were of larger dimensions, two of them had cylinders 63in. diameter, and were capable of working with a load of 11 lb. or 12 lb. on the square inch of the piston. The first-named of these three, that at Ting-Tang, was put up with the concurrence of one of the Hornblowers, who was engineer to the mine at the time. In Watt's first engines—and in this among the number—the air-pump and condenser were exhausted previously to starting by means of a small pump worked by hand, and on the first trial the engine suddenly started and killed the man who was working the pump. Watt, who was present at the time, afterwards added the arrangement of *blowing through*, in order to produce the vacuum at starting by condensation.

The success of these trials induced the rapid adoption of the improved engine, and rendered Cornwall the richest field of profit to the patentees; for in about twelve years the whole of the atmospheric engines in the district had been replaced by patent ones, whose dimensions varied from 24in. to 66in. cylinders, and many of which were double-acting. The extension of the mining operations kept up a constant demand upon the manufacturers of the engines, either for new machines or for the enlargement of old ones, which lasted, with only one or two temporary interruptions, until the year 1800, when the monopoly expired, and the connection of Messrs. Boulton and Watt with the county entirely ceased. Watt made some very radical changes in the construction of the pumping engine; he introduced the separate condenser, the system of blowing through, the double-acting engine, the parallel motion. He substituted the wagon-shaped for the dome boiler, and last, but not least, he introduced the principle of expansive working and steam-jacketing. He also removed the cylinder from the top of the boiler, and fixed it on a separate foundation. All these and other minor improvements were made in the pumping engine by Watt during his connection with the mines of Cornwall. Messrs. Boulton and Watt were exceedingly enterprising in the introduction of their engines; in some cases the engines were made by engineers in the county, at the expense of the proprietors of the mine, Messrs. Boulton and Watt supplying the drawings, and receiving for the patent-right one-third of the value of the fuel saved by the improvements. In order to meet the objections raised against the outlay of capital required for the purchase of the patent engines, they often took old atmospheric engines in part payment, and in some cases erected the engines at their own cost, considering them as their own property, and paying themselves out of the saving in fuel which accrued from their working. Such allowances were not needed as the merits of the engine became more known, and therefore were soon discontinued.

Messrs. Boulton and Watt issued a book of directions for erecting and working the newly invented steam engine. The book was full of practical information, as may be gathered from the following extracts, which give a fair sample of the whole:—

"To set the engine to work, raise the steam in the boiler until the index of the steam gauge is at three inches on the scale. When the outer cylinder is fully warmed, and the steam issues freely on opening the small valve at the bottom of the syphon, or waste pipe, which discharges the condensed water from the outer bottoms, open all the regulators. The steam will then blow out the air or water contained in the eduction pipe by the blowing valve, but cannot immediately take place of the air in the cylinder itself. To get it quite out: after you have blown the engine a few minutes, shut the steam regulator. The cold water of the condensing cistern will condense some of the steam contained in the eduction pipe, and its place will be supplied by some of the air from the cylinder. Open the steam regulator and blow out that air, and repeat the operation until you judge the cylinder to be clear of air. When that is the case shut all the regulators, and observe if the barometer shows that there is any vacuum in the

such as is applied to a 50in. pumping engine and 12in. pit work. All the dimensions are taken from the actual machine.

In commencing a mine, the engine shaft is first put down to a certain depth; the engine house is then built, and the capstan and shears put up, that the pit work may be lowered into its place. The capstan is erected directly over the engine shaft, in such a position that the rope may hang just over the pumps; and the capstan is usually placed in a line with the shears, as shown on the lithograph. The wood used in the construction should be red pine, but yellow pine is often substituted. The legs of the shears are square in section, with just the angles taken off. The top pulley is carried in plummer blocks, which are secured to two pieces of red pine (one on each side of the pulley), supported on shoulders formed on the top of the legs, and filling pieces secured to the sides by means of strapping plates, which are made to receive glands, for the purpose of firmly securing the pieces which support the pulley. The bottom pulley is like the top one, and is placed on the inside of one of the shear legs; the outer bearing is carried in a plummer block supported on a piece of timber firmly secured to the leg by means of staples and glands.

The construction of the framing of the capstan will be readily understood from an inspection of the drawing. It is usual to stay the two uprights by means of struts, and to stay the shear legs by means of iron or wood rods from the walls of the engine house. The shaft of the capstan is of wrought iron; on it is keyed a cast iron drum provided with socket pieces to receive eight wood arms each; in the top socket piece the arms of the capstan are secured. At the top of the shaft a cast iron centre piece is keyed, from which tie rods extend to each of the arms; tie rods are also carried from one arm to the other, just under the outer part of the wood roofing. The details of the iron work we shall give more fully in our next impression.

The object of the balance-bob is to afford a means by which the surplus weight of the pump rods may be taken up. A beam of red pine, with a kingpost, tie rods, and balance box, forms the bob. The bearings forming the fulcrum are of cast iron, and are made on the socket, which receives the foot of the kingpost; a flange is also formed around the socket, and is provided with bolt holes to receive the staples, which serve to secure the beam to the socket piece; a cast iron socket is provided to receive the top of the kingpost, which is called the "bishop's head." A toe-piece is bolted to the shaft end of the beam for the purpose of carrying the pin for the connecting rod, and is formed with a gap which receives the head of the connecting rod. The tie rods are usually made flat. The connecting rod from the balance-bob to the pump rods is sometimes made of iron and sometimes of wood. When formed of wood it is made six or seven fathoms long, and the bottom end is secured to the pump rods by means of staples and glands, on a set-off to bring it in a vertical line when at half-stroke. The vibration is given by the elasticity of the timber. The construction of the box will be clearly seen on inspecting the engraving.

Before we proceed further with the subject it will be well, perhaps, to give a few definitions of technical terms used in Cornish mines in connection with the pumping machinery, &c.

Adit, tye, or level.—An adit is a tunnel or conduit, driven or cut in the side of a hill, sometimes used for the purpose of bringing out ore, but usually for the purpose of draining the mine at that level. The pumping engine lifts the water from the bottom of the mine to the adit, through

ON THE DYNAMICAL PRINCIPLES OF THE MOTION OF VELOCIPEDES.

By W. J. MACQUORN RANKINE, C.E., LL.D., F.R.S.

SUPPLEMENT.

26. *Promptitude in recovering the balance.*—When the base-point M, Fig. 6, happens to have swerved to one side of its proper position under the centre of mass, so as to risk the overturn of the vehicle, that deviation is corrected, as already stated in Section I., Article 7, page 79, by inclining the front or steering-wheel to the contrary side, so as to cause the track of the base-point to incline in that direction also, and so bring that point back to its proper place. For example, in Fig. 6, representing a plan of the roadway, A is the fore-wheel, B the hind-wheel, A B the wheel-base, M the base-point, which is supposed to have swerved to the right, thus causing the centre of mass to tend to fall towards the left. The rider inclines the fore-wheel towards the left, as shown at A; the velocipede begins to move round a centre at C, where the projections A C and B C of the axes of the wheels cut each other; the tracks of the two wheels and of the base-point become concentric circular arcs, A *a*, B *b*, M *m*, described about C; and the lateral deviation of the base-point M from its former track brings it back to its proper position under the centre of mass, and causes the balance to be recovered.

The *promptitude* with which the balance is recovered, after a given extent of deviation of the base-point to one side of its proper position, depends on the transverse component of the speed with which that point moves in the curved track M *m*; and that transverse component is less than the speed of advance of the velocipede in the proportion in which M B, the distance of the base-point from the point of support of the hind-wheel, is less than C M, the radius of curvature of the track of the base-point. Let v denote the speed of advance; then the *promptitude of recovery* may be represented as a quantity by the following expression:—

$$v.\frac{\text{M B}}{\text{C M}}$$

Hence it appears that promptitude in balancing is favoured not only by a high speed, as already stated in Article 7, but by placing the base-point (and, therefore, the centre of mass) well forward, so that M B may be as great as possible consistently with having a load on the hind-wheel sufficient to prevent it from slipping sideways.

27. *Difficulty of balancing with the steering-wheel behind.*—It has sometimes been proposed to make the hind-wheel the steering-wheel, as shown in Fig. 7, in order that the rider's legs may not be liable to be grazed by the rim of the wheel when in an inclined position. It is true that for the purpose of steering, or describing curves, as distinguished from balancing, the hind-wheel is quite as suitable as the fore-wheel; but a fatal objection to the proposed alteration arises from the fact that with the steering-wheel behind, it becomes extremely difficult for the rider to keep the balance of the vehicle.

To show why such is the case, let it be supposed that the base-point M in Fig. 7 has swerved to the right of its proper position, thus causing the centre of mass to tend to fall over towards the left. In order that the base-point

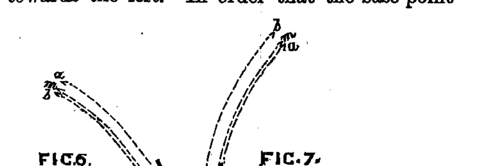

FIG.6. FIG.7.

their own property, and paying themselves out of the saving in fuel which accrued from their working. Such allowances were not needed as the merits of the engine became more known, and therefore were soon discontinued.

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"Should the engine work with too great violence, on account of its being underloaded, you may correct it by giving the top regulator a lesser opening, and shutting it at such part of the stroke as it will give the piston sufficient force to come to the bottom. Whenever the top regulator is used the exhaustion regulator should be thrown fully open at every stroke, in order to give a free exit to the steam, on which a great part of the good effects of the top regulator depends. The engine should always be made to work full stroke, that is, until the catch-pins come within half an inch of the springs on each end, which is easily managed by an attention to the pegs. Care must be taken that the piston rises high enough in the cylinder when the engine is at rest, to spill over into the perpendicular steam pipe any water which may be condensed above it; for if any water remains there, or in any other part of the cylinder while it is working, it will very much increase the consumption of steam. When the engine is stopped, shut the injection and secure it, put a peg in the plug-tree to prevent the exhaustion regulator from opening, and take out the peg on the other side, so as to allow the steam regulator to open, and to remain open—otherwise you will have a partial vacuum in the cylinder, and it may be filled with water from the injection or leakages, which will be a troublesome accident. The top regulator must also be open when the engine is at rest. When an engine is in tolerably good order it may bear to stand ten minutes, and go to work again without blowing afresh, and though it has stood two or three hours, if there has been any steam issuing from the boiler, and no air has been admitted into the cylinder, it will generally go off with once blowing for about a minute."

In commencing our series of working drawings illustrative of the best modern construction of the Cornish engine and "pit work," we give a large lithograph with figured dimensions of capstan, shears, and balance-bob, socket piece; a cast iron socket is provided to receive the top of the kingpost, which is called the "bishop's head." A toe-piece is bolted to the shaft end of the beam for the purpose of carrying the pin for the connecting rod, and is formed with a gap which receives the head of the connecting rod. The tie rods are usually made flat. The connecting rod from the balance-bob to the pump rods is sometimes made of iron and sometimes of wood. When formed of wood it is made six or seven fathoms long, and the bottom end is secured to the pump rods by means of staples and glands, on a set-off to bring it in a vertical line when at half-stroke. The vibration is given by the elasticity of the timber. The construction of the box will be clearly seen on inspecting the engraving.

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Angle-bob.—A contrivance, consisting of strut made to vibrate on a fixed centre, one end of which strut is connected to a line of rods, and serves to change the direction of the motion from a straight line to an angular direction.

Balance-bob.—A lever and weight applied to the purpose of taking up or balancing the surplus weight of pump rods, when the rods are heavier than that required to lift the water in the pumps.

Bob.—The beam of an engine.

Box.—The bucket of a lifting pump.

Cataract.—An adjustable piece of mechanism, which times the opening of the steam valve, and which is also sometimes applied to the equilibrium valve, and which determines the speed of the engine.

Collar launder.—A spout at the top of a lift of pumps, which serves to deliver the water away from the rising main.

Engine shaft.—The shaft in which the pit work is placed. The shaft is sometimes vertical and sometimes oblique.

Fork.—The bottom of the sumph. "Forking the water" is drawing it out. The engine is said to "work in fork" when the water is out of the mine and the pumps take air.

Grass.—Surface of the ground or mine. "Going to grass" signifies going to the surface.

House lift.—The lift of pumps which is employed to lift water from the adit to the condensing cistern of the engine, or to "grass."

House pole.—The plunger of the house lift.

Pole or plunger pole.—The plunger of a force pump.

Pole case.—The barrel in which the pole works.

Pole connection.—The connection of the pole with the pump rods.

Sumph.—The sumph is a pit dug in the bottom of the mine, which serves to collect the water of the mine together, that it may be drawn out by means of the pumps.

Tye.—The adit.

Tye lift.—The top lift of pumps.

Wheal, Whele, or Huel taken from a word signifying a hole or pit).—A mine; as Wheal Arthur, Wheal Vor, meaning Arthur Mine and Vor Mine. Wheal is the modern orthography; the word was formerly spelt huel.

The Messageries Imperiales steamship Cambodge is expected to pass through the Suez Canal, home-bound from China, about the 10th inst. She is a very big ship, and will probably have a large cargo,

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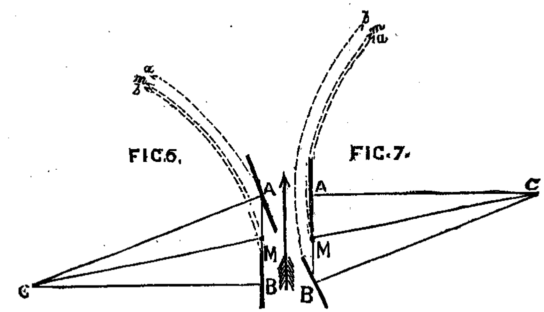

FIG. 5. FIG. 7.

may move sideways towards the left, so as to restore the balance, the hind-wheel B is to be inclined towards the left, when the velocipede will begin to move round the centre C, situated at the intersection of the projections B C and A C of the axes of the wheels. The tracks of the wheels and of the base-point will become concentric circular arcs, B b, M m, A a, described about the point C.

The base-point begins, as required, to deviate sideways towards the left, with the transverse velocity $v. \frac{MA}{MC}$; and this motion may possibly, with extremely delicate management of the steering-bar, serve to restore the balance. But by the time the vehicle has advanced through the distance M A, between the base-point and the fore-wheel, the base-point has reached its extreme deviation towards the left: if that is insufficient to restore the balance the velocipede must upset; and should the deviation be sufficient to restore the balance, the rider must instantly bring back the steering-wheel to the steady position; otherwise, the base-point, moving in the circular track M m, will come back to a point in its original straight track, cross this track, and rapidly swerve towards the right of it, thus renewing the loss of balance in the same direction as before, and making an overturn almost certain.

A bicycle, then, with the steering-wheel behind, may possibly be balanced by a very skilful rider as a feat of dexterity; but it is not suited for ordinary use in practice.

Glasgow University, 1870. W. J. M. R.

Docks and Harbours in France.—Authority is granted by imperial decrees to carry out the following harbour works:—A harbour at Berre, on the lagoon of that name, at the mouth of the Rhone river; estimate, 170,000f. = £6800. A breakwater at Le Portel, near Boulogne; 5000f. = £200, are provided for this work out of the local rates, but the total estimate will probably be much more. New floating docks at Dunkerque and Bordeaux A new graving dock (Bassin de Radoub) in the harbour of La Ciotat, conceded to the Messageries Impériales Company, and a new harbour in the Bay of Portstrein (Finisterre); estimate, 23,250,000f. = £930,000.