CHAPTER XV.

VESSELS IN COMMUNICATION—LEVELS.

178. Liquids tend to Find their own Level.—When a liquid is contained in vessels communicating with each other, and is in equilibrium, it stands at the same height in the different parts of the system, so that the free surfaces all lie in the same horizontal plane. This is obvious from the considerations pointed out in §§ 138, 139, being merely a particular case of the more general law that points of a liquid at rest which are at the same pressure are at the same level.

In the apparatus represented in Fig. 87, the liquid is seen to stand at the same height in the principal vessel and in the variously shaped tubes communicating with it. If one of these tubes is cut off at a height less than that of the liquid in the principal vessel, and is made to terminate in a narrow mouth, the liquid will be seen to spout up nearly to the level of that in the principal vessel.

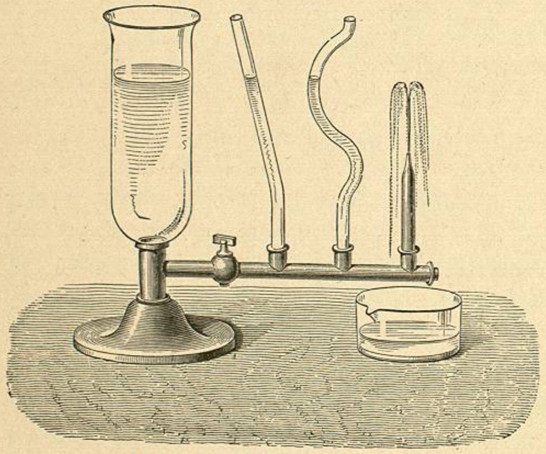

Fig. 87.—Vessels in Communication.

This tendency of liquids to find their own level is utilized for the water-supply of towns. Water will find its way from a reservoir through pipes of any length, provided that all parts of them are below the level of the water in the reservoir. It is necessary how-

ever to distinguish between the conditions of statical equilibrium and the conditions of flow. If no water were allowed to escape from the pipes in a town, their extremities might be carried to the height of the reservoir and they would still be kept full. But in practice there is a continual abstraction of energy, partly in the shape of the kinetic energy of the water which issues from taps, often with considerable velocity, and partly in the shape of work done against friction in the pipes. When there is a continual drawing off from various points of a main, the height to which the water will rise in the houses which it supplies is least in those which are most distant from the reservoir.

179. Water-level.—The instrument called the water-level is another illustration of the same principle. It consists of a metal tube *bb*, bent at right angles at its extremities. These carry two glass tubes

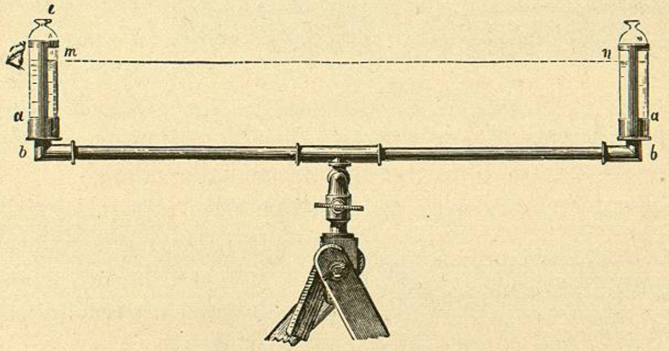

Fig. 88.—Water-level.

aa, very narrow at the top, and of the same diameter. The tube rests on a tripod stand, at the top of which is a joint that enables the observer to turn the apparatus and set it in any direction. The tube is placed in a position *nearly* horizontal, and water, generally coloured a little, is poured in until it stands at about three-fourths of the height of each of the glass tubes.

By the principle of equilibrium in vessels communicating with each other, the surfaces of the liquid in the two branches are in the same horizontal plane, so that if the line of the observer's sight just grazes the two surfaces it will be horizontal.

This is the principle of the operation called *levelling*, the object of which is to determine the difference of vertical height, or *difference of level*, between two given points. Suppose A and B to be the two points (Fig. 89). At each of these points is fixed a levelling-staff, that is, an upright rod divided into parts of equal length, on which slides a small square board whose centre serves as a mark for the observer.

The level being placed at an intermediate station, the observer directs the line of sight towards each levelling-staff, and the mark is raised or lowered till the line of sight passes through its centre. The marks on the two staves are in this way brought to the same level. The staff in the rear is then carried in advance of the other, the level is again placed between the two, and another observation taken. In this way, by noting the division of the staff at which the sliding mark stands in each case, the difference of levels of two distant stations can be deduced from observations at a number of intermediate points.

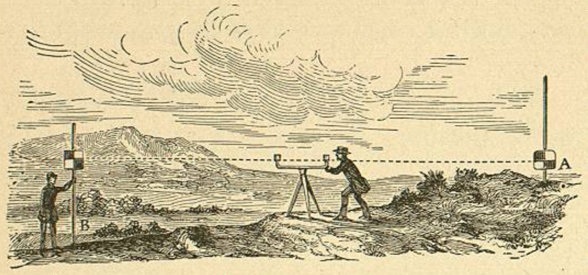

Fig. 89.—Levelling.

For more accurate work, a telescope with attached spirit-level (§ 181) is used, and the levelling staff has divisions upon it which are read off through the telescope.

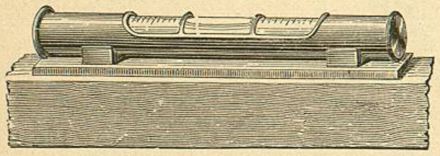

Fig. 90.—Spirit-level.

180. Spirit-level.—The spirit-level is composed of a glass tube slightly curved, containing a liquid, which is generally alcohol, and which fills the whole extent of the tube, except a small space occupied by an air-bubble. This tube is inclosed in a mounting which is firmly supported on a stand.

Suppose the tube to have been so constructed that a vertical section of its upper surface is an arc of a circle, and suppose the instrument placed upon a horizontal plane (Fig. 91). The air-bubble will take up a position MN at the highest part of the tube, such that the arcs MA and NB are equal. Hence it follows that if the level

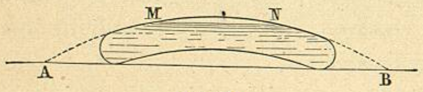

Fig. 91.

be reversed end for end, the bubble will occupy the same position in the tube, the point N coming to M, and *vice versa*. This will not be the case if AB is inclined to the horizon (Fig. 92), for then the bubble will always stand nearest to that end of the tube which is highest, and will therefore change its place in the tube when the latter is reversed. The test, then, of the horizontality of the line on which the spirit-level rests is, that after this operation of reversal the bubble should remain between the same marks on the tube. The maker marks upon the tube two points equidistant from the centre, the distance between them being equal to the usual length of the bubble; and the instrument ought to be so adjusted that when the line on which it stands is horizontal, the ends of the bubble are at these marks.

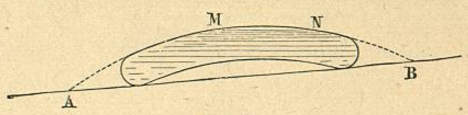

Fig 92.

In order that a plane surface may be horizontal, we must have two lines in it horizontal. This result may be attained in the following manner:—The body whose surface is to be levelled is made to rest on three levelling-screws which form the three vertices of an isosceles triangle; the level is first placed parallel to the base of the triangle, and, by means of one of the screws, the bubble is brought between the reference-marks. The instrument is then placed perpendicularly to its first position, and the bubble is brought between the marks by means of the third screw; this second operation cannot disturb the result of the first, since the plane has only been turned about a horizontal line as hinge.

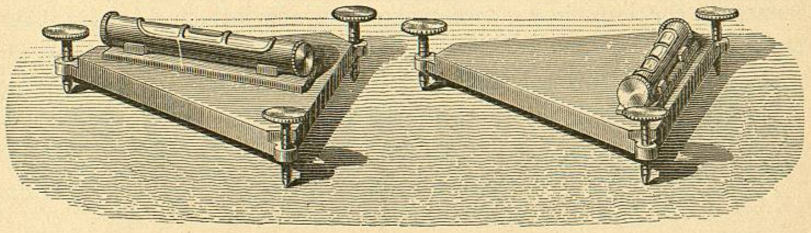

Fig. 93.—Testing the Horizontality of a Surface.

181. Telescope with Attached Level.—In order to apply the spirit-level to land-surveying, an apparatus such as that represented in

Fig. 94 is employed. Upon a frame AA, movable about a vertical axis B, are placed a spirit-level *nn*, and a telescope LL, in positions parallel to each other. The telescope is furnished at its focus with two fine wires crossing one another, whose point of intersection determines the line of sight with great precision. The apparatus, which is provided with levelling-screws H, rests on a tripod stand, and the observer is able, by turning it about its axis, to command the different points of the horizon. By a process of adjustment which need not here be described, it is known that when the bubble is between the marks the line of sight is horizontal. By furnishing the instrument with a graduated horizontal circle P, we may obtain the azimuths of the points observed, and thus map out contour lines.

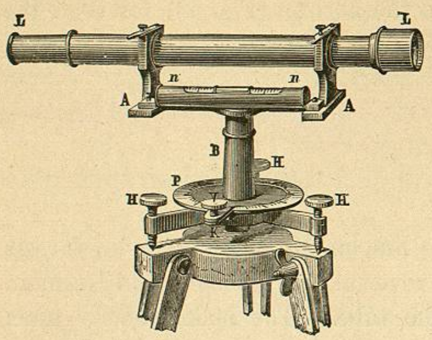

Fig. 94.—Spirit-level with Telescope.

Divisions are sometimes placed on each side of the reference-marks of the bubble, for measuring small deviations from horizontality. It is, in fact, easy to see, by reference to Fig. 91, that by tilting the level through any small angle, the bubble is displaced by a quantity proportional to this angle, at least when the curvature of the instrument is that of a circle.

For determining the angular value corresponding to each division of the tube, it is usual to employ an apparatus opening like a pair of compasses by a hinge C (Fig. 95), on one of the legs of which rests, by two V-shaped supports, the tube T of the level. The compass is opened by means of a micrometer screw V, of very regular action; and as the distance of the screw from the hinge is known, as well as the distance between the threads of the screw, it is easy to calculate beforehand the value of the divisions on the micrometer head. The levelling-screws of the instrument serve to bring the bubble between its reference-marks, so that the micrometer screw is only used to determine the value of the divisions on the tube.

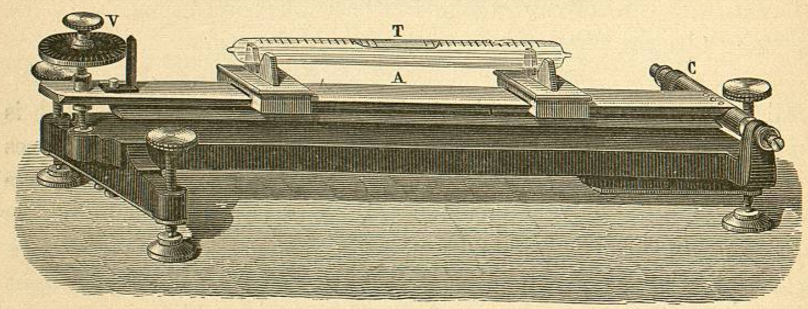

Fig. 95.—Graduation of Spirit-level.