88° 51' 15", when the range = 50 × AB. If it is inconvenient to measure AB, the observer can retire from B in the line OB until the third prism records the angle OCA = 74° 53' 15", when the range = 200 × BC. The prisms must be held in the plane of the objects and looked into at the same point. This rangefinder is very simple and portable, but is frequently inappli­cable on hilly or broken ground, and does not possess great accuracy.

The merits of different field range­finders depend mainly upon the balance of advantages they offer with respect to accuracy, suitability to variety of ground, simplicity, portability, and durability, these conditions being of a more or less conflicting character. The fol­lowing are recognized principles : — (1) the naked eye cannot with certainty appreciate less than one minute dif­ference of angle, therefore telescopic power is necessary in proportion as the base is short compared with the range ; (2) telescopes of high power cannot be steadied by hand alone ; (3) the longer the base the more incon­venient are any restrictions as to its length or direction ; (4) it is a disadvantage to be compelled to traverse the line joining base points; (5) the longest base which it is convenient to measure by hand is that length of measuring line which can be stretched tight in a high wind.

(2) *Rangefinders for Coast Batteries.—*Rangefinding is less adapted to the requirements of coast defence than “ position finding,”—a method which furnishes every gun with its proper training and elevation so that it can be fired without sighting the target. Rangefinders are, how­ever, sometimes employed. The most worthy of notice is the Watkin depression rangefinder used by the British artillery in coast batteries. The instrument resembles in principle the Watkin field rangefinder, the height above the sea-level being a vertical base. The range is found by observing the angle of depression to the object. This is done by a powerful cross-wire telescope, which forms part of the instrument. The fastest steamer can be continuously followed, and even the successive grazes of shot and shell can be observed. The instrument is levelled upon a tripod stand. When necessary, it finds its exact height in feet above the water-level in any state of tide by reference to a datum distance, and it records the range in yards auto­matically on a graduated cylinder. An interesting con­trivance combining telemeter and gun-sight, applicable to guns in permanent emplacements over non-tidal waters, has been tried in Italy. By means of a cam the hind-sight of the gun is always maintained in the position necessary to give the proper elevation in firing, so that it only remains to make the sights cover the target. (a. w. w.\*)

TELEPHONE

TELEPHONY is the art of reproducing sounds at a distance from their source. The term was first used by Philip Reis of Friedrichsdorf, in a lecture delivered before the Physical Society of Frankfort in 1861.@@1 But, although this lecture and Reis’s subsequent work received considerable notice, little progress was made until the sub­ject was taken up between 1874 and 1876 by Alexander Graham Bell, a native of Edinburgh, then resident in Boston, Mass. Bell, like Reis, employed electricity for the reproduction of sounds ; but he attacked the problem in a totally different manner. This will be better understood if we consider shortly on what the chief characteristics of sound depend (compare Acoustics).

The sensation of sound is produced by rapid fluctuations in the pressure of the atmosphere on the tympanum of the ear. If the fluctuations are irregular and non-periodic, the sound is called a noise ; if they are cyclic and follow a regular and sufficiently rapid periodic law, the sound is musical. In connexion with the present subject it is im­portant to notice the three characteristics of a musical sound, namely, *pitch, loudness,* and *quality.* The pitch of a musical sound depends on the number of cycles passed through by the fluctuations of the pressure per unit of time ; the loudness depends on the amount or the ampli­tude of the fluctuation in each cycle ; the quality depends on the form or the nature of the fluctuation in each cycle. The necessary condition for a successful system of tele­phony is the ability to reproduce these characteristics.

I. History.

In 1831 Wheatstone by his “magic lyre” experiment showed@@2 that, when the sounding-boards of two musical instruments are connected together by a rod of pine wood, a tune played on one will be faithfully reproduced by the other. This only answers, however, for telephoning mu­sical sounds to short distances. Another and somewhat

similar example is furnished by what has been variously designated as the “string,” “toy,” “lovers,” and “mechan­ical ” telephone. Two disks of thin metal, or two stretched membranes, each furnished with a mouthpiece, are con­nected together by a thin string or wire attached at each end to the centres of the membranes. A good example may be made with two cylindrical tin cups ; the bottoms form the membranes and the cups the mouthpieces. When the connecting string is held taut and sounds, such as those of ordinary speech, are produced in front of one of the membranes, pulses corresponding to the fluctuations of the atmospheric pressure are transmitted along the string and communicated to the other membrane, which in its turn communicates them to the air, thus reproducing the sound. In both these examples all the three characteristics—pitch, relative intensity, and quality—of sound are reproduced.

Let us now return to the development of the application of electricity to telephony. In July 1837 Dr C. G. Page of Salem, Mass., drew attention to the sound given out by an electromagnet at the instant when the electric circuit is closed or broken, and in October of the same year he dis­cussed, in a short article@@3 entitled “Galvanic Music,” the musical note produced by rapidly revolving the armature of an electromagnet in front of the poles. Experiments bearing on this subject were subsequently made by a great number of investigators.@@4 Page’s discovery is of considerable im­portance in connexion with the theory of action of various forms of telephone, and was a very important feature in the early attempts by Reis to transmit music and speech. On

@@@1 “ Ueber Telephonie durch den galvanischen Strom,” in *Jahresber. d. physikalischen Vereins zu Frankfurt am Main,* 1860-61, p. 57.

@@@2 See his *Scientific Papers,* p. 47.

@@@3 See *Silliman's Journ.,* xxxii. p. 396 and xxxiii. p. 118.

@@@4 Marrian, *Phil. Mag.,* 3d ser., xxv. p. 382 ; Beatson, *Arch. de l'Élect.,* V. p. 197 ; De la Rive, *Treatise on Electricity,* vol. i. p. 306, also *Phil. Mag.,* 3d ser., vol. xxxv. p. 422, and *Comp. Rend.,* xx. p. 1287, xxii. p. 432 ; Matteucci, *Arch. de l'Élect.,* v. 389 ; Guillemin, *Comp. Rend.,* xxii. p. 264; Wertheim, *Comp. Rend.,* xxii. pp. 336, 544, xxvi. p. 505, also *Ann. de Chim. et de Phys.,* xxiii. p. 302, and *Phil. Mag.,* 3d ser., xxviii. p. 544 ; Jannair, *Comp. Rend.,* xxiii. p. 319 ; Joule, *Phil. Mag.,* 3d ser., xxv. pp. 76, 225 ; Laborde, *Comp. Rend.,* 1. p. 692; Poggendorff, *Pogg. Ann.,* lxxxvii. p. 139, xcviii. p. 198 ; Du Moncel, *Exp. de l’Élect.,* vol. ii. p. 125, iii. p. 83 ; and Delesenne, *Bibl. Uniυ.,* 1841, xvi. p. 406.