails fixed on either side of the tender, so as to project some distance in front of it, and duly stayed with wire, etc. The tank of the tender was then filled with about 5 tons of water to keep it steady, and to prevent its kicking up behind when the weight of the heavy trestles was taken on the projecting crane tackle.

The last heavy trestle was placed in position and the superstructure of the bridge completed on August 8th when the R.M.R.E. (M.) were inspected on the works by H.R.H. the Duke of Connaught.

It is scarcely necessary to add that on service the construction of a heavy trestle railway bridge would scarcely be attempted in such a depth of water; but a deviation of some considerable length of railway line would preferably be laid to some shallower portion of the river. Such a trestle bridge was constructed at this particular spot at Pwlholm, because it is only at this spot that any land is owned by the War Department on the other side of the river.

The height of water in the River Monnow varied from day to day during the construction of the bridge, as much as two feet variation being recorded, and this was mainly due to the intermittent working of the turbines of the Monmouth Corporation Electric Light Station situated about half a mile below Pwlholm.

The tallest trestle was 16 feet in height. 12 in. × 12 in. baulks were used for the legs, topsills, and groundsills of all the trestles, 12 in. × 6 in. for the side stays, and 12 in. × 3 in. for the back stays from trestle to trestle. The back stays of each trestle were fixed with coachscrews to the inside of the bottom of the legs, at the required angle, while the trestle was suspended from the crane and before it was lowered into position on the river bottom; the tops of the back stays were fixed to the previous trestle after being placed into position. The tops of the trestles were further stayed by 30 foot rails laid flat and spiked down to the topsill of each trestle.

It was originally intended to lay as road bearers two baulks of 12 in. × 12 in., one on the top of the other on each side of bridge; but it was found that there was not sufficient timber available for this, and so one baulk only was used. This was found to be quite strong enough for the load the bridge would have to carry, the trestles being only 10 feet apart. Sleepers and rails were laid on the road bearers. The gauge was the standard gauge, 4 ft. 8½ in.

The locomotive weighed 14 tons, on a 4-ft. 6-in. wheel base. The tender weighed 7 tons; and, when converted into a crane, carried 5 tons water and (say) 1 ton superstructure of crane, making 13 tons in all on a 7-ft. 6-in. wheel base.

The locomotive, tender, rails, and sleepers originally formed part of the railway in use at Suakin in 1885.

A barrel-pier raft, which had been constructed by our Bridging Companies, was utilized to assist in placing the trestles in position.

THE ORGANISATION OF FIELD BATTALIONS IN THE ROYAL ENGINEERS.

By BT. COL. A. E. SANDBACH, D.S.O., R.E.

"*I hear that the proposition to form the Royal Engineers into battalions has been shelved for the present.*"—(Extract from Army News Letter, dated London 27th April, published at Allahabad in "*The Pioneer*" of 17th May, 1906.)

The above paragraph, which shows that the subject has been recently under consideration, induces me to put forward, for criticism by my brother officers, some ideas for the organisation of Field Battalions of Royal Engineers. These ideas have been formed after an experience of 27 years' service, at home and abroad, chiefly spent in regimental soldiering.

In the first place, two axioms may be stated, the truth of which can scarcely be denied. One is, that in any force in the field, whether it be a Brigade or a Division of all arms or an Army Corps, success is more likely to be attained if the component units, battalions, batteries, companies, have been accustomed to work and train together in peace time with their Generals and Staff Officers than if the units are thrown together at the last moment on the outbreak of war.

The other axiom, which in my opinion is equally indisputable, is that, although men are enlisted in the Royal Engineers for general service in the Corps, it is undesirable, *if* other provision can be made, to retain only one list for the promotion of non-commissioned officers in all Field and Fortress Companies, whether that list be kept, as formerly, in the office of the D.A.A.G., R.E., at the Horse Guards or, as at present, in the office of the Colonel in charge of R.E. Records at Chatham.

To ensure then that men, officers, and staff are trained together in peace time, I would allot to Field Battalions headquarter stations as under* :—

Headquarters,	1st	Field Battalion,	Aldershot.
„	2nd	„	Tidworth (Southern Command).
„	3rd	„	Curragh (Irish Command).
„	4th	„	Colchester (Eastern Command).

* In the three other home commands, we must rely for field engineer duties on the Monmouthshire and Anglesea Militia Engineers in the Western Command and on the several Corps of Volunteer Engineers in the Northern and Scottish Commands.

Each Field Battalion should consist of the requisite number of Field, Bridging,* and Telegraph Companies, allotted according to our organization to one Army Corps; that is, so far as those units are already in existence, I do not propose any increase of establishment. The Field Troops should be linked to one of the Field Battalions for their supply of men, according to the peace station of the Cavalry Brigade to which they are allotted. As the Balloon Companies and Balloon School have so recently been placed under the command of a Lieutenant-Colonel, they might for the present remain outside any Field Battalion organisation.

Seeing that the Royal Engineers are not territorialised, recruits on enlistment from all parts of the United Kingdom must be sent in the first instance to our R.E. Training Depôt at Chatham, or wherever else it may in the future be located; but on the conclusion of their recruits' course they should be posted to Field Battalions by the O.C. Depôt, and to their different Companies in each Field Battalion by the O.C. Battalion. The Riding Master from Aldershot should go round to make periodical inspections in regard to the training of remounts and system of equitation; but the rough riders in each battalion should train their own remounts at battalion headquarters.

The annual inspections by the Inspector of Royal Engineers would ensure that, although quartered at different stations, one system is followed in Pontoon and Telegraph training.

Nor need the organisation of Field Battalions, if carried out, interfere with the present system of drafting men from Field Companies at home to serve with Fortress Companies abroad. So long as that system is adhered to, it will be just as easy to call upon the O.C. Field Battalion to furnish a draft of so many men as to call for them from particular companies.

To ensure still further that peace conditions are, as far as possible assimilated to war requirements, it should be provided that the Lieutenant-Colonel Commanding the Field Battalion will command the Corps Engineers on service.†

Under the above system, the Lieutenant-Colonel Commanding a Field Battalion would be given, both in peace and war, a definite position and responsibility, which up to the present not even the Officer Commanding Troops and Companies, R.E., at Aldershot, is entrusted with.

There is no intention in the suggestion put forward to curtail in the smallest degree the initiative of the Company Commanders. The Company will still remain the unit. The Major in command of the

* This article was written in India in June last.

† Compare the system in the Russian Army—page 367, *R.E. Journal* for May, 1906.

Company will still train his men according to his own lights. But there will be between him and the higher authorities in the Corps, *in peace time*, a sympathetic Battalion Commander, who will back him up in all he undertakes and who will assist him rather than interfere with him; whilst, *on field service*, he can rely on the same Battalion Commander, whom he knows, being at headquarters in command of the Corps Engineers and ever ready, so far as possibly, to supply his needs in men and stores.

If it is considered advisable that the men should not pass the whole of their colour service in one permanent station, companies can be moved in relief, say from Bulford to Devonport, or from Shorncliffe to Colchester, or from Borden Camp to Aldershot, without any change of Battalion Headquarters. In this way some saving may be looked for in the present cost of periodical reliefs.

It will be sufficiently evident from the foregoing paragraphs that, if a Field Battalion organisation is adopted, it is intended that the promotion lists for non-commissioned officers shall be kept at Battalion Headquarters, and that promotions shall be made on the recommendations of Company Commanders by Officers Commanding Battalions. In this way an *esprit de corps* would soon be fostered in Battalions.

The promotions made would of course be notified in the usual casualty report for record in the office of the Colonel in charge of R.E. Records.

As regards expense, if there is no increase in personnel beyond existing units, the only actual expense involved would be that of the usual allowance of 2s. 6d. per day for three extra Adjutants, since the Officers Commanding Field Battalions might be provided for by a re-adjustment of the duties of C.R.E. Bulford, C.R.E. Curragh, and C.R.E. Colchester. This expense again would be partly met by a reduction in the cost of reliefs, as shown above.

The advantages claimed for the system advocated are:—

(1) Peace and war conditions are assimilated in organisation.
(2) Training is carried out, within the Field Battalion, of all its units, under the Generals and Staff Officers who would lead them in war.

It is neither necessary nor desirable to bring in at once a cut-and-dried battalion system throughout the whole Corps. The experiment might be first tried with the field units; if it proved a success, it would be easy to extend the principle to the other branches of the Corps.

DEFENSIVE POSITIONS ON OPEN GROUND.

By MAJOR A. T. MOORE, R.E.

CAPT. SWINTON'S article in the September number opens a question that merits the fullest consideration by all arms, and especially by engineers, viz., the effect of modern Q.F. artillery on the method of occupying a position on open ground, particularly when that ground is convex.

If the decisive factor is the fire of the attacking artillery, then it must necessarily follow that the guiding principle is to obtain immunity from that fire; the acquirement of a really good field of fire for the main firing line of the infantry must take second place.

So far as the main firing line of the infantry is concerned there appear to be three alternatives when taking up a position on open convex ground:—

(*a*). To place this line forward on a 'military crest,' in order to obtain a good field of fire over the immediate foreground. This results in the practical impossibility of reinforcing the line at the critical moment or of withdrawing the defenders in case of necessity.

(*b*). To place it further back on a 'covering crest,' *i.e.*, on some secondary crest in rear of the military one, or on the rear edge if a plateau, or even on the reverse slope. In this case, even if a sufficiently good field of fire, 250 yds. to 400 yds., is obtained, the task of the enemy in procuring a footing on the position and in maintaining himself there may be facilitated.

(*c*). To ignore the high ground altogether, and to place the main firing line at the foot of the front slope.

But, in occupying any position there are two other factors, in addition to that of the attacking artillery, viz., the strategical object (*i.e.*, whether the position is intended for temporary defence by a rear guard, or for stubborn and protracted defence as part of an extensive position covering some vital point), and the time and materials available for the construction of artificial cover.

There are thus three considerations affecting the solution of the problem:—

1. The strategical object.
2. The positions available for the enemy's artillery.
3. The facilities for constructing artificial cover.

As regards the third, it is obvious that in a rear-guard action there will probably be insufficient time for head cover and certainly insufficient time for over-head cover.

Just before reading Capt. Swinton's article, the present writer was confronted with a problem that was very much a case in point,—a rear-guard problem on ground represented by the accompanying map.

The ground is perhaps especially peculiar, though typical of 'down' country. Below the 50′ contour it is practically dead level, but much intersected by water ditches; between the 50′ and 200′ contours are large cultivated fields with low hedges, with a few coppices and parks; above the 200′ contour is open grass land. The peculiar shape of the hills is well shown on the section A-B, wherein it is seen that there are several 'military crests'; but that from any line behind the highest 'military crest' a great deal of the ground directly in front of the foot of the slope (1,000 yds. in the section given) is unseen from that line. From a defensive aspect the difficulty is greatly increased by the fact that the soil above the 200′ contour is chalk. As regards the attacking artillery there is the ominous menace of Asham Hill; this hill is within long range field artillery fire of the whole of the position and within effective range of the southern end; it also commands the whole position, which therefore has no 'covering crest' (as defined by General Langlois) with respect to this hill.

As the problem was one open to considerable argument and, possibly, to more than one good solution, I have thought it might interest readers of this Journal; and the details are accordingly given below as Problem A.

Since the method of occupying North and South Hills for protracted defence as part of an extensive position would perhaps be very different, the question of occupying them under such a condition is propounded as Problem B.

Readers are invited to air their views on both Problems.

Solutions will be submitted to three referees; those considered best will be published as far as possible *in extenso* and the remainder will be described.*

* Officers may obtain spare copies of the map from the Editor.

PROBLEM A.

A RED Force has been defeated by a BLUE Force at AYLESFORD (east of the map) and is retiring to GRINSTEAD (west of the map).

You are in command of the RED Rear Guard, consisting of

2 Companies M.I.,
1 Battery R.F.A.,
2 Battalions Infantry,

with orders to cover the passage of the Baggage and Supply Columns of the Main Body over the River ARUN and through the steep narrow streets of KINGSTON.

On arriving at 12 noon on 4th July at the NORTH HILL—SOUTH HILL position, you receive information that (*a*) the Baggage and Supply Columns will not be clear of KINGSTON until 6 p.m. the same day, and (*b*) the Enemy's Advanced Guard (strength unknown) reached LAUGHTON (12 miles east of WAKELANDS) at 12 noon the same day.

As Commander of the RED Rear Guard

(*a*) Explain how you would dispose your troops,
and (*b*) Describe the entrenchments you would make.

PROBLEM B.

NORTH HILL—SOUTH HILL forms the N.E. Section of a continuous line of defence, which has been taken up to protect at all costs a large Supply Depôt at rail-head.

You are in command of this Section and a force consisting of

1 Battery R.F.A.,
2 5" Howitzers,
2 Sections, Field Company R.E.,
1 Brigade Infantry,

and have a week to make your preparations. Civilian labour and tools are procurable.

As Commander of the Section

(*a*) Explain how you would dispose your troops,
(*b*) Describe the entrenchments you would make,
and (*c*) Give a rough working table for labour and materials.

Note.—As the map is limited the effect of the adjoining Sections of defence must be ignored. It will simplify matters to assume that the strength of the enemy is equal in artillery and double in infantry, and that the Rivers Arun and Stone are non-existent; but Asham Hill remains as a thorn in the side of the defenders.

PROTECTION OF TIMBER AGAINST WHITE ANTS.

THE following is an extract from a letter despatched to General Officers Commanding Stations Abroad by the Director of Fortifications and Works, who has kindly communicated a copy for publication in this Journal :—

It has been found that a treatment of "blue oil" protects wood against the attack of white ants besides acting as a preservative generally.

2. The specification governing the supply of "blue oil" to the War Department contains the following provisions :—

(*a*). The oil to be a shale product.
(*b*). Its specific gravity (at 60° F.) to be 0·873 to 0·883.
(*c*). Its flashing temperature to be not lower than 275 F. (close test).

3. An extract from the Report of a Trial of the "blue oil" treatment of wood as a protective measure against the white ant is appended hereto.

> "The boxes treated with blue oil have been placed during the wet season in various positions in the open, and there is no sign of their having been attacked by white ants, although a quantity of timber in close proximity to them was considerably damaged by these insects.
>
> The blue oil has also acted as a preservative to the wood, which shows no signs of rotting from the extreme damp to which it has been exposed.
>
> One of the ammunition boxes was lent to the O.C. West African Frontier Force, for trial in his magazine, which is infested with white ants. On returning the box, he stated—
>
> 'Herewith ammunition box and a piece of wood. Both have been lying in the same place ever since you lent me the box. When I placed the box in my magazine, this wood and the ground in close proximity was swarming with white ants. I placed the box under the wood, between it and the ground. Since then the ants have disappeared from the wood and the ground referred to ; the box is not touched.' "

Notes on Some New Methods of LIGHT FIREPROOF CONSTRUCTION.

By Lieut. P. O. G. Usborne, R.E.

The progress of an ordinary fire, breaking out in a small domestic building, is usually as follows:—The curtains, or some inflammable object of that sort, flare up; surrounding objects get alight; and then the window goes, providing a first-class chimney flue to draw the flame up to the next storey. The ceiling is the next to catch, providing still better draught; and when finally the roof falls in, the flames shoot up to the sky, and the fate of that house is sealed.

About 27% of fires are known to be caused by faulty constructional details, such as timber housed into chimney flues, etc.

But besides giving proper attention to such details, there are two main ways in which the architect can strive to prevent fire and minimise its evil effects: namely, by allowing as little inflammable material as possible to be used in the construction of a building; and by cutting up the house into compartments of more or less fire-resisting material, which act like water-tight compartments and so isolate a fire and prevent its spreading.

It is impossible to dispense altogether with inflammable material, at any rate in domestic houses: wall paper, curtains, furniture, wood floors and roofs must remain. But there is no reason for continuing to use wood lath and plaster partitions on timber studding, etc., which are insanitary as well as dangerous.

In cutting a building up into compartments, the first object usually sought after is a fire-resisting floor; this enables a good deal of salvage work to be done by the Fire Brigade before the floor yields or the building gets beyond help. The next thing in order of importance is the staircase. After that come stout strong windows and fire-resisting partitions and doors.

The most efficient fireproof floor is one of reinforced concrete; any combination of a non-combustible material and steel is good, provided that the steel is efficiently covered from the fire, protected from the temperature, and allowed to expand at its ends. Such floors (of which there are many patent kinds) are, however, more suitable for a warehouse than a living room; they are expensive, where there is no heavy load to be carried, and entail heavier walls than would otherwise be required.

For partitions, brickwork is very excellent, being strong, sound-proof, and fairly fireproof. But it takes up a deal of valuable room in small quarters, and in upper stories it requires a wall or steel joist immediately underneath it, owing to its weight, and thereby greatly restricts design. Moreover, in a serious fire, bad, half-burnt bricks, such as are used for partition walls, will burn and finally collapse, wrecking the house.

To supply all these wants many patents have been placed on the market. All that have any real fire-resisting merit have been tested at the testing station of the British Fire Prevention Committee. The results of these tests are printed and published, though no opinion is expressed by the Committee. The tests are the severest and most impartial that exist, and serve as a standard of comparison between various similar articles.

Some of these materials will be enumerated here, with their cost, and instances given of their trial and use, taken as far as possible from War Department work.

EXPANDED METAL.

(Manufacturers:—The Expanded Metal Company, 39, Upper Thames Street, London, E.C. See *Figs.* 1 and 2).

The most universal application of this material is for reinforcing concrete. It is made from plates of very mild steel, which are slit and stretched by machinery to a diamond pattern, of any mesh required, varying from $\frac{3}{8}$ in. to 6 in.

As a substitute for wood lathing, it is very efficient, both in ceilings and partitions.

$\frac{3}{8}$-in. to $\frac{1}{2}$-in. mesh is the most suitable for use with plaster; with wood joists, ceiling fillets must be used.

In *ceilings*, it costs about 3s. per yard super finished complete, as compared with 2s. for ordinary lath and plaster work. It is, however, strong and sound-proof, and makes the floor to which it is fixed fire-resisting when combined with plaster. It is rather difficult to fix, owing to a tendency to buckle about; but it provides an excellent key for the plaster, which will never crack or sag.

When used in *partitions*, the Expanded Metal may be fixed on timber studding, making a hollow wall, or on steel vertical bars, about $\frac{1}{4}$ in. diameter, called tension bars. These are fixed about 12 in. apart, being hooked into eyes screwed into a joist of the ceiling and the floor of the room. Partitions can be made single or double, with one or two rows of tension bars accordingly. In the former case, the expanded metal sheets are threaded in and out of the vertical tension bars, so that they interlace in plan, and the plaster is applied from both sides at once.

Such a partition is not more than 2 in. thick finished, giving a great saving in space over a 9-in. wall. It is very light, requiring nothing to support it underneath beyond the ordinary floor. It is sound-proof, fire-resisting, clean, cheap, and will not crack. The makers claim that it is equally useful for external walls.

It has been found in some W.D. buildings that the metal is liable to crack when exposed to any considerable range of temperature, but this could be met by using cement mortar, which has exactly the same coefficient of expansion as steel.

The Expanded Metal Company's tender for the construction of a Warrant Officers' Quarter came to just about the same as the cost of a brick building.

Another application of this material is the *protection and concealment of steel columns or joists* wherever they may require it. For instance, deep steel I joists, which project through the underside of a concrete floor, may be wrapped in expanded metal, bent by hand, and this will form a key for encasing them in concrete.

Expanded Metal, in sheets from 3 ft. to 5 ft. wide is recommended by the firm for *light fencing*, costing from 1s. 6d. to 2s. 3d. per yard run (3-in. mesh).

For this purpose it can be obtained in sheets already painted. In a fence of this material surrounding a new gun emplacement at Shoeburyness it was found that the arrises of the metal were left so sharp by the slotting and pulling out machinery in the manufacture that to touch them meant certain bloodshed.

This material has been used in ceilings throughout the New Naval Hospital at Chatham, almost entirely in some office buildings at the Gun Wharf, Chatham, and very largely in some New Soldiers' Blocks and the New Hospital at Gibraltar.

For Barrack Rooms admirable ceilings can be made, without much increase of cost, which will stand any amount of vibration without need of repair; and in partitions it is fireproof and clean without being more expensive than brick.

Its application in civil practice is very large, especially for suburban dwelling houses, bungalows, artisans' cottages, etc.; also in reinforced concrete construction.

The best covering for use on expanded metal, except in ceilings, is Syrapite (see page 194), but ordinary plaster will do. If Syrapite be used, the first coat should have some hair mixed with it, to stiffen the plaster while setting.

In *Fig.* 1 additional protection is secured for the column by encasing it first in Slag Wool or Silicate of Cotton. The former material is absolutely incombustible, and an excellent non-conductor of sound or heat. Experiments to test its non-conducting powers were made at the testing station of the B.F.P.C. Two cantilever steel joists, one end fixed in a wall, were cased in slag wool and concrete respectively, and subjected to very high temperatures until the concrete-covered beam failed. The results seem to indicate that slag wool was about three times as good a covering for steel as concrete.

Slag wool can be got in several forms :—Loose, like cotton wool, it is useful for packing as in *Fig.* 1 ; pressed into rectangular slabs, 1 in. to 1½ in. thick and up to 1 yard super, with a layer of wire netting incorporated in it, it is known as Wire Net Felting. In this latter form it is used for pugging in floors, between the joists, making the floor sound-proof and also fire-resisting. When used in this manner, it is far more sanitary than the old accepted pugging of mud, chopped straw, and various rubbish.

It can also be obtained in the form of a tape, ½ in. to 2 in. thick, and from 4 in. to 12 in. wide, with a backing of canvas or other similar material. In this form it is used for wrapping round steam pipes, hot water pipes, etc., and is very efficient. It does not appear to disintegrate and fly about, as some jacketing materials do.

It is impossible to give prices here, as this material is made in so many forms and sizes, but it is in every way excellent for its purposes. It is obtainable from F. Jones, Ryland Rd., Kentish Town, London.

FIBROUS PLASTER.

There is one other kind of cheap and efficient fire-resisting ceiling, consisting of fibrous plaster slabs.

Fibrous Plaster is made of some composition of gypsum, cast into slabs, varying from ½ in. to ¾ in. thick, either on a fibrous backing, or with a patent non-combustible fibre incorporated in them. These slabs vary in size (for ceilings usually 4 ft. by 2 ft.). They are nailed direct to the underneath of ceiling joists with zinc nails ; they can be made at the works, or *in situ*, by the Company. They have a roughened surface underneath to give a key to a setting coat, which completes the ceiling and hides the joints. They are fire-resisting and cheaper than expanded metal in ceilings. There is also a saving in workmen's time in fixing.

It seems probable, however, that they will show cracks along the joints in time. Some ceilings have been made of this material in the Married Soldiers' Quarters at Tidworth Barracks. They seem very successful and cheap.

Special moulded cornices of excellent design can be got in lengths from 3 ft. to 6 ft. ; these can be fixed to any ceiling, and are much lighter and cheaper than an ordinary run cornice. In the New Electrical School at Chatham, such cornices have been fixed to the underside of reinforced concrete floors by nailing direct to floor and joints made good.

It should be remembered in all fireproof construction that the advantages gained by use of non-combustible materials are all thrown away, unless the joints between the ceiling and walls be most carefully and thoroughly closed up.

Uralite in ceilings is also an excellent fire-resister. Its more usual application is, however, as a roofing material, and it will be dealt with later on.

The above are briefly the best methods of rendering a simple timber floor fire-resisting. If the flames cannot get round the joists, or at their ends through cracks in the junction to the wall, actual high temperatures will take a long time to do any damage. It is surprising how long a good sound timber floor will stand under these circumstances.

There is nothing very new to be said about staircases, and the main principles remain as cogent as ever.

Stone cracks up and disintegrates under heat, and is therefore bad. An instance is on record of a stone staircase becoming heated, owing to a fire in a small timber cupboard underneath it, and collapsing entirely when a single bucket of water was thrown over it. Stone should therefore be avoided, unless supported solid underneath. Iron or steel staircases are good, if provided outside the building; but if inside, they crack up and collapse under a high temperature and subsequent streams of cold water.

Concrete made with stone as an aggregate is bad. Limestone is the worst of all materials in this respect, as it calcines in the heat. Breeze concrete is good, if made with proper "breeze" (the incombustible residue from a blast furnace). Otherwise it will burn.

Reinforced concrete is about the best fire-resister for stairs as well as for floors. It is however inapplicable to domestic houses, and the best staircase for such buildings is one of good strong hard wood. Such a structure will stand for a long time, especially if protected underneath by a plaster and expanded metal ceiling.

PATENT BLOCKS.

The favourite kind of light fire-resisting partition for modern cheap cottage and similar construction is one made of patent blocks. There are many kinds of these on the market, and it is impossible to say that any one is better than any other.

A few of the best known are mentioned here.

Mack Slabs (J. A. King & Co., 181, Queen Victoria Street, London, E.C.); *Fram Slabs*; *Arc Slabs*; etc.

These slabs are all very much alike, and are made of some composition of gypsum.

For erection in partitions they are used in slabs about 6 ft. by 1 ft. by 2 in. or 2¾ in. thick. Each slab has some sort of groove or slot on its edges to act as a key; the exact shape of this key varies in the different patents and really constitutes the only difference between them. This groove is run or grouted with strong plaster when the blocks are being erected. The face of the blocks is roughened to take a coat of rendering consisting of Portland cement and sand, or the face may be left smooth for distempering. This is not a very good finish. The partition complete is from 3 in. to 4 in. thick.

The walls can be erected by unskilled labour, provided that a little common sense is available. Full directions are given in the Companies' circulars.

Such partitions are very useful for hospital or cubicle partitions, exhibition walling, cutting up existing large rooms, partitions in small quarters, offices, bathrooms, lavatories, etc. They are used by civilian architects in nearly all flats, offices, and hotels in London.

The cost of Mack Slabs is 5s. per yard super erected and rendered, not including cutting as for doors, etc.

The cost of a 9-in. brick wall rendered both sides is 8s. 3d. per yard super, not including doors, etc.

Mack Slabs, perhaps the most frequently used of them all, are shown in *Fig.* 3. They are quite strong, and sound-proof. They can be cut with a saw and will take nails. They have recently been used at Shorncliffe for lavatory partitions, with success and a saving of money and space.

SPANDREL WALLS.

(Manufacturers:—F.P. and Spandrel Wall Coy., 92, Tooley Street, London Bridge, S.E.).

Another light wall can be made of bricks, 3 in. thick, with hoop iron reinforcement. This type of wall is known as a Spandrel Wall. It is virtually reinforced brickwork, consisting of brick nogging (brick on edge) laid with mortar in the usual way, but with iron straps laid along the joints, both vertically and horizontally, at 18-in. intervals (*Fig.* 4). There is no particular virtue in the bond shown in the figure.

The chief advantages of this construction are that the wall, although only 3 in. thick, is extremely strong, and equal to an ordinary 9-in. wall, or even, as claimed by the patentees, to a 14-in. wall. For erection some scaffolding is required, viz., vertical posts at about 10-ft. intervals, and a top horizontal rail to hold the iron straps during construction. The vertical posts are subsequently taken out.

Such walls are well adapted for light boundary walls, for any semi-permanent buildings, for office partitions, etc.

They are frequently used by the engineers of the German Army. They have been used in Woolwich Arsenal recently for some offices and store sheds, and have proved both cheap and satisfactory.

SYRAPITE.

The cost is 6s. 6d. per yard super, plastered both sides and finished in fine cement (London Dist.). Buildings on this system work out about the same as for galvanized corrugated iron. Skilled labour is not necessary. Foundations are not required all along the foot of a boundary wall, for the wall, being reinforced, will stand of its own accord, acting as a bridge from one foundation pier to another, spaced say 10-ft. apart for a 3-in. wall. The main objection is that these walls will not carry much weight.

For joints in patent block partitions described above Keene's cement is best. But for all other plaster work on walls, cornices, etc., syrapite is recommended. (Gypsum Mines, Ltd., Robertsbridge, Sussex).

This is a quick-setting plaster supplied ready for use at 31s. per ton (delivered). It is applied in the same manner as ordinary plaster, and the setting coat can be laid on as soon as the first is dry.

By this means a wall can be finished complete with two coats in one day. This is of great advantage to contractors and builders, who can now let their gang of plasterers finish a house outright at one go, instead of having to wait an indefinite number of days as formerly.

When set syrapite is as hard as Keene's cement. It therefore requires no addition at angles and arrises, and remains uninjured through very rough wear. Two-coat work executed with syrapite is equivalent to ordinary three-coat work; and while architects are now specifying its use almost universally, a very much more potent recommendation is to be found in the fact that contractors are always willing to substitute 2 coats syrapite for 3 coats plaster, without extra charge in their contracts.

Syrapite costs more, supplied only, but this is all saved in labour.

Cost per yd. super for walls (1 syrapite, 3 sand), 1s. 3d., fixed.

Cost per yd. super for ceilings or walls on laths (2 syrapite and 1 sand), 1s. 8d., fixed.

At the same time, while belauding the various qualities of syrapite and pointing out its wave of popularity, it must be added that, when set, it is so hard that it conducts sound when used in ceilings, etc. It forms in fact a very perfect sound-transmitter and sounding-board; its use in ceilings under single *un*pugged floors, or in thin partitions between married soldiers' quarters, should not be permitted.

When it is used in vertical work on Expanded Metal, or in ceilings, hair must be mixed with it, to keep it from running, for it is very "short" in composition.

According to contractors' experience, it works out to about the same cost as lime plaster. Sawn laths can be used instead of cleft.

It is therefore desirable to specify it for all new buildings or repairs, at any rate in England.

URALITE.

There is one other class of materials that must be touched on. This class includes :—

Uralite (British Uralite Co., Ltd., 59, Cannon Street, London, E.C.).

Kentish Slabs (Kent Slab Co., 59, Cannon Street, London, E.C.).

Fibro Cement (Fibro Cement Co., Norfolk House, Lawrence Pountney Hill, E.C.).

Eternit (G. R. Speaker & Co., 29, Mincing Lane, E.C.).

Externit, etc., and many other similar forms.

The main advantage of these patents is not so much their fire-resisting qualities as their lightness, toughness, and apparent durability. They have not of course been long enough on the market for this latter quality to be adequately tested. These materials are made in slabs, ranging from $\frac{1}{16}$ in. to $\frac{1}{2}$ in. thick, about 6 ft. by 3 ft. maximum size, and are intended for fixing on walls and roofs.

Uralite, as a wall material, is fixed to timber studding covered with $\frac{3}{4}$-in. rough boarding. It must be thoroughly nailed along all edges, and the junction of adjacent sheets is covered with a slip fillet of uralite fixed behind it on the studding. It can be sawn or cut to sizes required, wherever trimming is necessary.

Experience shows that the nailing must be most thorough to prevent warping. This method of fixing (shown in *Fig.* 5) is generally known as the Colonial method.

The sheets can also be fixed with an overlap like weather boarding.

Uralite is suitable for the walls of temporary buildings, light sheds, etc., and makes a fair substitute for galvanized corrugated iron in this respect.

As a roofing material it can be fixed in two ways. Colonial roofing is laid in a similar manner to the walling (see *Fig.* 6). It is cheaper than the other method, but not so ornamental.

When laid as slates, Uralite is bought in rectangular slabs for use as in *Fig.* 7, or of diamond shape for use as in *Fig.* 8. Uralite slates do not crack or break up; they lie very close, giving no entrance to wind; and being extremely light (1·2 lbs. per ft. super) they allow of great saving in roof timbers. They are ornamental, and can be got in various shades of colour or thickness. $\frac{1}{16}$ in. to $\frac{3}{8}$ in. is suitable thickness for roofing.

The Uralite Company also manufacture *Kentish Slabs*, which are very similar, but are slightly better adapted for external walls. They are fixed to studding, weathered like slates or tiles, and do not require boarding underneath; in this case they would be used $\frac{3}{16}$ in. to $\frac{1}{2}$ in. thick.

A tender was asked for for the construction and erection complete of a Range Warden's Quarters—to be of Kentish Slab throughout, except Uralite ceilings; and the price named was £217, as compared with £200 for a galvanised corrugated iron building. Such a house would certainly be more sightly than one of iron.

A shed was constructed recently at Devonport with walls and roof of Uralite. It was in a position exposed to fire from bullets, splinters, etc., and was close to the sea front. The following is a

summary of a report on this shed by the C.R.E. Devonport :—
"Apparently Uralite is

(1) Not affected by changes of temperature.
(2) Unaffected by salt sea air.
(3) Fireproof.
(4) More sound-proof and less liable to splinter than galvanized corrugated iron.
(5) Very easy to work.
(6) Lighter than galvanized corrugated iron, but less rigid.
(7) Not very durable.

A backing of deal boards is always required; and the material should be securely and amply nailed to prevent buckling.

The cost for hut type of building is not large :—

Galvanized corrugated iron = $4\frac{1}{2}$d. foot cube.
Uralite = $5\frac{1}{2}$d. foot cube."

Uralite has been used for doors of fire-proof rooms, non-conducting screens behind stoves, iron chimney pipes, etc., for the construction of the bodies of light tradesman's vans, for some W.D. vehicles, for safes, and for a large variety of other purposes.

It appears cheap and durable, and requires very little skilled labour to fix, provided no jointing is necessary. Its most practical and useful application seems to be in roofs of all kinds, other than those of a very high-class and permanent character.

Eternit, a similar material, is fixed in almost identically the same manner. A new bicycle shed, close to the R.E. Institute, has been roofed with this material. The appearance is pleasing and it is easy to fix. The slabs or slates, $15\frac{1}{2}$ in. square, are fixed in a diamond pattern, and ridge capping of the same material finishes the roof. The slabs do not crack, or break in transit, but the ridging appears to be almost as brittle as tiles. The overhang of the eaves at the ends of the roof must be adjusted to suit the diagonal dimension of an *Eternit* slate. Battens are all that is required to carry the slates.

The most noteworthy point about this roof is its cost. Although the advertised cost of roofing is 28s. per square, measured net, yet the actual tender by the Eternit Company for the roof in question ($7\frac{1}{4}$ squares) was £15, which was subsequently reduced to £12 12s.: this works out to 36s. (approx.) per square. The ridge capping and the tilting slates for eaves course were included in this and the roof area to be covered was a small one, but the discrepancy in price is large. On the whole Eternit works out a good deal more expensive than Uralite.

The other patent materials mentioned above are very similar. Of them all Uralite seems to be the most popular and the cheapest, with the exception of *Fibro Cement*. This latter easily beats the others in question of cost. It consists of slabs, as before, made of some patent composition. Its cost in roofs is 29s. to 32s., complete, per square; it is advertised at 22s. per square net.

It has been used in various W.D. buildings, as at Waltham Abbey for lining danger rooms. It was fixed as covering for a store shed at Aldershot and favourably reported on by the C.R.E. there. It was found cheap and light, did not warp, and was apparently easy to fix, durable, and quite satisfactory for its purpose.

All these materials have the advantage over galvanized corrugated iron of being less noisy in rain and better non-conductors of heat, although not so simple to fix, nor quite so cheap.

AN ACCOUNT OF THE SCIENTIFIC WORK OF THE SURVEY OF INDIA,

*AND A COMPARISON OF ITS PROGRESS WITH THAT OF FOREIGN SURVEYS.**

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THE CONNECTION BETWEEN SCIENCE AND SURVEYS.

THE scientific work of the Survey of India consists of:—

Principal Triangulation.
Levelling Operations.
Astronomical Operations.
Pendulum Operations.
Tidal Operations.
Magnetic Survey.
Solar Photography.

I beg that I may show in a few brief notes the uses and aims of the scientific work of the survey, but before doing so I wish to premise that no distinction can properly be drawn between scientific and practical work. Many operations conducted on scientific principles have immediate practical uses: they may in fact be likened to the exploitation of visible outcrops of coal. Others are more experimental, and may be likened to borings for invisible coal, believed to exist at certain depths. Others again are speculative, and may be likened to deeper borings, made to ascertain the strata in the crust, with the hope that something valuable, perhaps coal or iron or gold, may turn up. But whether such operations are practical or experimental or speculative, they all have the same twofold purpose, viz., the acquisition of information and the rendering of that information useful. Almost all the scientific operations of the Survey of India will be found to fall into the first category, and to possess immediate practical uses.

Before I enter into the details of the different scientific operations of the Survey of India I may perhaps be allowed to refer briefly to the general question of the connection between science and surveys in modern times.

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The primary object of a national survey is the making of maps, and all operations are subordinated to that end. It is for topographical purposes that a national survey measures its allotted portion of the earth's surface. If, however, these measurements be subsequently combined with astronomical determinations, the size and shape of the earth can be deduced, and a knowledge of this size and shape is essential to astronomers, geographers, geologists, and meteorologists, all of whom look to surveys for information.

The great accuracy of modern astronomical observations for stellar and lunar parallax, and the difficulty which mathematicians still experience in predicting exactly the places of the moon and the planets, are constantly necessitating more refined determinations of the figure of the earth, and astronomy is continually bringing pressure to bear upon surveys to lend her their aid—for her celestial measurements must always emanate from a terrestrial base.

Man's first conception of the earth's figure was a plane: Greek philosophers thought it a sphere: Sir Isaac Newton showed that it must be a spheroid. Colonel Clarke, of the Ordnance Survey, contended that it was a triaxial ellipsoid. Modern Geodesy, after encountering great difficulties in testing in the field the theories of Newton and Clarke, has pronounced it a geoid. Astronomy now wishes us to tell her the dimensions of this geoid, and its departures from a spheroid.*

In the days of Everest the figure of the earth was deduced from linear measurements, and the Great Arc of India was the only series of triangulation in India originally designed for a figural determination: all our other triangulation was intended and executed for the purpose of controlling topography. In 1858, Colonel Clarke showed that the figure and dimensions of the earth could be better deduced from measured areas than from measured arcs, and the whole triangulation of India became at once available for the discussion, provided it were subjected to astronomical tests.

A small portion only, however, of the earth's surface has so far been surveyed; and our present idea of the dimensions of our planet has been derived from wide generalisations. The total area of land and sea amounts to nearly 200 millions of square miles: the areas that have been surveyed do not aggregate 6 millions of square miles.

The determination of the figure, and of the dimensions and of the specific gravity of the geoid, is now in the hands of an International Geodetic Association, at whose conferences Professor George Darwin, F.R.S., represents Great Britain: India's co-operation is the more valued by the Association, because she alone of the civilized nations possesses an equatorial area, and because she

* The geoid is the figure enclosed by the surface of the sea: this surface is that of a spheroid disfigured by protuberances and hollows.

includes within her dominions the highest points of the earth's surface.

The amount of money spent annually by Europe and America on astronomical observations runs into many millions sterling. Humanity is striving to discover new facts concerning the myriads of distant bodies moving in space. As her development progresses, she grows ever more desirous too of investigating the one celestial body which she can touch, and on which she finds herself travelling amongst the stars.

The difficulties, however, of studying even our own earth are great, because we are tied to its surface: our meteorologists cannot ascend into the atmosphere; our geologists cannot penetrate into the interior. We have learnt that the globe of rock, which constitutes our inter-planetary home, is the source of two great forces, gravity and magnetism; and a knowledge of the actions of these forces has become of importance to almost every branch of science. Their actions we have discovered are strangely dissimilar, and vary both with time and place.

The civilized nations are now making gravimetric and magnetic surveys of the earth, and are measuring the intensities, the directions, and the pulsations of the terrestrial forces. India has been asked to bear her share, and to carry these operations over her own fraction of land-surface.

THE PRINCIPAL TRIANGULATION OF INDIA.

ITS ACCURACY.

The principal triangulation of India has been repeatedly attacked on the grounds that it is too accurate and too scientific for practical purposes. In 1800, in 1824, in 1850, and in 1886 attacks were made, but the Government after enquiry ordered its continuance. The present seems a good opportunity to take stock, to see what the triangulation has done for us and what it has cost us, and to consider by the light of modern requirements its accuracy and its errors.

The operations of a survey may be conveniently divided into (1) the controlling framework, (2) the artistic superstructure. In discussing errors and accuracy it is advisable to keep these two divisions distinct, for, whilst the controlling framework has to be guarded against cumulative errors, the artistic superstructure is only liable to accidental or local errors. The framework is constructed as follows:—

Foundation	...	Principal Triangulation.
Plinth ...	...	Secondary Triangulation.
Walls ...	...	Tertiary Triangulation and Traversing.

Points fixed by tertiary triangulation or traverse should be sufficiently numerous to save the topographer from cumulative errors. Tertiary triangulation and traverses themselves are liable only to accumulate errors over the short distances between secondary stations. In secondary triangulation the accumulation of error is confined to the distance which separates stations of the principal triangulations. In all survey operations, therefore, *after* the principal triangulation the accumulation of error is arrested. But what arrests the accumulation of error in the principal triangulation itself? The answer is that observations of a principal triangulation must be sufficiently accurate in themselves to avoid *embarrassing accumulations of error*.

We have been accustomed to state the error of triangulation in so many inches or so many feet per mile, and this custom has led laymen to believe that the errors of principal triangulation are dispersed throughout its length. But the statement that an error has been found of 1 foot in a mile is merely made to enable the merit of the triangulation to be gauged: in a length of 500 miles an error generated of a foot a mile is not dispersed, but is accumulated at the terminal. It follows, therefore, that the *requisite* precision of a principal triangulation must vary with the *distance* to be triangulated.*

The following table shows the relative degrees of accuracy in the triangulations of different countries: the precision and length of the triangulation of Great Britain have been taken as the units:—

Country.	Precision of Triangulation.†	Length of Triangulation.	Ratio of Precision to Length.
Russia	2·0	3·3	0·6
India	2·2	3·0	0·7
Great Britain	1·0	1·0	1·0
Austria	2·0	1·4	1·4
Italy	2·0	1·25	1·6
Spain	2·2	1·2	1·8
France (modern)	3·0	1·2	2·5
Prussia (modern)	3·6	1·4	2·6

The triangulations of South Africa and the United States are equal in precision to those of France and Prussia.

So long as a country is isolated, its survey will not concern itself with errors accumulated at its frontiers: a country like Prussia,

* The *weight* of triangulation varies inversely with its distance. The error of mean square increases with $\sqrt{\text{distance}}$, but in practice the terminal accumulation over a great length appears to be generally more due to systematic than to accidental errors.

† General Ferrero's report to the International Conference at Stuttgart in 1898.

whose triangulation meets other triangulations on all sides, has experienced troubles that India has never felt. But India is losing her insularity, and though the loss may be slow it is certain. Fifteen years ago the Indian frontier topographers began to experience embarrassments, because the longitudes of Indian mapping were $2\frac{1}{2}$ miles in error. It was futile to tell them that an error of $2\frac{1}{2}$ miles in 6,000 miles was a small matter; the error was not dispersed over the 6,000 miles between Greenwich and India: it came in between our Indian and Afghan topography. The frontier surveyors suggested that each meridian should be drawn in two places on all Indian maps, and they subsequently proposed to project trans-frontier maps in terms of Europe instead of in terms of India, thus transferring the $2\frac{1}{2}$-mile gap from their front to their rear. It was the topographical surveyor and not the scientific branch that was experiencing the trouble. The incident teaches that an error of $2\frac{1}{2}$ miles may remain unnoticed during a century of insularity, but that at the first appearance of a small-scale trans-frontier survey it begins to cause embarrassment.

The accuracy of European surveys gradually increased throughout the nineteenth century, and the difficulties of adjusting the discrepancies between contiguous triangulations became ever correspondingly greater. Eventually it was agreed to create a permanent court of arbitration, and the International Geodetic Association, to which all civilised nations now belong, was called into being.

ITS ERRORS.

The triangulation of India has been controlled by base-lines: its errors of length do not, therefore, need consideration.* But base-lines exercise no control on direction, and, if our astronomical results are to be believed, the triangulation has exhibited a constant tendency to deviate from the true course. Between Karachi and Calcutta an error in azimuth of $11''$ has been generated, and this has increased to $15''$ at Mandalay: our trigonometrical points in Eastern Burma have consequently been all displaced some 400 feet too far south. Between Cape Comorin and Peshawar an azimuthal error of $12''$ has been generated, and the relative orientation of these two places is 200 feet in error in consequence.

But the chief errors in the framework of Indian mapping are due not to faults in its construction, but to its location on the globe. Owing to errors in the original observations of longitude the Indian area has been placed on the globe $2\frac{1}{2}$ miles too far east: owing to

* In the 747 miles separating Karachi and Attock the error in *length* accumulated in the triangulation, and eliminated by the measurement of the Attock Base-line, was 99 feet.

obstacles placed by nature in the way of correct determinations of latitude in Central India, the Indian area has been located some 600 feet too far north on the globe.

Owing mainly to the deformation of the geoid in India, Everest's figure of the earth, on which all our calculations of latitudes and longitudes are based, has been given a diameter too small by 2 miles; the result is that our maps, though correct in their detail, have all been given too large a share of the earth's surface: our distance from Peshawar to Cape Comorin has been accurately measured, but we have given it in our maps 11 seconds more of latitude than it has a right to: our distance from Karachi to Mandalay has been made to embrace 17 seconds more of longitude than it is entitled to. At present we have no neighbours complaining of these overlaps, and the time has not come for us to trouble about them: it would in fact be premature for us to adopt a new figure, when great earth measurements are now in progress in Africa and America, and it would be premature for us to attempt a new location of India on that figure until our pendulum and astronomical work has been extended.

If we sum up the errors in position accumulated on our frontiers, they are as follows:—

Peshawar has been placed too far north in latitude by 400 feet owing to figural errors, and by 600 feet more owing to errors of location on the globe: it is thus shown on our maps 1,000 feet too far north. Peshawar is, moreover, shown $2\frac{1}{2}$ miles too far east of Greenwich.

The Salween has been placed in longitude 1,100 feet too far east owing to figural errors, and $2\frac{1}{2}$ miles too far east owing to errors of initial longitude: it is thus shown on our maps $2\frac{3}{4}$ miles too far east. The Salween is shown some 300 feet too far north, the effects of the initial latitudinal error and of the accumulated azimuthal error being opposite in East Burma.

It is difficult to define numerically the meaning of an "embarrassing accumulation of error," because as a survey matures it begins to feel the pinch of errors which it failed to notice in its youth. Any accumulation of error is embarrassing that obliges surveyors to recalculate their data. Changes in data due to revisions of computations, even when such revisions are based upon important new observations, cause great inconvenience and decrease the value of the data for co-ordination purposes.

In dealing with problems connected with the determination of the figure of the earth no inconvenience arises from using revised data, and it is relatively easy to make revisions, as comparatively few points are concerned.

When triangulation is being used for controlling maps and co-ordinating surveys, the aim of adjustment is to avoid purely local distortions; but when it is being employed to investigate the form of the geoid, it is of importance only to have correct relations between very distant points. In discussing, then, the meaning of "embarrassing accumulations of error," we have only to consider the geographic purposes of triangulation, and we can dismiss from our minds the geodetic.

There is no doubt that the error of $2\frac{1}{2}$ miles in longitude has already become embarrassing to India: our $\frac{1}{1000000}$ maps have different longitudes to our 1-mile maps, and our 4-mile maps have longitudes differing from the other two; and these discrepancies must be inconvenient to the great body of map-users, who are not in the secret of the longitude footnotes. The longitude error is in fact so large that it will probably, in the future, necessitate a revision of data: and if such a revision comes to be carried out, the opportunity will doubtless be taken to eliminate also our figural and latitudinal and azimuthal errors.

As to the error of 1,000 feet in the latitude of the triangulation at Peshawar, this accumulation causes at present no inconvenience: but if our triangulation ever comes to be connected with Russia's, the overlap in latitude will amount to half a mile or more, because Russia is projecting her triangulation on too small a spheroid, just as we are doing. The two surveys will then have different values of latitude for every boundary pillar; it is impossible to foresee now what course they will agree to take: but if we may judge from examples in Europe, they will refer to the International Association, and they will perhaps be advised to correct their data.

ITS COST.

In a Parliamentary paper published in 1851, Sir A. Waugh estimated the cost of the principal triangulation at Rupees 7-2-5 per square mile. If the same work were to be executed now, it would probably cost double. Since the estimate was prepared, triangulation has been carried over Rájputána, Sind, and the Punjab, at a cost averaging 15 Rupees per square mile. The average original cost of the whole principal triangulation of India may be estimated to have been about 9 Rupees per square mile. This cost applies to the area actually triangulated, and not to the total area controlled.

In 1798 Colonel Lambton started working on the network system, but in 1824 Colonel Blacker and Colonel Everest substituted the gridiron system and, by so doing, greatly reduced the cost. The whole area of India is almost three times as large as the area triangulated; and as the whole has been controlled by principal fixings, the cost of the triangulation works out at about 3 Rupees per square mile. The cost of a 1-inch = 1-mile survey exceeds generally

Rupees 20 per square mile, and amounts at times to Rupees 40 or more. The secondary and tertiary triangulation on which a 1-inch survey is based will cost 10 Rupees per square mile: the traversing on which a 1-inch survey is based in flat countries will cost 15 Rupees per square mile. The principal triangulation will, therefore, increase the original cost of a 1-inch survey by less than 10 per cent.—by less perhaps than the cost of its fair-mapping.

But a 1-inch survey requires to be periodically revised, and the principal triangulation remains available for all revisions. Moreover, surveys on larger scales than 1-inch are in progress throughout the country at costs varying from Rupees 60 to Rupees 200 per square mile, and these are all based on the same principal triangulation. Furthermore, it must be remembered that the true expense of our principal triangulation has not been its total additional cost, but its excess over the cost of the secondary triangulation, which would have had to be substituted if the primary had not been executed.

The differences between our principal and good secondary triangulations have been as follows:—

(*a*). The principal costs perhaps 20 per cent. more than the secondary.*

(*b*). The principal stations are more solidly built, and the positions of the mark-stones are carefully protected for the use of the future.

(*c*). Our principal triangulation has generated an error in position of 200 feet and in azimuth of 12″ between Cape Comorin and Peshawar: our good and expensive secondary work, such as the Quetta series, might easily have generated over the same distance an error in position of half a mile and in azimuth of 150″. Triangulation such as the Kalat series might well have generated between Cape Comorin and Peshawar an error in position of a mile and a quarter, and in azimuth of 400″. Secondary work, such as that observed with a 12-inch theodolite on the Cutch Coast, might have generated an error of 5 miles in position and of 20 minutes in azimuth.

ITS USES.

It is a great mistake to imagine that the principal triangulation of India was executed for the purpose of measuring the figure of the earth. *The principal triangulation of India was executed to control the topography.* A triangulation, however, furnishes only the distances apart of the points fixed and their mutual directions: these

* Secondary is cheaper than principal in that its progress is faster, but dearer in that its triangles are smaller. In clear weather and suitable country the extra size of the principal triangles will at times compensate the slowness of progress, and render the principal on the whole cheaper than secondary.

data are not sufficient for topography, which requires the latitudes and longitudes of points. In order to convert the distances and directions of the triangulation into the latitudes and longitudes of topography, we require a knowledge of the earth's dimensions. When Lambton commenced the triangulation of India, the figure of the earth was not known with sufficient accuracy even for the calculation of the spherical excesses of his triangles. During his twenty-five years of trigonometrical work he was always, as he extended his triangulation, having to recalculate the earth's figure, and he died without having succeeded in obtaining a satisfactory result. In 1823 Everest attacked the problem, and, in the belief that Lambton's arcs had been too short, he extended the triangulation northwards into Central India. To his great disappointment a careful determination then gave the polar diameter of the earth longer than the equatorial. Though this anomaly had been met with in other countries, Everest was convinced that the fault lay in his measurements and not in the theory of gravitation.

It was not till 1830 that Everest succeeded in obtaining a figure of the earth sufficiently accurate for the needs of topographers.

There is no doubt that Lambton's and Everest's unexpected difficulties attracted much attention in Europe: these officers were testing in the field the great Newtonian theory that the earth was an oblate spheroid, and their instructive failures took the scientific world by surprise. But the interest excited in their work does not alter the facts that the principal triangulation was executed for the control of topography, and that its utilisation for figural determinations was incidental.

The *first* great practical use of the principal triangulation has been its prevention of embarrassing accumulations of errors at our frontiers.

Its *second* use has been to unify and co-ordinate all the separate surveys of Madras, Bombay, Sind, and Bengal; to give them one origin; to combine them into one harmonious whole: to get rid of gaps and overlaps from the internal mapping of India; to free India from the internal boundary disputes that have so troubled other countries.

Its *third* use has been to facilitate and cheapen by tower stations the topographical surveys of the extensive plains of Upper India, a difficult country to map, being the only large portion of the earth's surface that is flat, intricate, and valuable.

Its *fourth* use has been to enable the positions and heights of distant peaks to be determined with accuracy all along our trans-frontier, and thereby to afford points to topographers in Afghanistan and Tibet.

Its *fifth* use has been to furnish perpetual points for the use of posterity, without which revisions of maps would be impossible.

ITS FUTURE.

The questions that arise concerning the future of the principal triangulation have to do, firstly with the preservation of its stations, and secondly with its extensions.

The measures that have been taken to preserve the stations have not been altogether successful, and require, I think, to be supplemented—but not supplanted—by departmental inspections: furthermore, seeing the importance of preserving all these marks intact, I think that a call by the Government of India for a special report on the condition of all existing stations, if made every twenty years, would tend to prevent the protective work from degenerating into routine.

The only future extensions of triangulation that require present consideration are those of Burma and Baluchistan. In Burma the completion of the Great Salween series, the extension of the Mandalay Meridional series to Sadiya, and the revision of the Assam Valley triangles are required to consolidate the triangulation east of Chittagong and Gauhati.

A principal series is being carried westwards from Kalat in order to co-ordinate the separate surveys that have been made of recent years in Baluchistan, and to provide a foundation for other surveys that are likely to be required in those regions in the near future.

If we are to follow the practices of European nations, of the United States, and of South Africa, we should arrange to measure two or three base-lines in Burma, and possibly one in Baluchistan, within the next few years.

The following table shows the numbers of base-lines of the first class measured in various countries:—

	No. of Base-Lines.*	Area triangulated, in thousands of square miles.	Ratio of Base-Lines to Area.
Italy	9	110	$\frac{1}{12}$
Germany	13	204	$\frac{1}{15}$
Great Britain	6	121	$\frac{1}{20}$
France	7	207	$\frac{1}{29}$
Russia	19	2,000	$\frac{1}{105}$
India...	10	1,520	$\frac{1}{152}$
Burma	0	240	0

There is a base-line at Mergui, in South Burma, but its length of 3 miles is too small to allow of its being classified as first class. The base-lines in India Proper are completed, and though it is a matter of regret that the projected base-line at Bombay was omitted, the

* General Ferrero's report to the International Conference at Stuttgart in 1898.

question is closed: whether our distant successor will re-open it will depend upon the future developments of geodesy.

In the above list there is little doubt that the 2,000,000 square miles allotted to Russia are in excess of her triangulated area: prior to 1895 good triangulation had been carried over Western and Southern Russia, Finland, the Caucasus, and the Cis-Caspian Provinces: and a great arc of parallel had been taken eastwards from Warsaw to Orenburg, and was being extended into Central Asia.

THE LEVELLING OPERATIONS.

THEIR USES.

Levelling operations conducted on scientific principles form as essential a part of a survey as triangulation. Levelling constitutes the framework that controls the vertical measurements of a survey, just as triangulation controls the horizontal measurements. In addition to affording a basis for topographical heights, levelling contributes to topography by co-ordinating the Canal and Railway levels and rendering them available for maps.

ERRORS OF VERTICAL ANGLES.

The altitudes entered on Indian topographical maps have been mostly derived from vertical angles: the degree of accuracy with which these angles have been measured has varied from those observed to decimals of a second with large telescopes to those observed to the nearest degree with wooden clinometers. Our levelling operations have brought to light the following errors in the first-class heights of the principal triangulation :—

Madras Coast	5	feet too high
Bombay Coast	17	„
Mysore	9	„
Deccan	7	„
Cutch Coast	11	„
Khándesh	14	„
Punjab	5	„
Ganges Valley ... errors varying from	13	„
	to 31	feet too low.

Errors of height amounting to 20 and 30 feet are of but little importance in mountainous regions, but are liable to mislead engineers who have to study the hydrography of the plains.

To take a well-known example—Ambala is in the Indo-Sutlej basin and its height is 902 feet: Sahâranpore is in the Gangetic basin and its height is 903 feet. From Ambala to Sahâranpore the ground rises 11 feet in the first 20 miles; the natural watershed between the drainage systems of the Arabian Sea and the Bay of Bengal is 913 feet high near Mustafabad railway station: the ground then falls 7 feet in the 13 miles to the Jumna, and 3 feet in the 17 miles between the Jumna and Sahâranpore.

WORK IN HAND.

The work in hand at present in connection with Levelling may be classed as follows:—

(1) Erection of standard bench-marks.
(2) Extensions of lines of levelling in the field.
(3) Preparation of level charts.
(4) Preparation for press of half a century's levelling results.

The scheme of erecting standard bench-marks has been initiated this winter. From information received at different times there are reasons to fear that numbers of ordinary bench-marks are destroyed when towns expand, and when railways or roads are widened. In the last few years we have discovered that the bench-marks between Rangoon and Mandalay have not maintained their original altitudes: the discovery was accidental; we had not intended to revise the Burmese levels. Revisions in India might bring to light similar displacements. We now propose to erect standard bench-marks in the important towns of India: these new marks will be solidly built in carefully chosen places, and will be handed over to the local engineers, who will report to the Survey annually: their heights will be determined by levelling and engraved on the stones.

PROJECTED EXTENSIONS.

The lines of levelling that remain to be executed may be divided into three classes:—

(i.). The scientific, which are required to close circuits and to furnish the closing errors for the forthcoming adjustment of the level net. These amount to 6 years' work.
(ii.). The engineering, which are required by the Public Works Department to control and unify their Canal and Railway levels. These amount to 17 years' work.
(iii.). The protective, which are required to fix the heights of our standard bench-marks and to preserve thereby, for posterity, a few of the altitudes determined in our time. These amount to 20 years' work.

Of these three classes the third is of supreme importance; to postpone, however, the lines of levels required by the Public Works Department for 20 years is practically to omit them altogether.

For many years past the levelling detachment has been assisting the Public Works Department, and has furnished bench-marks to the

Bengal State Railways, to the Burma Railways, to the Burma Irrigation Department, and to the Irrigation Department of Sind. There has been no opportunity of completing the scientific lines, which are wanted to consolidate the network.

The preparation of Level Charts was commenced thirty-eight years ago: 34 Charts have been published, and 112 remain. Level Charts are intended to show all Canal and Railway levels in terms of the datum of the Survey, and will be of use to both engineers and topographers.

COMPARISON WITH FOREIGN SURVEYS.

I have endeavoured to ascertain the amount of levelling executed in Europe and America, but it is difficult to obtain statistics: in all countries the publication of results lags behind the fieldwork.

India.—Up to May, 1904, there had been executed in India 15,500 miles of precise levelling.

Great Britain.—Prior to 1861, the Ordnance Survey had executed 4,000 miles of accurate levelling in England and Wales, 3,000 miles in Scotland, and 1,500 miles in Ireland. These operations have been widely extended since 1861.

France.—Prior to 1898, France had carried out (*a*) 7,000 miles of levelling of the highest degree of accuracy, (*b*) 10,500 miles of a class of levelling denominated by her surveyors second class, (*c*) 4,900 miles of so-called third class, (*d*) 10,200 miles of so-called fourth class. The lower orders of levelling are used in France to break up the fundamental network into smaller areas.*

United States.—In 1809, the Survey adjusted their precise level net; 19,753 miles of precise levelling were included in the net: between 1899 and 1903 additional first-class levelling extending over 6,000 miles was carried out.*

Germany.—Prior to 1892, Germany had carried out 18,600 miles of first-class levelling, and Austria had carried out 10,000.

Japan.—Prior to 1898, Japan had carried out and projected 5,700 miles of levelling of precision.*

Ratio of first-class Levelling to area:—

Germany in 1892...	$\frac{1}{11}$
Great Britain in 1861	$\frac{1}{14}$
Austria in 1892	$\frac{1}{21}$
Japan in 1898	$\frac{1}{22}$
France in 1898	$\frac{1}{25}$
India in 1905	$\frac{1}{110}$
United States in 1899	$\frac{1}{115}$

* Reports of the International Conferences, Stuttgart, 1898, Paris, 1900, Copenhagen, 1902.

Seeing how valueless large portions of the Indian area are, no one could advocate that the ratio for India should be raised to that of Great Britain. American surveyors would probably take exception to the ratio allotted to their country, as it makes no allowance for the large unsurveyed regions that form part of the United States.

In adjusting the errors of her levelling net, France had to take into account that her lines had been connected with those of foreign countries at 18 different points, viz.:—

with Spain at three points,
with Italy at three points,
with Switzerland at five points,
with Germany at three points,
with Belgium at four points.

Owing to the errors in her connections with France, Switzerland had to revise 80 miles of levelling in 1896 and 183 miles in 1897. India's insularity renders her levelling independent of foreign checks.

THEIR COST.

Seeing how useful our levelled heights and bench-marks have been in India to the engineering departments, it is questionable whether we ought to charge the total expenditure on them against topography. If, however, we decide to do so, the cost to topography of the levelling control, up to the present time, will work out at about nine annas per square mile of area controlled.

On the average four bench-marks have been erected in every 1-inch standard sheet of surveyed area.

THE ASTRONOMICAL OPERATIONS.

PRIMARY AIMS.

The primary duty of the Astronomical party is the location of India in its correct position on the globe. The origin of our triangulation is a point in Central India: we have had to determine astronomically the terrestrial position of this point, and we have had to determine astronomically the terrestrial directions in which our several diverging series of triangulation have trended; one series has run into Makrán, others into the Punjab and Himalayas, others into Assam and Burma, others into South India, and, in spite of unremitting care, all these ramifications have developed errors of orientation and direction.

The area of India is more than one-fourth of the total triangulated area of the world: it is the largest triangulated area that has yet been undertaken by one survey; it is the largest triangulated area that has ever been made to emanate from a single point: and our astronomical officers have had to fit this area into its true position on the globe. They have had to discover the relative dimensions of the area to be located and of the globe receiving it: they have had to keep a watch on the triangulation, to see that it is not trespassing beyond our correct frontiers and coasts, and to warn us of the errors that we shall have to deal with when we meet with a foreign survey.

It must be remembered that nature has placed obstacles in the path of astronomical surveyors in India: the direction of gravity is the only test they have of verticality, the surface of liquid at rest is their only test of horizontality. In no other part of the world has the direction of gravity been found to undergo such abnormal variations as have been discovered by the Russians in Fergana and by ourselves in Northern India: in no other country does the surface of liquid at rest deviate so much from the horizontal.

There appears to be an idea that the primary object of our astronomical work is the investigation of mountain attraction and of deflections of the plumb-line. But this is a mistake. Its true goal is the determination of the geographic errors of area, shape, and position that have been generated by the triangulation. But just as the triangulators found themselves unable to control the topography without a knowledge of the figure of the earth, so have the astronomers found themselves unable to control the triangulation without a knowledge of the direction of gravity. Just as the triangulators had to digress and make earth-measurements, so have the astronomers had to halt on their way to investigate the attractive effects of mountains.

It is true that discoveries made in the course of these secondary operations have won the interest and sympathy of learned societies in Europe: the discovery that an extraordinary deficiency of matter underlies the Himalayas, that a range of mountains is hidden and buried beneath the plains of Central India, that seaward deflections of gravity prevail round the coasts of southern India—these discoveries have led geologists and geodesists to press for a further investigation of the distribution of mass in the earth's crust. But the interest that has been awakened does not alter the fact that the primary object of our astronomical operations is geographic.

THE HEIGHTS OF HIMALAYAN PEAKS.

Difficult questions have arisen in connection with the heights of the Himalayan and trans-frontier peaks: our values for these heights are in error, (*1stly*) because of the extraordinary deformation of the level surface at the observing stations in submontane regions; (*2ndly*) because of our ignorance of the laws of refraction, when rays traverse rarefied air in snow-covered regions; (*3rdly*) because of our ignorance of the variations in the actual heights of peaks due to the increase and decrease of snow. It is part now of the programme of the Astronomical party to determine the errors in height arising from geoidal deformations, to investigate the laws of refraction at high altitudes, and to measure the actual variations that are occurring in the heights of peaks.

There are but three known methods of determining the height of a station, viz., (1) by Spirit level: (2) by Atmospheric pressure: (3) by Angular measurement. Of these three methods the first two require the station itself to be visited, and the third alone is available when the station is inaccessible.

To obtain an idea of the degree of uncertainty which attaches to values of heights determined from very distant observing stations, we may suppose that an observer measured the elevation of Mount Everest from Darjeeling in October, and again from the plains of Bengal in April; his second series of observations might give a larger value of height than his first series by 100 feet on account of geoidal deformation, by 300 feet on account of inequalities in refraction,* and by 100 feet or more on account of increase of snow—by 500 feet in all.

I do not presume to argue that our heights are in error by this amount, but I do say that the above figures give a fair numerical idea of the range of uncertainty. Apart from topographical requirements, it is of interest to the world at large to know the heights of the highest points of the earth, and the duty of determining them belongs to the Indian Survey.

The values of height now attaching to the three highest mountains in the world are by no means the most probable.

Heights of the Three Highest Mountains in the World.

	Present Survey values of height.	Most probable values.
Mount Everest	29,002	29,141
K^2	28,250	28,191
Kinchinjunga	28,146	28,225

It is possible that we are robbing Kinchinjunga of the honour of second place.

My most probable values of height have been derived from observations of refraction that were not available when the present Survey values of height were adopted. It would, however, be premature to exchange yet our present values for the most probable values, for nothing leads more to confusion than repeated alterations of data.

* Refraction is probably less at Darjeeling than over the plains: if, therefore, the same co-efficient be employed, the height obtained from Darjeeling will be less than that obtained from the plains.

It is true that the values at present most probable would be improvements on the accepted values, but we want something more than improvement or correction to justify us in changing data: we want finality and certainty, and these we shall never attain until we appreciate the magnitude of the problem and go systematically to work. In the course of the Trigonometrical Survey we have accumulated a mass of evidence relating to refraction, but it is entangled with the effects of local attraction and of snowfall, and it cannot be classified or utilised until we have disentangled the three.

SPECIAL DUTIES IN THE PAST.

The Astronomical party of the Survey has been often called upon in the past to perform miscellaneous duties that would in Great Britain have fallen upon the staff of Greenwich Observatory. It has had to observe Transits of Venus: in 1894, 1895, and in 1896 it was observing in Persia and Europe to determine the error of Indian longitudes: in 1898 it was deputed to assist the Astronomer Royal in observations of the total Eclipse of the Sun. It has worked in conjunction with the Government Astronomer at Madras to obtain a fundamental value of latitude for the Indian Star Catalogue.

SPECIAL FUTURE WORK.

The Director of Kŏdaikanál Observatory requested the Survey some years ago to determine his geographical co-ordinates both astronomically and by triangulation: I regard this request as of first importance, but no officers have been available for the work.

It is to be hoped that in the future the Astronomical party may be given an opportunity of determining the mean density of the earth: Astronomers Royal did this for Great Britain at Schiehallion and Cardiff, and the Ordnance Survey made a fine determination at Arthur's Seat at Edinburgh. The three measures were, however, not accordant,* and a determination in the low latitudes of India would be a valuable contribution. The present time is peculiarly opportune, because we could count upon the co-operation of our pendulum party: in no one of the British determinations could astronomical and pendulum observations be combined. When, therefore, the Ordnance Survey had to deduce the weight of the earth from the weight of Arthur's Seat, they were not aware of the density of the crust underlying Arthur's Seat, and they were obliged to assume that it was normal: if we undertook to measure now the relative weights of the earth and Mount Abu, we could, with our pendulums, discover whether the foundations of Mount Abu were abnormally heavy or light.

* Mr. Maskelyne at Schiehallion	4·56
Sir George Airy at Cardiff	6·57
Sir Henry James at Edinburgh	5·32

COMPARISON WITH FOREIGN SURVEYS.

The errors in the geographic position and area and shape of a survey are determined by Astronomical measurements of latitude, longitude, and azimuth at stations of its triangulation. The following table shows the present position of the Survey of India as compared with other surveys :—

Survey of	The proportional number of stations of the triangulation at which Astronomical observations have been made.*		The total number of Arcs of longitude measured.†
	For Latitude.	For Azimuth.	
Germany	1 in 3	1 in 4	107
Trans-continental triangulation of America	1 in 2	1 in 3	67
Great Britain	1 in 7	1 in 4	‡
Austria	1 in 6	1 in 7	95
France	1 in 8	1 in 11	62
Italy	1 in 11	1 in 12	34
Russia	1 in 12	1 in 12	81
India proper	1 in 11	1 in 12	47
Baluchistan	0	0	2
Burma‡	0	1 in 11	5
Kashmir	0	0	0

NORMAL FUTURE WORK.

Observations for latitude are still much wanted on branches of our triangulation, more especially in Burma, Baluchistan, Kashmir, and the Himalayas.

Observations for azimuth will be required on future extensions of the triangulation.

The measurement of a few additional arcs of longitude in Burma, the Punjab, South India, and Kashmir has for many years been considered desirable.

* Reports of the International Conferences at Stuttgart, 1899, and at Copenhagen, 1903.

† Many of the arcs of longitude measured by Great Britain cross the English Channel and the Atlantic : it is doubtful whether these should be included in the table.

‡ Including the Manipur Meridional series.

INTERNATIONAL DETERMINATION OF THE VARIATION OF LATITUDE.

Of recent years endeavours have been made in Europe and America to measure the changes in the positions of the earth's centre of gravity and of the earth's rotation axis; that changes are always going on has been made clear by the discovery that the latitude of every place is continually varying. Some few years ago an International Congress decided that a systematic investigation should be made, and they suggested that the earth should be surrounded by a girdle of special observatories. The parallel of 39° north was selected for the girdle, with the result that three observatories fell in the United States, one in Japan, one in Russia, one in Sardinia. The Russian Government was asked in accordance with this scheme to erect an observatory at Tschardjui: Russia had been already for some years observing the variations of latitude at Pulkowa, at Moscow, at Warsaw, and at Kazan, and the new observatory at Tschardjui made her fifth. India has so far not been asked to contribute to this work: she profits nevertheless from the results.

THE PENDULUM OPERATIONS.

THE PROGRESS OF FOREIGN SURVEYS.

The number of stations at which the pendulum had been observed prior to 1903, were*—

Great Britain	63
Italy	193
France	89
Austria	569
Germany	280
United States	108
Russia	153
India	29

Pendulum observations are now being taken by the surveys of France, Germany, Russia, Austria, Italy, Japan, and the United States.

France has volunteered to undertake a gravimetric survey of the Andes: Germany has undertaken one of the oceans and coastlines

* Reports of the International Conferences at Paris in 1900 and at Copenhagen in 1903. Observations at 29 pendulum stations in India were made between 1866 and 1871: the work was stopped because the only apparatus procurable was too heavy and wearisome. Of the 63 stations appertaining to Great Britain but 16 fall in Great Britain itself: the remainder, though occupied by British observers, fall in Spitzbergen, South America, and other places.

of the world; the United States and Russia have enormous areas of their own; and Great Britain sent a complete pendulum equipment to the Antarctic two years ago.

But, for pendulum research, the most interesting place on the earth is the mountainous region of Northern India, and the International Conference that met at Copenhagen in 1903 passed the following resolution on this subject for submission to the Government of India:--

"Il est desirable qu'on fasse dans les Indes anglaises une étude approfondie de la répartition de la pesanteur, tant dans les contrées montagneuses que dans les plaines."

"Attendu que c'est seulment par cette étude qu'on pourra obtenir une representation exacte de la distribution des masses dans l'écorce terrestre et de la forme du géoide dans ces contrées."

The British Ambassador at Berlin submitted the above resolution to the Government of India on October 6th, 1903. Pendulum observations were commenced in India in 1904.*

THE PURPOSES SERVED BY PENDULUM OBSERVATIONS.

Pendulum observations are of use—

(*1stly*). For correcting and perfecting our astronomical checks on the triangulation.

(*2ndly*). For determining the earth's elipticity by a method independent of arc-measurements.

(*3rdly*). For investigating the departures of the geoid from a Newtonian spheroid.

(*4thly*). For investigating the constitution of the earth's crust.

The first purpose served by pendulum observations is, therefore, geographic, the second and third are astronomic, the fourth is geologic; all are geodetic.

We are profoundly ignorant of the constitution of the earth: we do not know if its interior is rock or metal, solid or molten: we talk of its crust, but we do not know if it has a crust distinct from its core: we do not know if the existence of high mountains is an incident of the earth's surface only, or if their superincumbent weight is producing inequalities of density at great depths. We do not know how these mountains have arisen. Pendulum operations have consequently a high value and interest for geologists and geodesists.

Geographical, astronomical, and geological observations have all in their turn revealed peculiar physical features in the Himalayas, and

* The Surveyor-General had obtained the sanction of Government to the purchase of a pendulum apparatus in 1902, and thus anticipated the wish of the International Conferences.

we are now calling the pendulum to our aid to supplement our knowledge of Himalayan structure.

But when discussing the numerous uses of pendulum observations, we must not lose sight of the important fact that the pendulum is primarily a surveying instrument.

The connection between topography and pendulum work is, however, too complex to be described clearly in a single sentence, and must be traced step by step, as follows :—

(i.). The geographical adjustment of the triangulation is dependent upon astronomical observations.

(ii.). The correctness of astronomical observations depends upon the direction of gravity.

(iii.). We cannot *measure* the direction of gravity, because we have no zero from which to measure. We can measure the *height* of a station, because the mean level of the sea is a reliable zero : we can measure *temperatures*, because the freezing point of water is a reliable zero : we can measure the deviation of the needle from true north. But we cannot measure the deviation of gravity from the true vertical, because the true vertical is not discoverable by observation as the true north is.

(iv.). Owing to the deflections of gravity, astronomical measurements may cause an error of 800 or 1,000 feet in the geographical position of any point, and an error of a mile in the position of a Himalayan point.

(v.). No deflections of gravity would occur on a perfectly level spheroid formed of homogeneous spheroidal layers : they are caused by the irregular distribution of masses of the earth's surface and in the earth's crust. The pendulum is required to demonstrate the true distribution of mass, and to show to us the extent to which our actual earth differs from a level spheroid composed of homogeneous layers.

(vi.). If we know the mean density of the earth and the local distribution of mass at its surface, we can calculate the amount that gravity will be deflected from the normal. By providing us, therefore, with an ideal spheroid the pendulum supplies the zero which nature has failed to furnish.

The primary use, then, of pendulum work is that it enables the surveyors to correct their astronomical results for the unavoidable errors caused by deflections of gravity. The location of India on the globe has, for instance, rested upon astronomical observations made at a point in Central India. Everest selected this spot because there were no mountains visible, and because it seemed to be a place at which the direction of gravity would be truly vertical, and at which the instrumental levels would be truly horizontal. But only in the last few years we have discovered that Everest's point is situated on the scarp of a buried range or table-land ; this range is deflecting gravity out of the normal, and must have disturbed the horizontality of Everest's levels; pendulum observations will disclose the mass and position of the hidden range, and will enable us to compute corrections for the astronomical results.

Thus it will be seen that pendulum observations are used to control astronomical results, just as astronomical observations are used to control the triangulation, and as the triangulation is used to control the topography: all are links in one chain.

THE TIDAL OPERATIONS.

RETROSPECT.

The investigations and writings of Professor George Darwin have, within the last thirty years, considerably increased our knowledge of the tides. Though we are still unable to foretell the course of the tides at places where no observations have been taken, yet our predictions at ports at which the tides have been observed are now attaining an accuracy which would not have been credited half a century ago.

Tidal operations in India were initiated for the following purposes:—

(1) To provide a datum for the levelling operations of the survey.
(2) To afford data for the calculation of tidal predictions.
(3) To obtain evidence of the rising and sinking of land and of variations in mean sea-level.

Up to 1883, predictions of the tides were calculated by an arbitrary method which made no allowance for what is known as the diurnal inequality.*

In home waters the diurnal inequality is practically absent, and the European admiralties and surveys have never been really troubled by it. But in Indian waters it is very large, so large that in some of our ports at certain times there is only one tide in 24 hours. Owing to this phenomenon the earliest attempts at tidal prediction which were made in India for Karachi and Bombay were not successful; and for many years all endeavours to foretell the tides at Aden failed. In 1883, Darwin revised the method of Harmonic Analysis as applied to the tides formulated by Sir William Thomson in 1872, and we are now able to unravel their extreme complication in Indian waters. The average error in the predicted height of high water at Aden is now one inch. If we reflect that the motions of the sun and moon,

* This inequality is easily understood from a diagram.

the complex outline of our coasts, the ever-varying depths of the sea, and the earth's rotation and figure are all involved, we cannot but regard modern tidal prediction as one of the greatest triumphs of science.

India was the first country to adopt this method of prediction: her success has been extraordinary, and her example has been slowly followed by Canada, the United States, France, and other European nations.

By means of Harmonic Analysis we can separate the observed tides into twenty-four components, and by means of Lord Kelvin's tide-predicting machine we can again combine these components and discover, mechanically, the actual tides of the future. For many years India was the only country that possessed a tide-predicting machine: but latterly France, the United States, and Canada have had machines constructed. The tide-predicting machine of the Indian Government has been used in Europe for the tidal predictions of British colonies, and for this reason has never been sent to India. For many years it stood at Lambeth, but has lately been received at the National Physical Laboratory at Teddington.

The predictions of the Indian tides are carried out under the following quadruple arrangement:—

(i.). The tidal observations are taken under the superintendence and orders of the local port officers and engineers.

(ii.). The Survey of India has the duty of inspecting the several tidal observatories and of maintaining uniformity of method: the Survey of India has the further duties of reading off the tidal diagrams and of calculating by Harmonic Analysis the twenty-four tidal components.

(iii.). The National Physical Laboratory in England sets the tidal machine to accord with the results of our calculations, and prepares the tidal predictions from the curves drawn by the machine.

(iv.). From the beginning the operations have been under the scientific direction of Professor Darwin, whose advice has been constantly sought.

If tidal observations are taken for five years, sufficient data are accumulated to enable predictions to be made; the present predictions for some of the Indian ports are being still based upon observations taken more than twenty years ago, and continue to be accurate. But lest in the course of years the tides may be slowly varying, or lest the relative heights of sea and land may be altering, a few observatories have been established on a permanent basis.

Between 1874 and 1904 tidal observations were taken at 42 places: of these observatories 34 were temporary and 8 permanent. At the present time 1 temporary observatory and the 8 permanent are working.

Of our 42 tidal observatories 2 were in the Red Sea, 2 in Arabia, 1 in the Persian Gulf, 1 in the Maldives, 3 in Ceylon, 1 in the Andamans, 24 in India, and 8 in Burma.

COMPARISONS WITH FOREIGN SURVEYS.

The levelling results have been tested against tidal determinations of mean sea-level at 20 different places on the coasts of India.

In Great Britain, prior to 1861, the levelling results of the Ordnance Survey had been compared with tidal measurements of sea-level at 30 places in England and Wales, at 18 places in Scotland, and at 21 places in Ireland.*

The following table shows the number of permanent tidal observatories working in 1902† :—

Country.	Length of Coast-line in Miles.	No. of Tidal Observatories.
Tonquin (France)	150	1
Austria	300	1
Holland	400	20
Denmark	500	10
Algiers (France)	600	1
Germany	800	26
New South Wales	800	3
France	1,300	11
Italy	1,600	16
Canada	2,000	7
Russia	2,000	10
Japan	2,600	10
New Zealand	3,000	6
Great Britain	3,000	9
India	4,000	8

FUTURE WORK.

The following tidal work will be carried out by the Survey of India in future :—

(i.). Maintenance of 8 permanent tidal observatories.

(ii.). Annual calculations for the tide-predictions for 42 different ports.

(iii.). Opening of new tidal observatories, of which 2 have been proposed for the Malay Peninsula, 1 for the Red Sea, and 2 for the Gulf of Cutch.

* Abstracts of Spirit Levelling, Ordnance Survey, 1861.

† International Conferences, Stuttgart, 1898, and Copenhagen, 1903.

SCIENTIFIC INVESTIGATIONS.

Up to a few years ago it was generally held by geologists that the earth was a globe of molten matter enclosed by a thin crust. Lord Kelvin has, however, shown that such a globe would yield to tidal forces, and that the oceanic tides would then be imperceptible. The oceanic tides consist in a motion of the water relatively to the land, and their existence proves that the land does not yield with perfect freedom. From the fortnightly tide observed in Indian waters, Lord Kelvin and Professor Darwin have shown that the earth possesses a rigidity greater than that of solid glass, though not greater than that of solid steel.

In my previous note on Astronomical work I alluded to the variation of latitude: this phenomenon has been attributed to shiftings of the earth's axis of rotation, to movements of the earth's centre of gravity, and to variations in the position of the equatorial protuberance with reference to places fixed on the earth's surface: as the axis of rotation and the centre of gravity and the equatorial protuberance shift, the oceans become disturbed, and a tide becomes generated. We are endeavouring now, under the direction of Professor Darwin, to detect a tide at Karachi corresponding in its period of 430 days with the variation of latitude: the United States Geodetic Survey has discovered such a tide on their coasts, and the Geodetic Survey of Holland has also detected it. This tide is of course minute, as the movements of the earth's axis are small: if the displacements of the axis were considerable, whole continents would be drowned by gigantic waves.*

THE MAGNETIC SURVEY AND SOLAR PHOTOGRAPHY.

A Magnetic Survey of India was proposed in 1896 by Sir John Eliot and General Strahan, and was recommended by the Astronomers who visited India in 1898 on the occasion of the total eclipse of the sun.† At the outset there was some uncertainty as to whether the work should be undertaken by the Survey of India or by the Meteorological Department, and it was eventually decided that the field-work should be carried out under the Surveyor-General, and that the fixed observatories should be under the Meteorological Reporter. By mutual agreement, however, the Meteorological Reporter has now handed over the charge of four of the five observatories to the Surveyor-General. The Magnetic Survey of India was begun in 1900.

* Darwin's *Tides*: p. 230.

† See Reports by Sir W. Christie, K.C.B., F.R.S., and Sir Norman Lockyer, K.C.B., F.R.S.

Many branches of science are interested in a Magnetic Survey: the meteorologists require it to assist them in their investigation of the connection between sunspots and rainfall: the geologists expect it to show them the positions of magnetic rocks: geographers and navigators derive from it their knowledge of the declination of the compass, and the secular changes in the declination.

The existence of magnetic rocks in the crust can at times be detected by ordinary compasses; but if iron ore is lying concealed at any great depth from the surface, its presence would be only discovered by a systematic and rigorous survey.

Though the magnetic surveys of Europe and America have greatly progressed of recent years, but a small fraction of the surface of the globe has as yet been examined. We do not at present know whether the earth's magnetism is due to permanent centres of attraction or to its rotatory motion: we do not know whether the earth is a permanent magnet or not.

DATES OF MAGNETIC DISCOVERIES.

1492. Discovery that a needle does not point true north, and that its declination differs in different parts of the earth.

1576. Discovery that the north end of a needle, if properly balanced, will dip below the horizon, and that the amount of dip differs in different parts of the earth.

1634. Discovery that the magnetic declination constantly undergoes slow changes in the course of years, and that the rate of its change differs in different countries.

1720. Discovery that the strength or intensity of the earth's magnetic force differs in different countries and at different times.

1722. Discovery that the magnetic declination is subject to an appreciable diurnal tide, and that the range of this tide differs in different countries and at different seasons.

19th century. General Sabine shows that the earth's magnetism is not only a telluric but a cosmical force.

THE INDIAN MAGNETIC SURVEY.

The immediate aim of a modern Magnetic Survey is to determine the declination, the dip, and the intensity of the earth's magnetic force in every portion of the area involved, and to measure the several changes that these elements undergo.

In the Magnetic Survey of India five field parties have been observing the declination, dip, and intensity in different parts of India since 1900; annual observations have also been taken at 17 "Repeat" stations to test the annual local variations in the elements; and continuous photographic records have been obtained at five observatories of the direction and intensity of the magnetic force.

The preliminary Magnetic Survey of India will be completed in 1906. Charts will then be prepared to show the localities where magnetic disturbances exist, and a detailed Magnetic Survey of those localities will be commenced under the guidance of the Royal Society.

In projecting the detailed survey, the Survey of India, conscious of a heavy responsibility, will rely upon the co-operation of the Meteorological Reporter and of the Director of the Geological Survey.

We have been much indebted to Sir Arthur Rücker, K.C.B., F.R.S., for his interest, advice, and instructions, and we count with confidence upon the continued sympathy of this eminent physicist.

COMPARISON OF THE MAGNETIC SURVEYS OF GREAT BRITAIN AND OF INDIA.

The first complete Magnetic Survey was that of Great Britain in 1837–38. The example set by Great Britain was followed by Austria, Germany, Holland, France, Canada, Russia, Italy, and the United States.

In 1857–62, after the lapse of twenty years, Great Britain repeated its original Magnetic Survey in order to investigate the changes that had occurred.

Between 1884 and 1888 Great Britain carried out a third Magnetic Survey, and between 1889 and 1892 it amplified this survey and made it the most detailed of the world.

Our present Magnetic Survey is the first attempted in India, but magnetic observations have been taken since 1846 at the Observatory at Colába, which was established by the East India Company, and this continuous series is undoubtedly a very valuable record.

The following Magnetic Observatories are now working :—

In Great Britain.	*In India.*
Greenwich.	Colába.
Kew.	Kōdaikanál.
Stonyhurst.	Dehra Dún.
Valentia.	Barrackpore.
Falmouth.	Toungoo.

In Great Britain there were 26 "Repeat" stations, that is one "Repeat" station on the average to every 4,700 square miles. In India there are projected 24 "Repeat" stations, or one "Repeat" station on the average to every 73,000 square miles.

In Great Britain there were 882 field stations, or one field station on the average to every 139 square miles. In India there are projected 1,200 field stations, or one field station on the average to every 1,500 square miles.

I am not making these comparisons to illustrate the inferiority of the Indian Survey to the British, but to show that the Magnetic Survey of India has been designed with a proper regard for economy, and that no undue multiplicity of observations is being contemplated.

It is possible that, when the detailed Magnetic Survey is being undertaken, we shall be pressed to multiply field stations in regions of magnetic disturbance.

The following information is extracted from the last report of the United States Survey, dated Washington, 1904:—

"Observations have been made at 1,636 stations, of which about one-eighth are 'Repeat' stations: the average distance between the stations is 25 miles,* although in regions of pronounced disturbances the distances are much less: the area covered is one-third of the area of the United States."

"Observatory work has been carried on at five stations."

"It is hoped that the next five years may witness greater progress."

SOLAR PHOTOGRAPHY.

Photographs of the Sun have been taken twice daily, clouds permitting, at Dehra Dún since 1879. Similar photographs have been also taken daily at Greenwich Observatory and at Mauritius. For many years Greenwich, Dehra Dún, and Mauritius have acted together under one scheme and on one system. We send our photographs to England weekly to Sir Norman Lockyer, K.C.B., F.R.S., under whose directions we have carried out the work from its inception. In 1898 Sir William Christie, the Astronomer Royal, wrote to the Secretary of State: "The daily photographs of the Sun should be continued at Dehra Dún, where they are being taken satisfactorily under the Surveyor-General's direction."†

* Average distance in India 39 miles.

† Report on Indian Observatories.

TRANSCRIPT.

ADVANCED POSITIONS IN FORTRESS WARFARE.*

From an article by Major Alexander Kuchinka, Austrian Engineers, in the February, 1906, number of the *Mitteilungen über Gegenstande des Artillerie-und Genie Wesens.*

The battles round Port Arthur have again brought to the front the vexed question of the value of advanced positions in fortress warfare. It may be of interest to glance briefly at the opinions held on this subject by different military nations, and to consider the question in the light afforded by the history of two instructive sieges—those of Belfort and Port Arthur.

The opinions held in Austria on this subject are well known. We lay down that advanced positions should only be occupied when the number of troops and the amount of matériel available are such as to admit of their being properly held and fortified without weakening the fortress itself.

The leading German writers disapprove of advanced positions. Thus Stavenhagen (*Elements of Fortress Warfare*, 1901) writes :—" In order to retain command of the outlying country as long as possible, it is permissible, as an extreme measure, to occupy entrenched positions in advance of the girdle of forts at a distance sufficient to constitute them a separate line of defence. This may be done when the girdle forts are unduly near the fortress, or when the country is such that every foot of ground can be disputed. But in general such advanced positions are to be avoided."

Colonel Schroeter, formerly Instructor at the German Military College, has just published a fresh edition of his admirable work *The Fortress in Modern Warfare*. He says : " In the case of a fortress prepared for war, the occupation of so-called advanced positions in order to keep command of the foreground will only weaken the main defence. Assuming that the fortress is correctly designed with respect to the strength of its garrison, such a measure can only be justified in case the number of troops available for defence is greatly in excess of the regular garrison. This was the case at Sebastopol and at Metz."

The French and the Russians take a diametrically opposite view. The latter may be influenced by the special qualities of their troops, who are naturally well suited for an obstinate step-by-step defence. Moreover they count upon the presence of regiments of fortress troops, thoroughly familiar with the ground.

* The original contained a map of Belfort.

France and Russia hold much the same views upon this question. Thus General Kasbeck's *Instructions for the Defence of Ivangorod*,* which may be taken to reflect Russian opinions, are practically a reproduction of the French *Instruction Générale sur la Guerre de Siège*. These latter instructions authorize the preparation and occupation of advanced positions, in the following terms:—

"When the defending troops can no longer manœuvre freely in the outlying country ('à grand rayon') they must retire upon the positions in advance of the girdle which have been previously prepared for defence. In these positions they administer the first effective check to the enemy's advance, and hinder him from establishing himself within effective range of the girdle forts.

"From these advanced positions attacks must continually be made upon the enemy's investing lines, destroying his works and compelling him to begin afresh. This will delay the completion of the investment.

"Generally speaking, advanced positions should only be prepared upon the fronts favourable to the enemy's attack. Their distance in advance of the girdle must depend upon the ground and upon the force available to hold them. This distance should be such as to allow of some support from the girdle forts without in any way prejudicing their defence.

"Advanced positions will consist of groups of entrenchments, each group including several *points d'appui* such as redoubts or villages placed in a state of defence. They will be held by mobile troops only (*i.e.*, no guns will be mounted).

"But if, under special conditions of ground, it is necessary to permanently occupy during the defence a detached position in advance of the girdle, this position must be more strongly entrenched and may be armed with heavy guns.

"Between these advanced positions and the girdle every fold of the ground will be utilized as a position, giving a succession of defensive lines one behind the other. As far as possible each position should command or flank the one in front of it. These intermediate positions will facilitate the withdrawal from the advanced positions, and will enable the defender to dispute every foot of ground.

"In preparing the outlying country for defence care must be taken to avoid constructing any works which may be of use to the enemy when the defenders retire from them.

"In the case of first-class fortresses the military authorities, with the co-operation of the civil authorities, will take all necessary steps in peace time to ensure the rapid construction of these advanced works when required. The necessary surveys and plans will be prepared beforehand."

The Italians hold similar extreme views, and their regulations bearing upon fortress warfare are conceived in the same spirit. Colonel Rocchi,

* *Note.*—For translations of these Instructions see M.A.G., 1901, Nos. 11 and 12, pp. 671 and 767. Notices of the second edition appeared in M.A.G., Nos. 10 of 1904 and 4 of 1905, pp. 981 and 336.

in his *Elements of Permanent Fortification*, even contends that advanced entrenchments are essential to an active defence. He cites the case of Belfort.

BELFORT.

Now, since the siege of Belfort has been generally adopted as a historical example of the successful use of advanced works, it may not be out of place to investigate the question—Does the experience of Belfort justify the views on advanced positions embodied in the French regulations?

We will commence with a brief retrospect upon the strategical object of this fortress and upon its preparation for defence between the outbreak of war (19th July, 1870) and the appearance of the enemy before it on 3rd November.

Belfort closes the gap between the Vosges and the Jura. It was intended to form an entrenched camp as a point of support for the French Southern armies during operations in the south of Alsace.

At the beginning of the war the defences consisted of the walled enceinte, the citadel, and Forts Miotte, La Justice, and Des Barres. The latter was then nearly completed.

The enceinte was a bastioned pentagon. The citadel was in advance of the south front, while the north front was covered by the Esperance hornwork. The citadel was built upon a rock rising 160 feet above the town; it consisted of a casemated cavalier, with three bastioned fronts to the south, which had rock scarps 70 feet high.

Forts Miotte and La Justice were also surrounded by impregnable rock scarps. They were on the opposite side of the town, and were connected with it and with each other by lines of fortification, thus forming a fortified camp, 1,200 by 600 yards, which might be considered safe against assault.

From the foregoing we may conclude that Belfort was, even in 1870, an antiquated fortress, which had ceased to serve its original purpose as an entrenched camp. It could only be considered as the nucleus of a system of defences.

The foreground was intersected, partly covered with woods, and dotted with numerous strongly-built villages. These afforded cover to the assailant, allowing him to approach on the south and west fronts to within 1,200 yards of the citadel. The two hills known as Les Perches to the south, and the Bellevue plateau to the west, could be occupied by the enemy without exposing themselves. All these completely commanded the city, so that if any one of them were taken the fortress would be rendered untenable.

A Board of Artillery and Engineer Officers had already reported upon the defences of Belfort in 1869. They had again brought to notice the fact that the defences were commanded by the above-mentioned heights. But no money was available to extend the defences. France was then the premier Continental power, and did not consider it necessary to spend money on her home defences.

So it happened that the important works required for the security of the place were left to be constructed on the outbreak of war. In view of the catastrophe to the French arms with which the war opened, the defenders may be considered fortunate in that the attack upon Belfort was not made till 3½ months later.

Owing to the events of the field campaign and to their consequences, it was found impossible to proceed to the organization of the garrison until the middle of September. The troops available for defence consisted of 3 battalions of infantry, totalling 2,600 men. Besides these there were 11,820 Gardes Mobiles; this latter force had been called into existence by the law of February, 1868, but in 1870 it was hardly yet organized; the men were untrained and unready for war; they consisted of the conscripts declared fit for service but excused from military duty for various reasons, and they were therefore not even as efficient as our second reserve. It was impossible to commence their training at once, as every man was required for work on the defences. Very little civil labour was available, since repeated panics had caused the inhabitants to fly from the district. The cavalry was represented by 8 troopers; the artillery numbered 2,000, and the engineers 338. The total defending force consisted of 370 officers and 17,224 men.

The total circumference of the defences, including the improvised forts at Les Perches and Fort Bellevue, was 5 English miles. At the present day a garrison of 17,000 men would be considered fully sufficient for this perimeter.

The armament was sufficient in point of quantity, if not of quality. Frobenius gives it as 158 rifled guns, of 3·15″, 4·7″, and 6″ calibre, the latter ranging up to 7,500 yards; also 204 smooth-bore cannons and mortars. Owing to the small extent of the town it was possible to turn most of the citadel guns upon any point likely to be attacked.

On the 19th October Major Denfert-Rochereau, who had been in command of the Engineers, was appointed Commandant of the Fortress. This officer knew his defences thoroughly, and, unlike most French Commandants of fortresses, he understood how to utilize his resources for the conduct of an active defence. The principal measures taken by him were as follows:—

Before the enemy appeared an infantry reconnaissance was pushed forward two days' march towards him. The troops composing this advanced force consisted of detachments of infantry, and their orders were to delay the enemy's advance as much as possible. Thirty detachments, 2 to 5 companies strong, were employed. The total number of the advanced force was 6,000 men, or about a third of the garrison. To some of the detachments special duties were allotted, such as the destruction of the Dammerkirch railway viaduct, which considerably hampered the attack. Their general orders were to check the enemy's columns and force them to deploy, but not to offer an obstinate defence. When pressed they were, if possible, to escape to a flank and thence fire upon the flanks of the advancing columns, thus further delaying their movements.

A secondary object of these measures was the fire-training of the troops; the Commandant hoped to instil into them the elements of firediscipline, and to raise their morale by small successes. The country was well adapted to this nature of warfare, being difficult and for the most part wooded. Several bands of franc-tireurs assisted in annoying the enemy.

On the German side, the force told off for the siege of Belfort consisted of the First Reserve Division, reinforced by troops from the Fourth Reserve Division. The total besieging force consisted of 11 battalions, $7\frac{3}{4}$ squadrons, 4 batteries, 1 company pioneers, making a total of 10,000 men, or about half the strength of the garrison.

This force advanced from Muehlhausen on the 2nd November, and, after some skirmishes with the advanced troops, completed the investment on the 3rd. The advanced detachments had failed to offer any serious resistance, but had retired as soon as artillery fire was brought to bear upon them.

When the enemy appeared before the fortress the Commandant detailed a portion of the garrison to remain in the field. Their task was to prevent the closer approach of the enemy, to annoy him persistently, and to maintain touch with him in order to keep the defence informed of his dispositions. The points assigned as supports for the field force were Perouse, Dangoutin, Cravanche, the wooded eminence styled Le Haut du Mont, the village of La Forge, and the Bois de Miotte. This left a wide gap between Dangoutin and Le Haut du Mont. But the villages of Essert and Bavillars, between these two points, were not commanded by the guns of the defence, and were therefore considered unsuitable as supporting points. Moreover this front was considered of minor importance.

The investing line was established at a distance of 3 to $3\frac{1}{2}$ miles from the citadel—that is, within range of its guns. Its total extent was nearly 25 miles. With such a small force it was impossible to make the investment complete, and, as a matter of fact, the Commandant was able to communicate fully with the outer world up to the end of the siege.

On the 3rd November the besieged occupied the above-named supporting points with detachments of infantry varying from $1\frac{1}{2}$ to 8 companies strong, and posted a reserve of 13 companies behind the still unfinished Fort Bellevue. Their orders were to place these villages, etc., in a state of defence,* to threaten the nearest supporting points of the investing line, and to constantly harass the enemy by the action of small skirmishing patrols and local counter-attacks. The fortress guns kept up a constant fire upon the supporting points of the investing line. Shortly afterwards sorties on a large scale were organized and carried out; these had the effect of accustoming the raw troops of the defence to contact with the enemy. These vigorous measures were effective.

The besieging force was extended so that the investing line was too thin for its work; and it was still further weakened by the detachment of strong bodies to oppose the bands of franc-tireurs.

Thus the besiegers soon found themselves on the defensive, and the

* *Author's Note.*—It would appear, then, that the advanced works were anything but "entrenchments carefully prepared beforehand."

besieging General concluded that under these conditions the investment, if protracted, would result in disaster. He therefore applied for sufficient reinforcements to undertake a regular siege, and this request was granted.

On the 18th November the first guns of the siege train arrived. The subsequent history of the siege, up to the surrender of the fortress by the French Government in February, 1871, is outside the scope of the present essay; for the preliminary holding of the advanced positions thenceforward ceased to affect the conduct of the siege.

The effect of the defensive measures adopted may be summed up as follows:—The result achieved by the advanced force of 6,000 men was insignificant. They delayed the enemy for less than a day, and inflicted only a few casualties upon him. As a reconnaissance the operation was a failure. Thus the Commandant, although in communication with the outer world, estimated the besieging force at twice or thrice their real number. During the critical days of the conflict on the Lisaine this false information deterred him from co-operating with the relieving force.

The present French regulations bearing upon the point are as follows:—"When the fortress is first threatened the defence will send out a field force, leaving a minimum garrison for the defence of the place. The duties of this field force will be to drive back the besieger's advanced screen upon his main body, and to take his columns in flank. But the advanced troops must not allow themselves to be cut off from the fortress."

In the present instance the conditions were unusually favourable to these tactics. Yet the results were not such as to encourage us to imitate this procedure. If we take the only sound strategical view of the object of a fortress, and cut down the garrison assigned to it to the minimum necessary for defence, then we shall have no troops to spare for occasional offensive operations.

As regards the occupation of the foreground, it must be clearly understood that neither Fort Bellevue nor Les Perches can be looked upon as advanced positions. These works, although hastily constructed on the outbreak of war, were most important points in the girdle of forts. Each of the Perches forts was armed with seven 4·7" guns and garrisoned by a company of infantry, constituting it a strong independent fort.

In siege warfare it will frequently be necessary to strengthen the girdle of forts by new works. But a sharp distinction must be drawn between these and advanced works, although their design and construction may be much the same.

From the point of view of the defenders, the long duration of the siege of Belfort is not an argument in favour of works advanced beyond the girdle, but in favour of completion and perfection of the girdle itself. This is exemplified by the Perches forts, which were not stormed till the 8th February after a gallant defence.

The occupation of advanced positions no doubt caused some annoyance to the besieger. But the manner in which this was carried out at Belfort is much the same as the procedure of a line of outposts in the preliminary stages of a siege, except that the great circumference of a modern girdle of forts necessitates the supporting points being more thinly held than was the case at Belfort.

As regards the defence of the near foreground, at Belfort $44\frac{1}{2}$ companies (including the reserve), or 9,000 men, were sent out for this duty. This measure may be justified on the ground of the small extent of the place, the necessity of training the troops for war, and the greater facilities for quartering them outside the town. And moreover there still remained 6,000 men to garrison the fortress.

The strength of the supporting points held by the field force lay less in their garrisons than in the fact that they were fully commanded by the fortress guns at ranges averaging under 1,200 yards. So long as the besiegers possessed only field artillery it was useless to assault these villages, since they could not be held. Whenever the enemy's field guns attempted to engage the fortress guns they were quickly silenced. But so soon as the siege train arrived, these villages became necessary to the besieger as positions for his siege batteries, and his veteran troops had no difficulty in driving back the defending field force behind their forts.

The French regulations require that "the whole or greater part of the reserve troops of the defence should occupy advanced positions prepared in peace-time, and thence offer a stubborn resistance to the attack." But this is exactly what the Belfort garrison did *not* do. And Denfert-Rochereau, who knew his troops as well as his fortress, was quite right to avoid this procedure. He already knew that his Mobiles were quite unfit for work in the field; and his three battalions of regular infantry were too valuable as instructors for the raw troops, and as a reserve to be kept in hand for critical situations, to be wasted in fruitless combats in the outlying country.

PORT ARTHUR.

The events of this siege are so recent that they need not here be described.

From a military point of view the situation of Port Arthur at the beginning of the war was unique. The newest and most modern fortress in the world was to be attacked by the newest and most modern troops. Engineer officers looked forward to a real practical test of the latest theories in fortification. But when the real facts became known they were sadly disappointed.

Political considerations had led to the amount of money allotted to the defences being restricted. Accordingly the construction of the fortress had been based on two principles, both unsound,—

(1). In view of the restricted area enclosed by the girdle, the fact that the girdle forts were commanded by the surrounding heights must be accepted, and the girdle forts made proportionately strong.

(2). The country was too difficult to admit of the enemy bringing up heavy siege guns, and consequently the casemates might be built to resist medium siege ordnance only.

The first of these principles was difficult to put into practice, especially as the Russian authorities do not approve of the use of armour plates on land fronts. But both principles were violated when the Russians built an open harbour at Dalny, and connected it by rail to Port Arthur so as to facilitate the besieger's operations.

Thus on the outbreak of war the Russians possessed a fortress newly built indeed but of obsolete design. Its girdle was so restricted as to correspond from a modern point of view rather to the enceinte than to the chain of forts surrounding a fortified harbour. Even so the communications between the different forts were in a very incomplete state.

The object of the defence was therefore to gain time, at any price, for the completion of the fortifications. This could only be attained by using a force far in excess of that required by the limited extent of the defences. Accordingly we find a marked difference in the methods adopted at Port Arthur and at Belfort. The garrison of the former place had been fixed at 11,300 men; but actually we find two divisions, totalling 27 battalions of regular troops, allotted to the defence. This force was employed to dispute the advance of the besieger from Kinchow to the fortress—a distance of 30 miles as the crow flies. This task was facilitated by the narrowness of the Kuantung peninsula. The defenders had only to oppose frontal attacks upon a narrow strip of land, each flank resting on the sea. These conditions do not correspond with those applicable to a land fortress which is exposed to an enveloping attack.

Thus the siege of Port Arthur cannot be taken as exemplifying the success of the French methods; the more so that the advance of the besiegers was delayed by outside events. (These were the cessation of operations necessitated by the detachment of Oku's army; the insufficient numbers of the remaining (Nogi's) army; and the delay in the transport by sea of the siege train).

Six months after the outbreak of war the Japanese arrived before Port Arthur. They had thoroughly reconnoitred the place in peace-time; but when they saw the fortress again they hardly recognized it. The Russians, during the six months afforded them for preparation, had erected semi-permanent works on the hills which commanded the girdle forts. They had, in fact, *corrected* the line of their girdle, just as the defenders of Belfort did when they fortified Les Perches and the Bellevue plateau. The Russians also built true advanced works, such as the entrenchments on Wolf's Hill, which were carried in the course of the first attack on the 31st July, 1904.

The Russian works on the hills commanding the girdle forts were little more than field works; the lack of time and the difficulties of the ground prevented regular fortifications being erected. For this reason they were constructed in a double and treble line, one behind the other, and their garrisons were very large compared to those assigned to the permanent forts. These large garrisons were required in view of the necessity of keeping the forts constantly ready to resist an attack.

The fact that these works were constructed at tactically decisive points, and at a proper distance from the harbour to be protected, is demonstrated by the fierce and protracted struggle for the possession of 203-Mètre Hill.

The sensational revelations made by General Kimtschenko in the pages of the *Voïennyï Sbórnik* have attracted much attention. He writes:—"It has been erroneously supposed that the battles of November and December were contests for the possession of advanced works; and many people have hence been led to attach an exaggerated importance to advanced positions. Others, including myself, hold a different opinion. I consider them inconsistent in principle with the true theory of the construction and defence of a fortress. They are only admissible in special cases. In the case of Port Arthur the only justification for the construction of advanced works was the lamentable incompleteness of the permanent defences. If we remember that Nos. 1 and 2 redoubts, in the line of forts, were taken as early as the 22nd August, we shall form a truer idea of the importance to be attached to such advanced works."

The foregoing investigation has brought to light no facts to modify the opinions which we have already expressed as to the small value of advanced positions.

We wish to lay especial stress upon the point that the advisability of constructing advanced defences depends upon the circumstances of each particular case, and cannot be judged in the abstract. If anything is to be learnt from the writings of the extreme champions of such defences, it is that the besieger must always be prepared to meet with advanced works, and must take measures accordingly. Whether these works will assist or prejudice the defence is another question.

Our own Austrian fortresses are designed on the sound principle of enabling a small force to hold out for a long time against great superiority of numbers. In allotting their garrisons the first consideration is economy of force. In the defence of these fortresses the occupation of advanced positions must be considered as a double-edged weapon, to be handled with extreme caution. It is only applicable in case the carefully-prepared permanent fortifications of the girdle are insufficient for their purpose. And in such cases, where peace-time neglect has to be expiated by a heavy sacrifice of life, it will be well to remember that it is only the best troops of whom such sacrifices can be demanded.

The French regulations endeavour to lay down beforehand a system to meet all emergencies. It is just this rigid system of formation that we, in our service, have for years successfully combated. In the Art of War forms and systems are but passing fashions. The spirit which animates them survives in the maxims which will endure to the end of time. At Belfort as at Port Arthur and in every other heroically-fought siege the system of defence may be summed up in the one word—energy.

REVIEW.

MANUAL OF ROAD CONSTRUCTION AND MAINTENANCE.

By MAJOR E. M. PAUL, R.E.—($7\frac{1}{2} \times 5\frac{1}{2}$. School of Military Engineering, Chatham*).

MAJOR PAUL is to be congratulated on having produced, in a comparatively small volume, a valuable series of notes on the important subject of road construction and maintenance.

The subject is a large one, and one which R.E. officers everywhere are supposed to know; and yet the variety of the conditions is such that even those who are most experienced find there is always something new to be learnt in each successive place where they carry out construction or maintenance.

The author has wisely borne in mind the fact that road construction in civilised lands is different in practice, though not in principle or result, from the same work in wild and barbarous countries. As both these branches of the science of road engineering may fall at some time or other to any officer of the Corps, he has devoted attention to both. While drawing largely on the published experience of R.E. officers who have written or lectured on this subject, and whose experience is as varied as it is valuable, Major Paul has not confined himself to these, but has given information drawn from world-wide sources, based on his own extensive travels and wide professional study. The result is most satisfactory and the book should be of the utmost possible value to all.

The illustrations are clear and good. Some are photographs giving representations of work, finished or in progress; others are plans of culverts, cross sections, etc.; and others are charts. Some description of one or two of the plates (*e.g. Plate* V., illustrating a valuable graphic form of progress report) might have been added with advantage.

While thoroughly appreciating the care and thoroughness of the work as a whole, it may be as well to point out certain matters which, in the writer's opinion, are either capable of improvement or might be added with advantage.

In treating the subject of roads over marshy ground, more emphasis should be laid on the necessity of draining the site. The entire swamp should be drained, if possible; but if this is not possible, the surface on

* This is a provisional issue of 200 copies printed at the S.M.E., Chatham, *for* the use of Officers under Instruction. The book is not on sale.

which the road foundation is to rest must be drained, longitudinally as well as transversely. Money and labour spent on this is not thrown away. If the road is for the passage of heavy artillery or mechanical transport—now so largely used in our Home Army—the foundation must, for obvious reasons, be more secure than for light traffic; but in any case there must be as dry a bed as it is possible to obtain. If a dry bed cannot be obtained, and if corduroy floating is impossible, there will be no alternative but to provide piles or cribwork instead of a continuous foundation.

On soft, but not absolute marshy, ground a fair foundation for a causeway is sometimes procured by laying branches of fir across the site, with their thick ends outwards, *i.e.* towards the edges of the road. The interlacing of the small twigs in the middle forms a sort of raft for the next layer, which may be of logs or fascines.

In Chapter II., treating of prospecting in hilly countries, no mention is made of the not unusual case of having to carry out this work in dense forests where no extensive view can be had. This of course enhances the difficulty of the work. The surveyor here must rely on such compass bearings as he can take, supplemented by time calculations of the distance he has travelled and by careful aneroid observation of heights. This is probably the most difficult of all tasks in road alignment. If precipices intervene among the forests, the difficulty is increased. But there is no reason why, with a little patience and trial of a few alternative routes, the greatest success should not follow the reconnaissance; and ultimately the triumph is great, for nothing seems to the uninitiated so successful a piece of engineering as a well-graded and well-built mountain road through forests and precipices. Tracing in wooded country is referred to on page 32.

In considering the essentials for success in road construction, priority of consideration, and special emphasis, should be given to *tackling the difficult parts first.* This is important, both because these parts will usually take most time, and because the personal supervision of the superintending officer should be directed there. Once the difficult points are in a fair way to be conquered, the other and easier parts will seem child's play.

In considering the cross section of hill roads—a much-disputed matter—it is stated that, if a road is less than 16 ft. wide it should always be sloped inwards. In the opinion of the writer the limit of width should be 10 ft. Anything over that width should have one-third of the surface sloping outwards.

Dry river causeways are dealt with on page 28. More specific mention might have been made of "Irish bridges." These are of very frequent occurrence on hill roads and are very frequently made on wrong principles. The apron on the down-stream side is generally made too steep, with the result that falling water undermines it. The slope should not exceed 2 in 1, or 3 in 1 if the other is impracticable. Also the longitudinal slope of the road at the site of the level crossing should be level, so that, if obstruction should occur on the crossing, the water may not pour down the road and wreck it.

In considering the subject of maintenance some comparative statement as to the relative cost of machine and hand-breaking of metal might be given. In India it is cheaper to break metal by hand, but at home stations machine breaking is unquestionably cheaper. The road chart given on *Plate* IV. and described on p. 43 is excellent, and should be adopted in every military station.

Chapter IV., dealing with waterway and scour, touches on many vexed questions, all of which are of the utmost importance. The calculation of flood discharge based on catchment area and rainfall should never be omitted in considering the design of large bridges, and yet it must be confessed that it is seldom that such calculations are not upset by some abnormal rainfall. For culverts and small bridges there is no use cutting down the waterway to calculated maxima, so calculations there should include the highest known flood. But with large bridges the case is different.

Taking small culverts first, the author treats of slab culverts, but he does not mention a simple way of carrying out these by means of corbelling the slabs; such culverts can be built up to 5-ft. span. Another and useful form of bridge or culvert is formed of rails or rolled steel joists, with a flooring of corrugated iron sheets.

Arch culverts may be economically built wholly of concrete—a fact which is obvious, but is not stated in the book.

As regards the very difficult question of scour, treated on p. 75, it may be noted that experience on Indian mountain roads points to the conclusion that the larger the boulders in the bed of the river, the less deep does the scour proceed. In a river which has a sandy bed—like the Ganges at Benares—the foundations must be very deep (at Benares they are 150 ft.). In the Swat River at Chakdara the foundations of the Connaught Bridge are 34 ft., and (in the writer's opinion) might have been 10 ft. less. At the Kharmana Bridge in the Kurram Valley the foundations are 14 ft., in the Dor Bridge the deepest foundation is 20 ft., and yet the mean calculated flood velocity in the latter case is 17·5 feet per second. In view of this practice, which is admittedly empirical, Major Paul's restriction of the velocity to 5 or 6 feet, except in cases where the foundation is about 40 ft., errs on the side of caution. The subject is a very difficult one, and no rule has so far been established.

The Corps in general, and officers engaged on hill road construction in particular, have reason to be grateful to Major Paul for this publication.

G. K. SCOTT-MONCRIEFF.

NOTICES OF MAGAZINES.

Bulletin of the International Railway Congress.

August, 1906.

The Automatic Coupling Question.—The discussions which took place on this subject at the last Congress meeting were decidedly interesting, and are reported in full in this number. It seems to be generally admitted that automatic couplings will have to be introduced everywhere sooner or later, though European experience tends to show that the greater safety to employés attained is hardly likely to compare with that which accompanied the change from the link-and-pin to the M.C.B. coupler in the United States.

Colonel Yorke (late R.E.), of the Board of Trade, very pertinently raised the question of combining auto-coupling of the air-brake, etc., with that of the drawgear, and elicited the fact that in America the process of coupling up and testing brakes, after the wagons had coupled automatically, absorbed a considerable time—and this at large yards where complete trains were made up. Roadside shunting did not come much under consideration.

Of course in Europe the adoption of a system uniform for all railways of the same gauge is essential, that is excluding Russia and Spain.

In Russia some experience has actually been gained. On the Continent generally the difficulties foreseen as attending the transition stage seem to render it likely that some different type from the M.C.B. is more probable for adoption; and the Boirault coupler, which is being tried in France, seems favourably thought of, though indeed from the illustrations it seems to have a good many loose parts.

In a note a description is given of the A.B.C. or Jepson coupler, which has been seen by the present writer. This is particularly adaptable to replace the link-and-pin coupling.

It may be remarked that the question of expense is a very serious one, particularly where, as in England, there is much private-owned stock. The Northern Railway of France produced statistics showing that improved regulations as to handling traffic had done so much to reduce accidents that it seemed to that management doubtful whether the introduction of auto-couplers would justify their expense by the greater immunity from accident which might be expected.

C. E. Vickers.

ENGINEERING NEWS.

July 12th, 1906.

COAL TAR PAINT.—Mr. A. M. Cunningham, M. AM. S.C.E., draws attention to some experiments made at New Orleans, where tar is used a good deal for painting hulls. The difficulty about tar is that it contains many mineral acids and will not thoroughly dry in its raw state.

Various coal tar paints can be bought, and contain a number of substances as neutralizers and dryers.

The interesting discovery made was that ordinary kerosene (petroleum) will act as a dryer to coal tar.

The mixture, which is pronounced by the Government chemist to be non-injurious to iron or steel, was composed as follows (mixture varying somewhat with climate):—

	Coal Tar.	Portland Cement.	Kerosene.
New Orleans mixture	8	1	1
Annapolis mixture	16	4	3

First stir the Portland cement into the kerosene to a creamy mixture, and then stir into the tar. The paint should be kept freshly mixed and well stirred. It will unquestionably stick to galvanized iron.

July 26th, 1906.

A DISTINCTIVE DISTANT SIGNAL LAMP.—Trials are now being made in England with a lamp for Distant Signals, showing an illuminated fishtail at night. The luminous slot is lighted by reflection from the main lamp. The slot always shows white. In America it is the practice to use a different colour for Distant Signals.

C. E. VICKERS.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

July, 1906.

MILITARY BALLOONING.—A lecture by Lieut.-Colonel J. E. Capper, C.B., R.E., which, avoiding technical details, contained many facts and suggestions of interest to all arms.

The *physical defects* of balloons, apart from the apparatus, are obstacles to view and obstacles to movement, the latter causing delay but not insuperable. The greatest enemy to a captive balloon is a high wind, which prevents the attainment of a sufficient height, besides rendering observation difficult; a "twisting motion" also interferes with orientation and the location of points.

In the *British* Service a small spherical balloon, steadied by rope attachments from the top and sides to the cable, and usually carrying only one person, is used in light winds (up to 25 miles an hour); whilst man-lifting kites are employed when the wind is too strong for a balloon (up to 50 miles an hour).

The *French* use a larger spherical balloon, with the car suspended from a trapeze some distance below in order to prevent swinging.

The *Germans* attempt to overcome unsteadiness by an elongated balloon rigged like a kite and kept head on to the wind. This requires treble the personnel for handling and double the transport of the British balloon, and the numerous ropes render it more liable to damage by shell fire.

The *British equipment* requires 5 wagons (with their horses and drivers) and 19 N.C.O.s and men to fill one balloon or put up one set of kites quickly. A well-trained detachment can unpack a balloon and send it up in 25 minutes. On a calm day 2 men can ascend up to 1,500 feet. The kites are also satisfactory up to 1,500 feet (the record height being 3,000 feet by Lieut. P. W. Broke Smith, R.E.).

The *tactical uses* of a captive balloon are:—

1. The obtaining of information.
2. The infliction of damage by directing artillery fire.
3. The indirect moral effect of preventing turning movements and surprises.

For (1) *obtaining information* it is found that one man by himself, provided he is a trained observer and knows what to observe, is more successful than two men; but two hours at a time is the limit of endurance.

In flat open country large bodies of troops can be seen at 15 miles distance, but their nature (*i.e.* cavalry or infantry, etc.) cannot be distinguished.

In fairly open and undulating country, single battalions, squadrons, or batteries can be distinguished in clear weather, at from 4 to 6 miles; infantry in open formation at from 2 to 3 miles. The former figures apply also to entrenchments, when troops are moving about in them; but otherwise only the general lines can be made out at these distances.

Fairly good eye sketches of country are possible up to from 4 to 8 miles. In this respect it is suggested that all military maps should be divided into squares, in order to facilitate the transmission of information as to the location of troops or their movements.

The results of photographs from balloons have been so far unsatisfactory, because it is impossible at present to obtain prints with sufficient rapidity for practical use.

For (2) the *direction of artillery fire* the balloon ascends close behind the position to be occupied by the guns; and the observer aligns two men on the ground below him by signalling with different coloured flags. With practice a line with an average error of 1° can be given in about 3 minutes.

The balloon is connected with the battery commander by telephone; and by the observer reporting the approximate distance short or over of each ranging shot, the target can generally be reached at the 5th to 7th round.

Observation of fire is easier from balloons than from the ground. In practices it has been found that the number of unobserved shots have been —17·8 per cent. out of 400 observed from the ground, 3·9 per cent. out of 700 observed from a balloon. In the same practices the percentages of rounds wrongly observed as over or short were 6 from the ground and 1 from the balloon.

On the march the position of a Balloon Company should normally be with the advanced guard. But the balloon would rarely be kept filled, except in very open country where it might save much scouting work by mounted troops.

In the attack the first aim of the balloon should be to locate the positions of the enemy's artillery, trenches, reserves, and massed cavalry. The balloon officer should be allowed to go as far forward as he wishes, for he must take some risks in order to obtain the best results. Even by drawing the hostile artillery fire, he may locate guns that would otherwise have remained concealed.

The safety of the balloon detachment must be secured by neighbouring troops reporting to the observer when any of the enemy are in close proximity.

In the defence also the balloon officer should be permitted to ascend where he likes. With a wind blowing from the enemy he can be well in front, if covered by advanced troops; and can eventually retire by going free. With an adverse wind the balloon must be hauled back, and the obstacles for such movement will influence the site for the balloon.

The *pace* of movement of an unfilled balloon with its gas is rather slower than that of field artillery. When filled, however, movement against wind or in close country is very slow; roads bordered with trees cannot ordinarily be used, and telegraph wires and buildings may necessitate long detours.

The question of *vulnerability* against fire has not been determined. It is, however, proved that shrapnel will rarely bring a balloon down with a run, and that even a considerable number of rifle bullets will not do material damage. Pom-poms might have the worst effect. Kites will probably be even more difficult to disable.

Transmission of intelligence must be arranged on a proper system, the telephone supplemented by signals. With a good system the general officer commanding has the advantage of the observer's position; without it the observer is little more than an interested spectator.

Co-operation with the Intelligence Staff.—Perhaps the most important part of the lecture is the plea that the observer must be in the very closest touch with the Intelligence Branch. He can only look in one direction at a time; and, unless he knows the military situation, he may waste time in observing what is already known and fail to observe something of supreme importance.

It is essential that officers of the General Staff should be trained to observe; unless and until this is done the duty must devolve on the balloon officer. The common supposition that captive balloon work is very incommoding to one's interior is a mistake as regards short ascents under normal conditions; only about one per cent. of people that go up under such conditions are affected by the height or the motion.

Signal balloons, small ones with simple signals, might be of great advantage in war, as messages can by this means be transmitted rapidly and simultaneously to troops separated by considerable distances.

Free balloons have very limited uses in war, as they are entirely at the mercy of the winds. Information might only be gained at the expense of sacrificing the balloon and observer, and even then it might be difficult to convey the information back.

Dirigible balloons will have to be faced in wars in the near future. Lebaudy's balloon has gone 40 miles in 2½ hours, and proved that an air-ship can, in light winds, proceed to desired points and return. Such an apparatus is, however, excessively vulnerable, as it is only by retaining its shape that it can make head against the air, and a few punctures would soon alter that shape.

Flying machines or propelled aeroplanes (motor-driven kites)—Valuable experiments in many parts of the world have shown that we may expect to see the problem of aerial flight solved within the next few years; over 20 miles in one flight has already been achieved. All such movement is relative to the air; a machine powerful enough to move at 50 miles an hour might hover in one place with the air moving at the same rate in a contrary direction; but going with the same wind it might travel 100 miles an hour. When such machines are perfected, war will be brought so close to the peaceful citizen and be so dreaded that the aeronaut may eventually prove to be the creator of universal peace.

A. T. MOORE.

NATURE.

August.

THE CONSTITUTION OF THE EARTH (p. 360).—Professor Griffiths, in his opening address in the Physical section of the British Association meeting at York, gave an interesting review of the advances made in science during the last quarter of a century. The discovery of radium and its effects on the temperature of the earth drives us to one of two assumptions; either (*a*) that the rate of heat production by radium diminishes as we approach the centre of the earth; or (*b*) that the interior of the earth differs markedly in constitution from the exterior crust. From known data it has been shown that the maximum temperature at the bottom of a crust of about 45 miles in thickness must be about 1,530° C., *i.e.*, about the melting point of platinum. Such a crust would contain about one-thirtieth of the earth's volume, and the whole of the central portion of the earth must consist of non-radio-active substances at this temperature. Professor Darwin has pointed out that while there is some evidence of a tidal yielding of the earth's mass, that yielding is certainly small, and that the effective rigidity is at least as great as that of steel; this has been confirmed by Professor Newcomb by his discovery of the prolongation of the Eulerian Nutation from 305 to 430 days.

The difference in the rate of propagation of earthquake waves through the earth's interior and through the crust has led Professor Milne to the conclusion that the material below a depth of about thirty miles is of a uniform nature and that the change in physical constitution is abrupt at that depth; for chords which lie within a depth of 30 miles the recorded tremor-speeds do not exceed those which we should expect for waves of compression in rocky material; beneath this limit there is probably a fairly homogeneous nucleus with a high rigidity transmitting waves with great rapidity.

Geodetical observations made by Colonel Burrard, R.E., in India have shown by pendulum and plumb line experiments that the density of the earth's crust is variable, but that the variations in density do not probably extend to greater depths than 30 or 40 miles.

It is interesting to notice the agreement between results drawn from such dissimilar sources. It justifies the belief that some marked physical change in the earth's constitution occurs at a depth of about 40 miles, the core consisting of a non-radio-active substance with a rigidity approaching that of steel, with a temperature of 1,500° C. and a density of about 5·6. The lecturer, after stating that it is generally admitted that during the last 25 years the increase in our "natural knowledge" has been greater than in any previous quarter of a century, indicated what appeared to him to explain the mystery of this acceleration, namely, the *extension of our senses* by mechanical appliances; when we supplement our eyes by the bolometer and the electric coherer, the range of our vision is augmented a thousandfold. By the use of the electroscope and the galvanometer we have extended our senses of sight and touch until we can detect the presence of an electron. One hundred millionth of a degree C. is now appreciable.

ARTIFICIAL RUBBER.—It was stated (p. 365) at the B.A.S. that chemical science will sooner or later be able to take a definite step towards the production of rubber by artificial means. The production of caoutchouc by chemical means has, indeed, virtually been accomplished in its formation from isoprene, but the exact nature of the change has still to be determined.

POISONOUS PLANTS.—During the first British expedition to the Sudan against the Mahdi, a number of transport animals were poisoned through eating a small vetch which springs up in the Nile valley during the fall of the river. The plant is well known to the Arabs by whom it is used when fully grown as fodder for animals. Dr. Henry has proved that the young plant generates prussic acid when crushed with water. It was found to contain a new glucoside together with an enzyme decomposing it into prussic acid and dextrose, thus accounting for its poisonous qualities.

"MODERN TUNNEL PRACTICE" (p. 409).—Mr. Stauffer, the author of this book, is an American engineer in New York, but he is also enrolled as a member of our Institution of Civil Engineers in London, and has had much practical experience of the difficulties of tunnelling. The use of explosives is gone into very fully, and the effects upon the workmen from the products of combustion of the explosives are referred to and instructions are given as to remedies. Ventilation is well considered. The extended use which is being made everywhere of concrete in cement is described. Even subaqueous tunnels, such as that at Boston, are being wholly constructed of concrete and loaded to the extent of 15 tons per square foot.

Tunnels are difficult and costly and should be avoided if possible, but the author mentions a well-known case in South America in which the engineers deliberately ran their railway into a mountain in order that their country should not retain the notoriety of not possessing a single work of the kind. Over the portal of that tunnel is marked in large letters — "This is the first tunnel in the country."

W. E. WARRAND.

REVUE DU GÉNIE MILITAIRE.

August, 1906.

DIRIGIBLE BALLOONS.—This is a continuation of the article published in the July number. The author concludes his investigation of the shape of balloons, and then proceeds to discuss the use of 'ballonets.'

These are small air receptacles of various shapes fixed inside the balloon. By pumping air into the ballonet it is possible to keep the balloon always fully distended. This is of the greatest importance with elongated balloons, as they lose their shape and stability if the envelope is not kept taut by an excess of internal pressure. The capacity of the 'ballonet' should not be less than one-sixth of that of the whole balloon. The author prefers a ring-shaped ballonet, fitted inside the lower portion of the envelope, though this form has seldom been tried with elongated balloons. The ballonet should have a safety valve, opening at a slightly lower pressure than the gas valve. The air pump which fills the ballonet should supply air fast enough to compensate for a descent at the rate of ten feet a second; it should not be driven by the main engine, but should have a motor of its own.

The method of suspending the car is a matter of great importance. As a rule it is now attached directly to the envelope. Each tie should form a tangent to the surface of the envelope, so that the tension shall not distort the shape of the balloon. The ties are sometimes made of piano wire, but it is difficult to fasten this securely; light cables composed of several strands of piano wire are more pliable, but they offer a greater resistance to the wind. It is most important that the car should be rigidly supported by a system of diagonal ties, otherwise the pitching motion of the balloon will break one tie after another. In addition to this, the weight of the car must be equally distributed over the whole of the envelope, or the shape of the latter will be distorted.

The car should be of medium length, and constructed of angle-iron and steel tubes. The screw shaft should be fixed between the car and the balloon, as near as possible to the centre of wind pressure on the whole system. All parts of the motor and mechanism should be as flexible as possible, so that they will yield, without breaking, to the various cross strains that will be put upon them. The rudder should be rigid, and long in comparison with its horizontal breadth.

The author next commences a mathematical investigation of the stability of elongated balloons. The article will be continued in the September number.

THE WATER SUPPLY OF LAGHOUAT.—The water is collected in a shallow tunnel, sunk in the sand, near the bed of the river, some three miles above the town. From the collecting tunnel, it is carried by a line of 6-in. glazed earthenware pipes to the distributing reservoir.

THE SIEGE OF PORT ARTHUR.—In the September and October, 1905, numbers of the *Eenzhenernee Zhoornal* appeared some notes, by Capt. A. B. von Schwarz, of the Russian Engineers, on the siege of Port Arthur. These were translated by Major Skey, and published in the *R.E. Journal* for June, 1906. The *Revue du Génie Militaire* now gives a translation of part of Major Skey's translation.

J. E. E. CRASTER.

RIVISTA DI ARTIGLIERIA E GENIO.

June, 1906

AERONAUTICS (*Conference at Rome in April*, 1906).—During the last months of the past year the dirigible balloon of the brothers Lebaudy was the subject of a programme of military experiments under the control of a commission nominated by the French Government with a view to ascertain the value in warfare of these aerial ships.

Starting from the riding school of the 13th Artillery at Toul, where the damage that it had sustained in previous trials had been repaired, the balloon, under the direction of the pilot Juchmès, and carrying Commandant Bouttiaux and Captain Voyer of the commission, undertook for several days a complete reconnaissance of the strongly fortified place of Toul, taking photographs of the works, and throwing search lights on the forts. In consequence of this demonstration and the reports of the military judges, the French Government immediately purchased the dirigible Lebaudy, and ordered the construction of new models.

This caused a lively commotion in aeronautic circles as the ardent hopes of the more knowing of the members seemed to have been fulfilled. All those in favour of the dirigible exulted in the joyful news that a machine had been constructed which obeyed with docility all the wishes of the aeronauts.

A few days after the successful affair at the forts of Toul, important news came from America: the brothers Willbour and Orville Wright, noted for their long experience with flying planes, had made on their aerial ship a magnificent flight of 29 km. in 33 minutes, followed by many others of less length, all ending for reasons independent of stability, and perfect as regards the requirements of safety. This notice was at first received in Europe as mere American *bluff*, but it was soon confirmed, and the importance of the discovery of the brothers Wright was placed beyond doubt.

This new and unexpected fact increased in its turn the enthusiasm of the adversaries of the dirigible. It was followed by a lively movement in favour of aeroplanes, to an extent that some constructors of the dirigible contemplated changing the direction of their studies.

At the same time the brothers Dufaux were working at a machine—the *hélicoptère*, another flying machine, neither a dirigible nor an aeroplane—and produced noteworthy results; and the Buchet workshops constructed a motor of 30 H.P. weighing only 45 kg. and promised one of 100 H.P. not weighing more than 100 kg.; and this, being in accordance with the theory of Renard on the construction of a light screw with centrifugal force, rendered at once mechanically possible a machine, of the type Forlanini, which up to yesterday seemed a mere utopian idea.

Now Santos Dumont has become imbued with the new idea; forgetting that in his book "Dans l'Air" he had advocated the gas dirigible as the flying machine of the future, he has set himself to work with his usual alacrity to construct a *hélicoptère*.

Thus, while even during the past year the promoters of these three systems of aerial navigation, so profoundly different, for the best and soundest reasons were working one against the other, and satirical journals as well as serious people sneered at the three contending parties and their methods, all at once the dirigibles, the aeroplanes, and the *hélicoptères* entered into the region of possibilities, the contending inventors remaining at peace and the satirists and serious persons suddenly changing their tone to one of enthusiastic praise.

It is easy to imagine with what a fervent revival of hope these sudden discoveries have been received in the aeronautic world. The "aero clubs," which have been instituted at various places in Europe and elsewhere, have received an addition to their members. The inventors and the students of the new science, who may be counted by hundreds, publish every month the result of their studies, courteously criticising one another, and considering themselves to be an important factor in the great problem. Journals and reviews launch out in technical descriptions, regarding as ardent the prospects of the application to industry and warfare of the new discovery. Prizes are promised and courses are arranged in which a "Gordon Bennet Cup" awaits the best course made in the air.

In fact the moment may without exaggeration be described as solemn; since, among all the fanciful rhetoric, it can no longer be denied that a new method of human locomotion may in the near future become of noteworthy importance in the relations of civil life.

June and July, 1906.

AERONAUTICS.—The June number contained a paper, read at the Conference on Aeronautics at Rome in April last by A. Crocco, lieutenant of Engineers, in which reference was made to Lebaudy's dirigible balloon, to the aeroplanes of the brothers Wright, and to other aerial machines.

The dirigible "Lebaudy" is the only balloon of the kind which can at present be spoken of as deserving great merit. Emerging from the many unfortunate and rudimentary attempts that had previously been made, the dirigible invented by the engineer Julliot is the one which displays a real progress in aeronautical science, and is the one to which the brothers Lebaudy have given their name.

This balloon, which is a marvel of docility, is not the issue of a flight of genius, as has been supposed, but is the result of seven years of study, of trials and modifications imposed by a diligent observation of facts.

The first pattern of "Lebaudy," which received its baptism of the air in 1902, was of a somewhat unsymmetrical form, and was not capable of executing evolutions or of direction. It could not in fact be properly called dirigible. In making the direction of the balloon depend upon the variability of thrust of two great lateral screw propellers the dynamical error became at once apparent and the balloon was then provided with a vertical rudder and a fin, which acted in the same manner as the keel of a ship.

The airship of the engineer Julliot has made many voyages; it has navigated the air as ships do the sea; it has moved by the propulsion of its small screw, actuated by a Daimler motor of 40 H.P., with a velocity of 40 km. an hour, which is about the medium speed of automobiles on ordinary roads and of many Italian railway trains. A description of the Lebaudy dirigible is given in the number of the *Rivista* for December, 1905, p. 430.

The description of this balloon, as well as that of Di Schio and others, would be of too great length for insertion in the *R.E. Journal*, and would not be intelligible without diagrams and photographs; so we pass now to the aeroplane of the brothers Wright.

Towards the end of 1903 the Wrights, having completed after many trials and experiments the first part of their proof (which had been known before to Lilienthal) of how to preserve the equilibrium of the aeroplane, commenced the second part of how to provide it with a motor.

On the 17th December, 1903, an aeroplane, weighing about 340 kg. and equipped with screw propellers and a motor of 16 H.P., performed with perfect equilibrium its first aerial flight, lasting about a minute, in a violent storm, the force of the wind being 12 mètres per second. This marked a memorable date in the history of aerial navigation, since it signalled the day on which a flying machine carrying a man had actually flown.

In 1901 Captain Ferber, attached to enormous planes in the form of the wings of a bat, had launched himself from a high tower, and succeeded in reaching the ground safely. Afterwards, in 1903 and 1905, he made further trials, having equipped his new machine with two propellers revolving inversely, and succeeded in making flights of more or less duration. Many other inventors, among whom may be mentioned the names of Pelleterie, Berger, Barin, Robart, Levasseur, and Archdeacon, have constructed and experimented with flying machines, and descriptions with photographs of several of these machines were given at the lecture.

But now the great mass of experiments were upset by the notice coming from America of the marvellous aeroplane of the brothers Wright. They wrote an important letter to Captain Ferber, in which they narrated having made ascents with their aeroplane five times in succession, covering a distance varying from 20 to 40 km., and with a velocity of 40 km. an hour. They offered their machine to the French Government. The negotiations for the sale did not, however, come to a satisfactory conclusion, and it is believed that the machine was acquired by a French syndicate.

At the present time, after centuries of effort, three fundamental types of flying machines stand, as it were together, to assert the dominion of the air. Which of these three will triumph in the experiments? It may seem vain to interrogate nature; she has neither created dirigibles nor aeroplanes. But perhaps she has indicated the solution of the problem by human beings, in the great birds, and especially also the small ones, which are able to close and spread their wings like an aeroplane, and in the insects, which have all the properties of small hélicoptères.

THE IMPORTANCE OF THE ART OF DEFENCE.—The July number contains an excellent article by E. Rocchi, Colonel of Engineers, under this title. The ancient tactics of siege warfare are still applicable at the commencement of the XXth century. These are the covered ways and trenches, which bring the besiegers within 60 mètres of the works, and the galleries excavated in the rocks, which open the way to the assaulting columns. The works of the sap and the mine, which passed out of fashion, are returning with honour, and thanks to technical resources are again coming to the front in siege tactics.

The obstacles to the assault—scarped walls, earthworks, and other more modern defences—may be damaged and overturned by artillery fire; but the action of the latter, powerful though it may be, will not bring about the total destruction and razing to the ground which is necessary for the success of the assault. Nor is it possible to do more by means of the mine, which can only be effective after the approaches have been carried as far as the covered way and the obstacles have been removed.

Simplicity and concealment of the work being the main idea in the defence, the ditch, which up to the present time has been considered an essential of fortification, may not in all cases be found indispensable. In certain conditions of the ground the ditch may contribute to expose the work from a distance. Leaving however the ditch, which may in many cases draw the enemy's fire, the near and immediate vicinity of the defensive works may be provided with barbed wire entanglements and other obstacles, subject to the fire of rifles and mitrailleuses. Ten years ago, with rifles of slow fire and high trajectories, it might have seemed absurd to trust to rifle fire for the immediate defence of a fortified work; but with the quick-firing rifles of to-day with their very low trajectories, this idea, as has been proved in war, is perfectly realizable and conforms to the active character of the defence.

Several important details of the Siege of Port Arthur, are described in this article.

E. T. THACKERAY.

RECENT PUBLICATIONS.

From Libau to Tsushima. A narrative of the Voyage of Admiral Rojdestvensky's Fleet to Eastern Seas, including a detailed account of the Dogger Bank incident. By the late Eugène S. Politovsky, Engineer-in-Chief to the Squadron; translated by Major F. R. Godfrey, R.M.L.I. (6s. Murray).

La Guerre Navale Moderne: De Lissa à Tsoushima, par Michel Mérys (G. Blanchon, late Lieut. French Navy). (3 frs. Challamel, Paris).

Die Kämpfe der deutschen Truppen in Südwest-afrika. Drittes heft. Der Entscheidungskampf am Waterberg: Der Untergang des Hererovolkes. von grossen Generalstabes. (55pf. Mittler, Berlin).

Examinations in Military Engineering. Specially arranged for officers studying for Promotion, Staff College, and Militia Competitive Exams., by Major E. C. Heath, 3rd Bn. Sherwood Foresters. (9 × 6. 1s. 8d. Christophers).

Examinations in Combined Training, by Major E. C. Heath, 3rd Bn. Sherwood Foresters. (9 × 6. 1s. 8d. Christophers).

Deutschlands koloniale Wehrmacht in ihrer gegenwärtigen Organisation und Schlagfähigkeit, von einem höheren Offizier. (5 mks. v. Decker, Berlin).

Working Hints for Suction Gas Producers, by A. Flurscheim. (Office of *Gas and Oil Engine Record*).

Report on Errors in Workmanship, published for the Engineering Standards Committee. (10s. 6d. Crosby, Lockwood)

Lift Irrigation, by A. Chatterton. (7½ × 5. 4s. Nateson, Madras).

The Practical Telephone Handbook and Guide to the Telephone Exchange, by J. Poole. 3rd edition, entirely re-written. (6s. Whittaker & Co.).

Applied Electricity, by J. Payley Yorke. (7½ × 5. 7s. 6d. Arnold).

A Manual of Hydraulics, by R. Busquet, translated by A. H. Peake. (7½ × 5. 7s. 6d. Arnold).

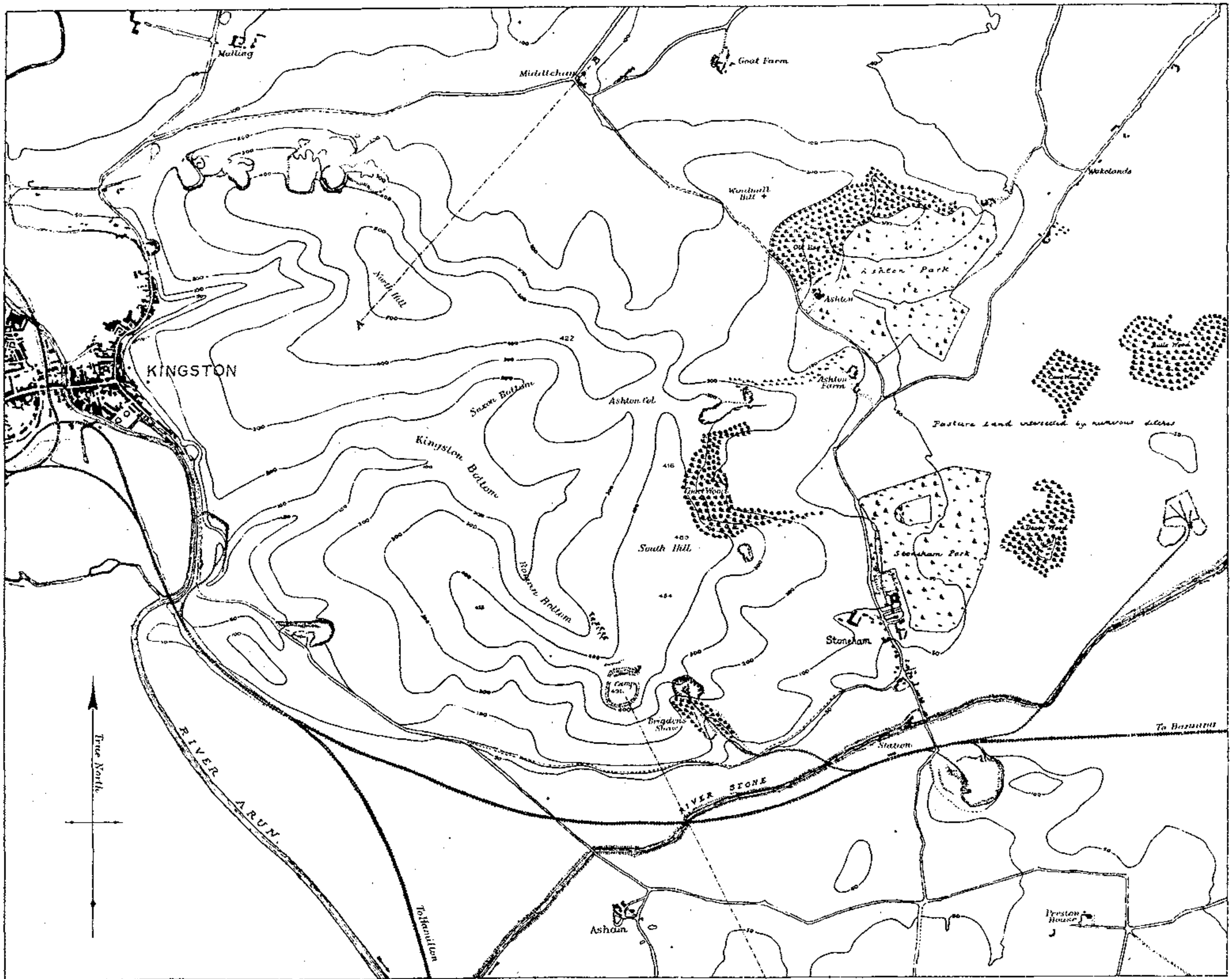
Mathematical Drawing, by G. M. Minchin, F.R.S., and J. B. Dale. (8½ × 5½. 7s. 6d. Arnold).

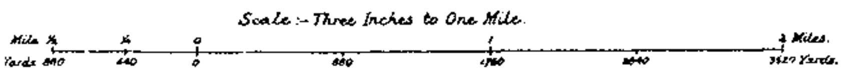
How to Learn on Shore the Rule of the Road at Sea, by E. W. Owens, F.R.A.S. (8½ × 5½. 3s. 6d. Philip & Son).

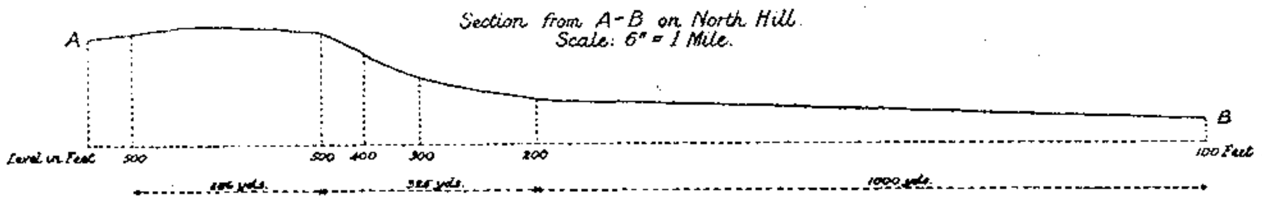
Uganda to Khartoum, by A. B. Lloyd. (9 × 6. 10s. 6d. Unwin).

Carthage and Tunis, by Douglas Sladen. 2 vols. (24s. Hutchinson).

DEFENCE OF POSITION ON OPEN GROUND







NOTE. To avoid confusing the contours, the fences have been omitted.

Below the 50' contour the country is practically dead level, consisting of marshy fields with numerous small ditches.

Between the 50' and 200' contours are cultivated fields, with low hedges about 250 yds. apart.

Above the 200' contour is open grass land.

South-east of the Position is a ridge running due east and west, its summits varying from 600' to 800' in height; the western-most height of this ridge is Asham Hill, 625' high, 3,500 yds. south-east of the "Camp" on South Hill. Except for this ridge the country north and east of the Position is practically dead level for several miles.

The River Arun is unfordable everywhere; the River Stone is unfordable up to a point 1 mile due east of Wakelands.

NEW METHODS OF LIGHT FIREPROOF CONSTRUCTION.

ig. 1.

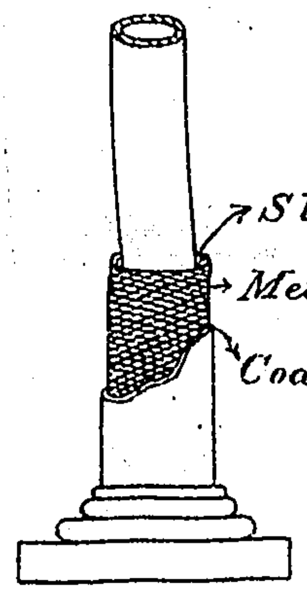


Fig. 3

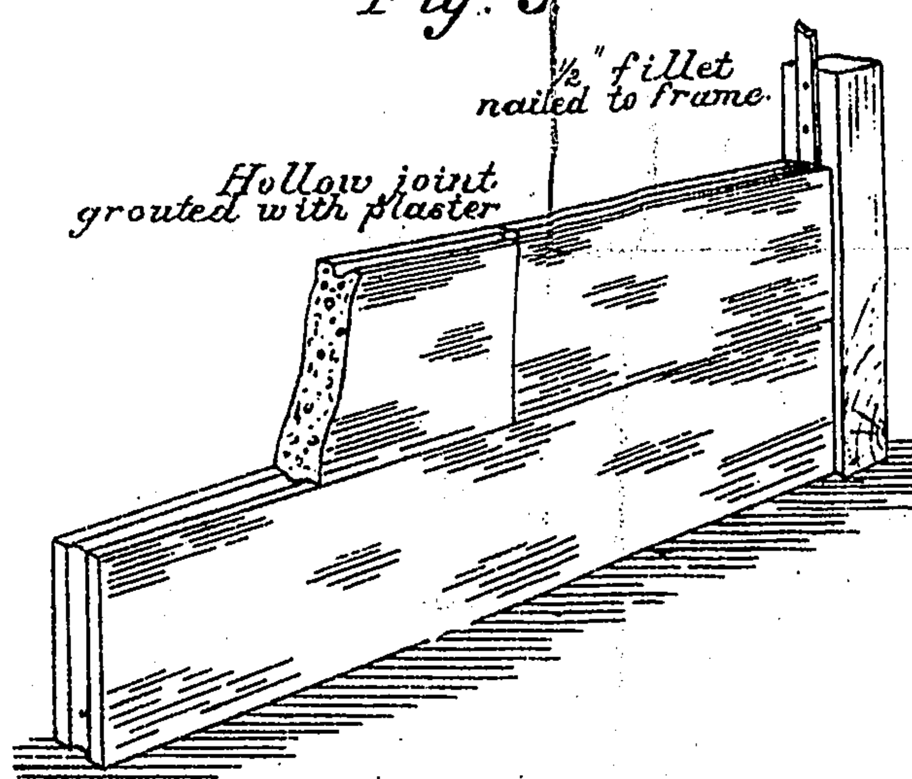
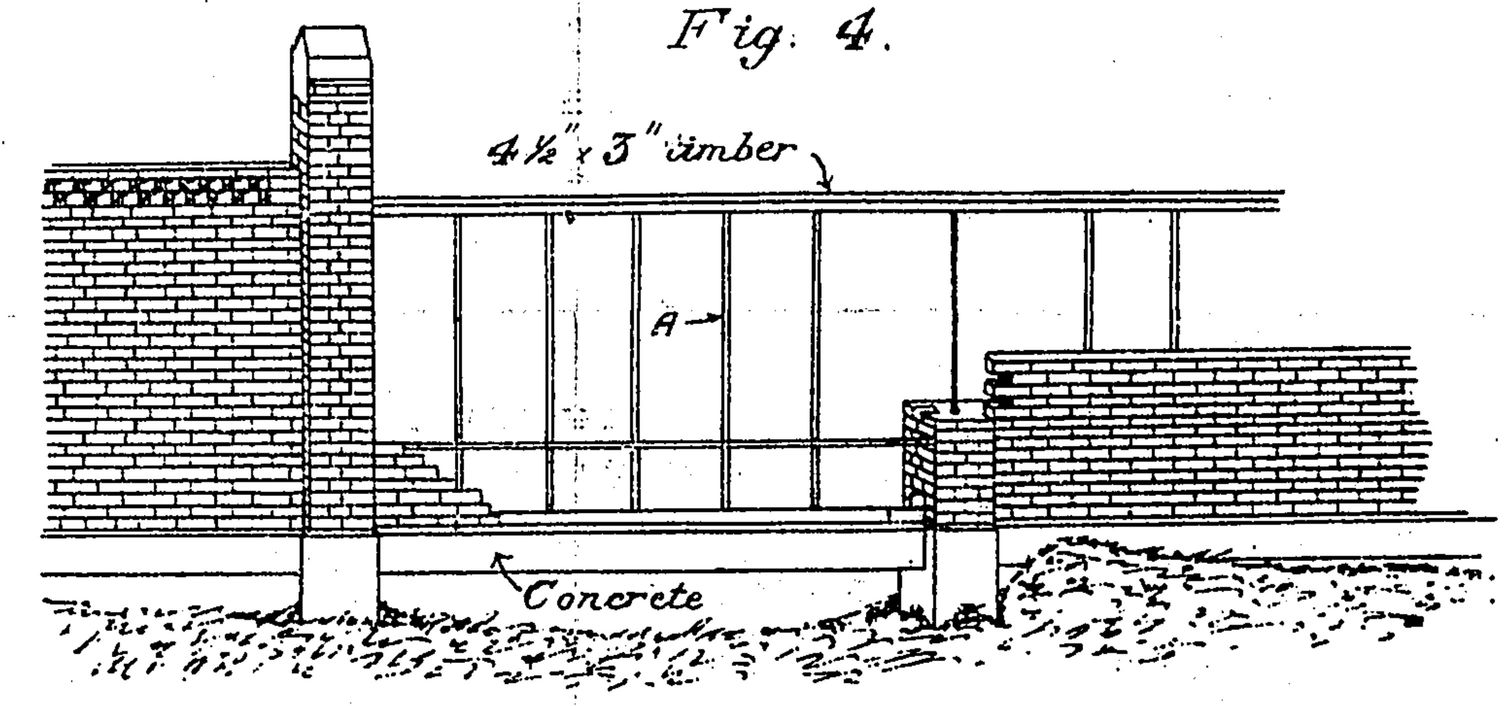
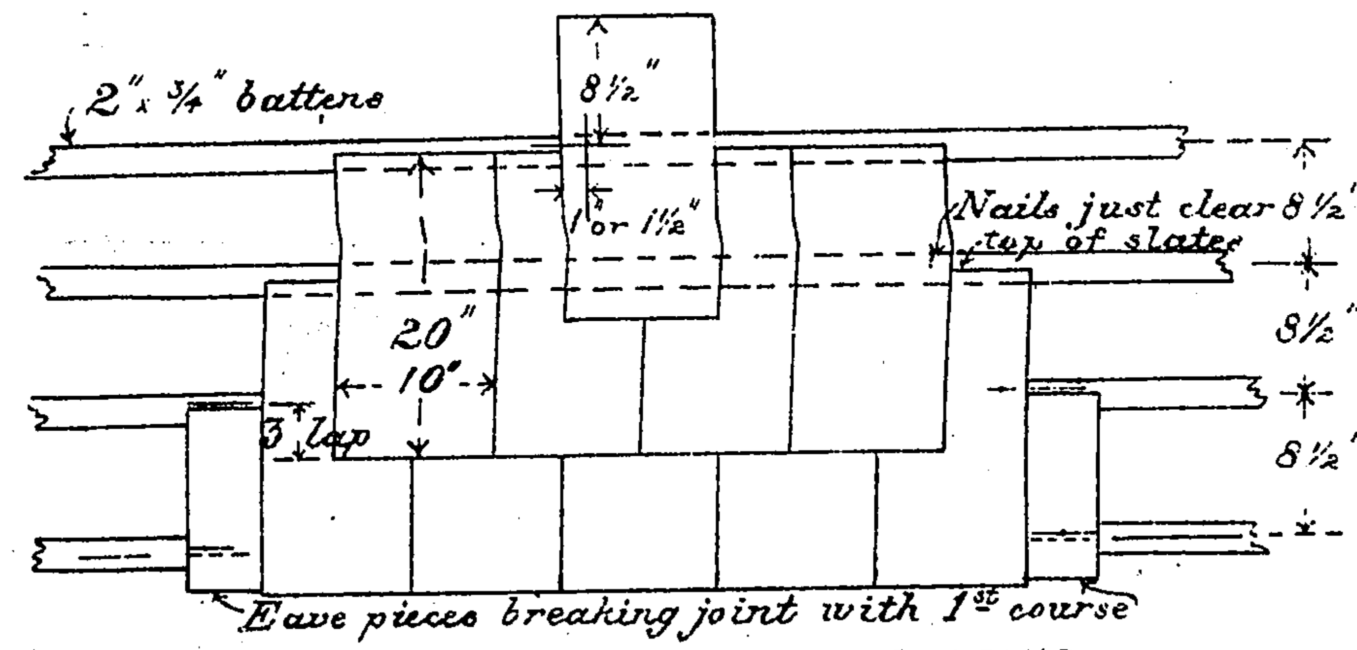


Fig. 4.



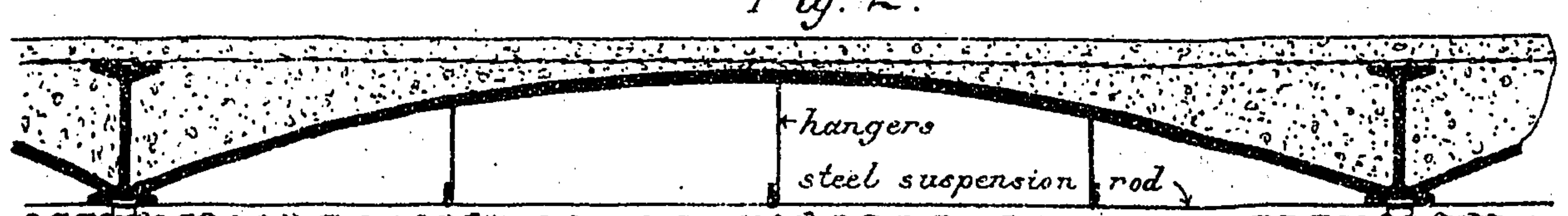
A is hoop iron, 18" interval

Fig. 7.



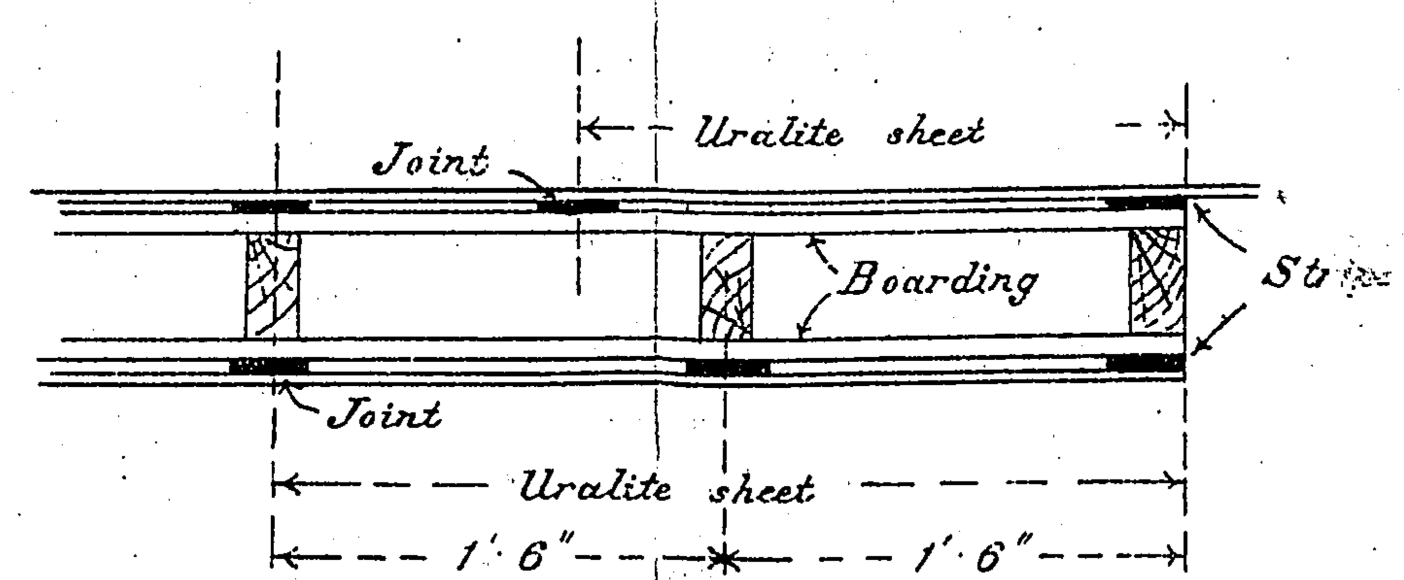
ARRANGEMENT OF SLATE ROOFING.
⅛" Countess sheets 20" x 10" x 3" lap.
Any slate size supplied.

Fig. 2.



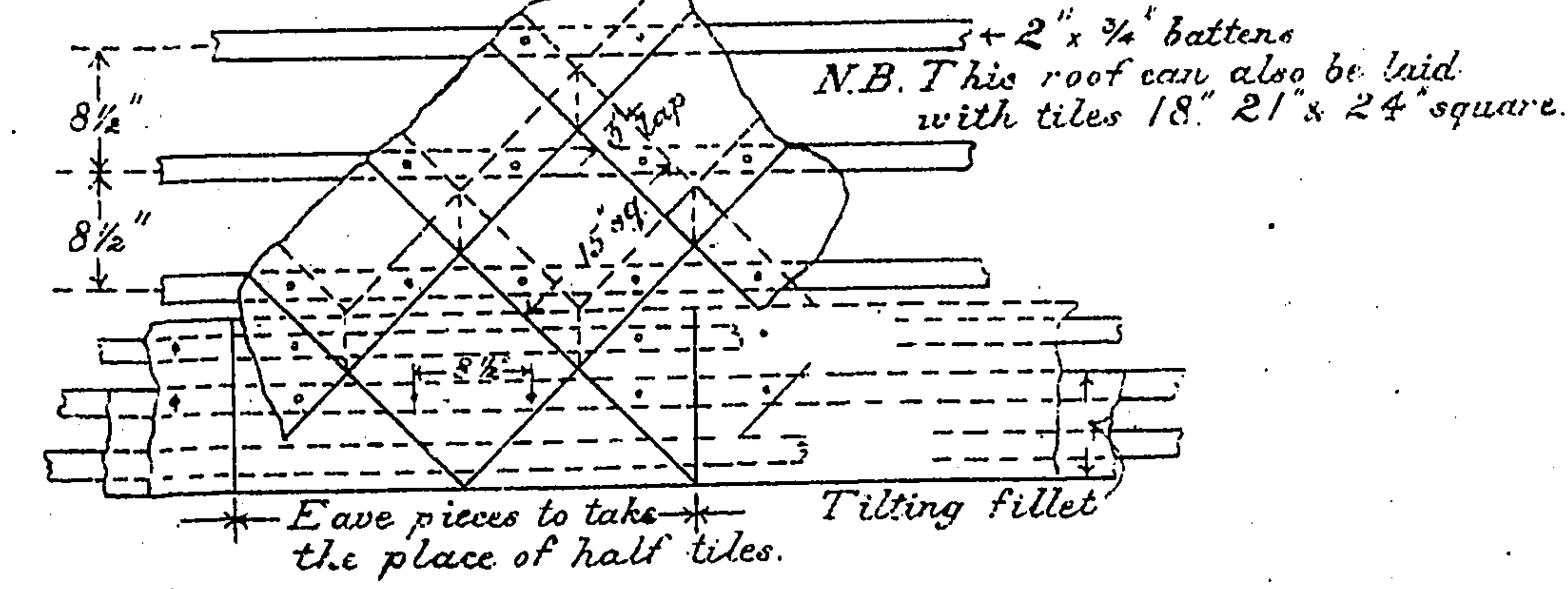
SECTION THROUGH REINFORCED CONCRETE FLOOR, EXPANDED METAL LATHING SUPPORTED BY WIRE FROM SUSPENSION RODS.

Fig. 5.



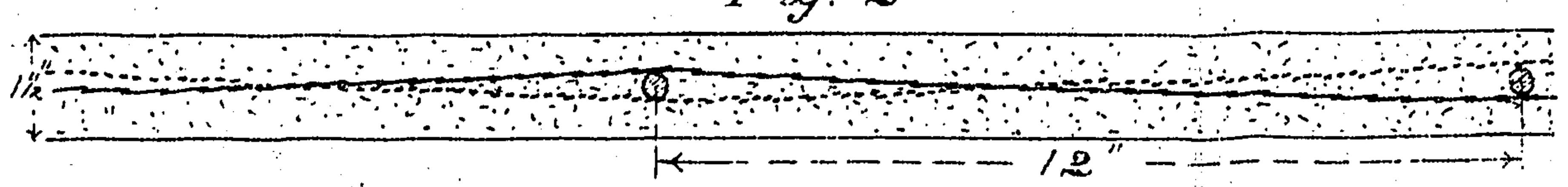
SECTION OF BOARDED PARTITION.
Shewing method of covering one or both sides

Fig. 8.



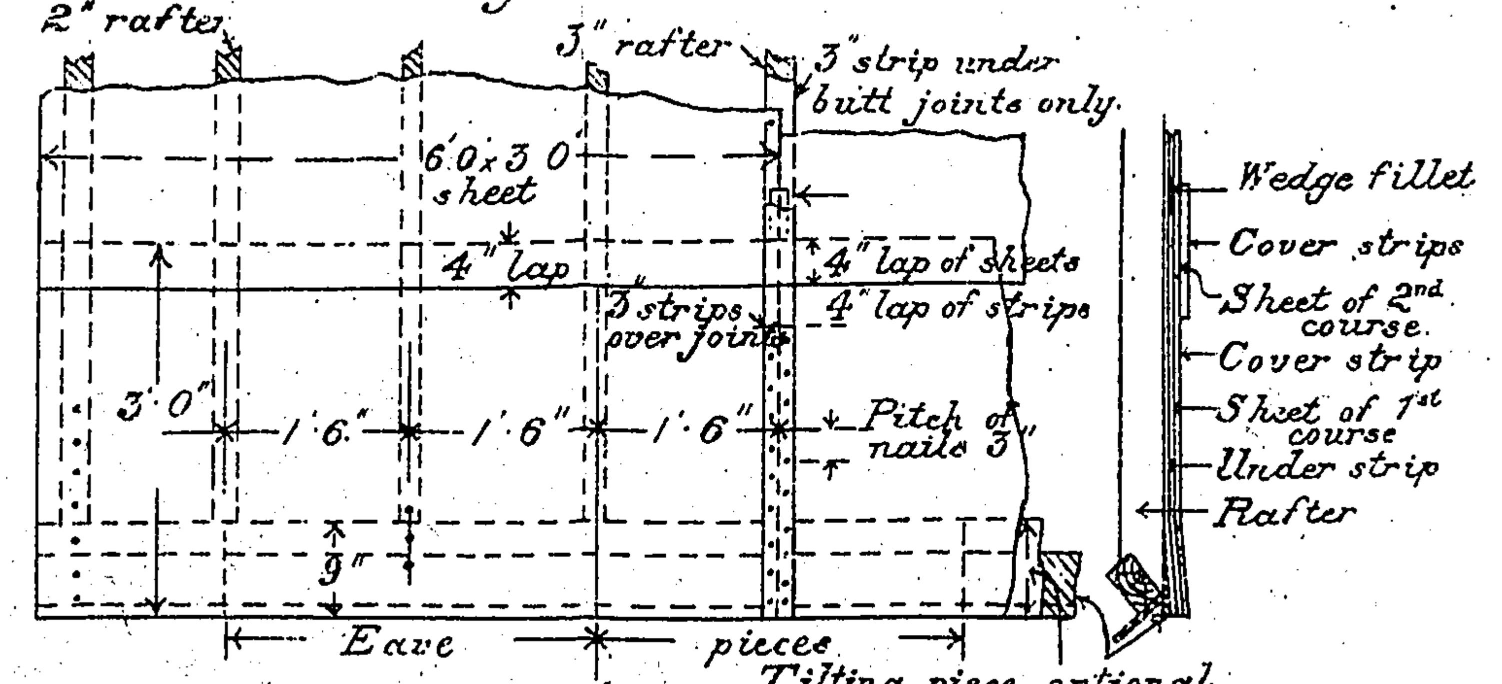
ARRANGEMENT OF DIAMOND ROOFING.
Using tiles 15" sq x 3" lap.

Fig. 2a



SECTION OF TAUT WIRE STUDS, INTERWOVEN EXPANDED METAL LATHING, AND CEMENT SOLID PARTITION.

Fig. 6.



ARRANGEMENT OF COLONIAL ROOFING.
Using sheets 6' 0" x 3' 0" x 4" lap.