ON D'AURIA'S ENGINE GOVERNOR.

By the Inventor, PROF. L. D'AURIA.

Whatever may be the scientific principle on which a steam engine governor is constructed, it is easily seen that when in operation all the forces acting on it can be reduced to two acting on its valve in a contrary direction to each other, one trying to shut the passage of the steam, the other to open it.

The first force is produced by the velocity which the engine communicates to the governor, and consequently is a function of the velocity of the engine; the second force is produced by a weight or by the elastic force of some spring.

Let P and Q be respectively those two forces, and W the velocity of the engine; will be

$$P = f(W);$$

and for the equilibrium of the valve, which is supposed to be balanced by the steam, that is, independent of the pressure of the steam, must be

$$Q = P = f(W) \quad (1)$$

As the pressure of the steam in the boiler, as well as the load of the engine, are subjected to variations, the engine cannot be rigorously governed if the valve is not in equilibrium in all its positions between the limits of its stroke with a constant velocity W of the engine.

Therefore the equation (1) must not be affected by the changes of position of the governor in reference to itself, or it must be independent of the cöordinates of the system constituting said governor. And if the force P is a function of those cöordinates (as takes place in all the governors constructed on the principle of centrifugal force), then, also, the other force Q must be a function of the same cöordinates, but such that the equation (1) results independently of them.

Let, now, H be the friction of the governor, considered at the same point of application of the forces P , Q . The equation of equilibrium of the valve when it moves so as to shut the passage of the steam, will be

$$Q + H = f(W); \quad (2)$$

and, when the contrary takes place, will be

$$Q - H = f(W) \quad (3)$$

Subtracting the equation (3) from the other (2), will be

$$2H = f(W) - f(W) = 0,$$

which is absurd unless H is equal to zero, or the value of W in the equation (2) is greater than that of W in the equation (3). But in this case, at every change of direction in the motion of the valve, a variation of speed takes place in the engine, more or less, according to the value of the friction H ; therefore, to obtain a perfect governor it is not enough that the equation of its equilibrium is independent of the changes of position of said governor, it must be independent also of friction.

Having thus established the conditions to be satisfied in the construction of a perfect governor, my first step toward the solution of this important problem was the elimination of the friction of the valve-stem in its stuffing box, which I consider the most pernicious to the sensitiveness of a governor.

I obtained this result in a very simple manner, by enclosing the mechanism of an ordinary ball governor in a steam chamber in which it revolves. This will be easily understood without special illustration. With the elimination of the friction of the valve-stem, another serious inconvenience is destroyed, that arising from the variable pressure of steam on said stem, which prevents the balancing of the valve.

The use of heavy balls being unnecessary in this improved form, I immediately thought to reduce the mechanism to only one ball and its arm, the valve and its valve chamber; after which I saw the possibility of using the ball arm itself as valve, pivoted on a movable valve chamber, thus reducing the mechanism to only two pieces, and the friction to its minimum, that is, to that of the points of suspension at the ball arm transformed into a throttle valve, which friction is so small as to be neglected in calculations.

One method for the practical realization of my last improvement, which seems to me to exhibit the greatest degree of simplicity in steam engine governors, is fully shown in the annexed drawing (Fig. 1) in which A is the steam chamber having in the centre of its bottom a vertical and cylindrical tube B , open at both ends and prolonged partly inside and partly outside of said steam chamber. C is the movable valve chamber in the drawing, having the form of a short cylindric box or case. It fits the upper part of the tube B , and is fixed on a vertical shaft receiving motion from the engine in the manner shown in the drawing. When this shaft is in motion, it revolves the valve chamber C around its seat B , but without any friction. The ends of the cylindrical valve chamber

C are closed by two parallel walls disposed vertically. On each of them is cut an equal port, conveniently shaped and situated so as to be regulated simultaneously by the oscillating double-weighted valve *D*, composed of two equal slide valves, sector-shaped, rigidly held parallel to each other internally by a bridge *D*, of proper weight, and hung by centre pins on the parallel walls of the valve chamber, so as to oscillate freely on the outside of them in a vertical plane.

Fig. 1.

The stroke of the double-weighted valve *D* is limited to open and shut the ports of the valve chamber without any lost motion. The centre of gravity of the valve is situated below the horizontal plane, passing through the axis of suspension *I*, and the right line joining the mean point of this axis with the centre of gravity, is crossed by the axis of rotation of the valve chamber at an angle of about 45° , so that, when the governor is put in motion the effect of centrifugal force will

be to turn the double-weighted valve D on its axis of suspension I , and close the ports on either side of the valve chamber C .

The inside of the steam chamber is divided in two compartments by a disc or diaphragm attached to the shell of the tube B , leaving all around its periphery an annular passage for the steam to flow from the lower compartment to which it is first admitted to the upper one, in which runs the mechanism C, D .

The object of this is the uniform distribution of the steam around C, D without affecting the double-weighted valve D , which, in consequence, is perfectly balanced.

The steam passes from the upper compartments of the steam chamber into the valve chamber through its ports, from which it flows into the tube B , communicating with the engine.

When the velocity of rotation of the mechanism C, D exceeds a certain limit, the centrifugal force raises the valve, the ports of the valve chamber shut, and the speed of the engine falls for want of steam. Then the valve itself falls for want of speed, and the ports of the valve chamber are again opened to the steam, and so on.

Having reduced the friction of my governor to such a minimum as to be neglected in calculations, my attention was directed to find the most convenient manner of suspending the valve, to satisfy as closely as possible the condition expressed in discussing the equation (1), that is, the condition that *with a constant velocity of the engine, the valve must indifferently be in equilibrium in all its positions between the limits of its stroke*.

The following is the calculation made for this object :

Let xx (Fig 2) be the vertical axis of rotation of the governor ; C the centre of gravity of the double-weighted valve ; y the distance of this point from the axis xx ; $T T$ the tangent line to the curve described by the point C , touching this same point ; θ , the angle formed by $T T$ with the axis xx ; P , the weight of the valve ; F , its centrifugal force, and N the number of revolutions per minute of the governor.

The equation of equilibrium will be

$$F \sin \theta = P \cos \theta \quad (4)$$

The value of F expressed in function of y and N is

$$F = \frac{P N^2 \pi^2 y}{900 \times g}$$

Substituting it in the equation (4), after reductions will be found

$$\frac{N^2 \pi^2 y \tan \theta}{900 \times g} = 1 \quad (5)$$

or

$$y \tan \theta = \frac{900 \times g}{N^2 \pi^2} = \text{Const} := C$$

If the axis xx is considered as axis of abscissas of the curve described by the point C and y as an ordinate of the same, will be

$$\tan \theta = \frac{dy}{dx}$$

Substituting this value in the last equation, will be

$$y dy = C dx;$$

and

$$\int y dy = C \int dx;$$

or,

$$y^2 = 2Cx$$

This equation represents a parabola; therefore, to satisfy mathematically the above-mentioned condition, the point C must move on such curve.

I could obtain this effect practically by suspending the valve with a chain, which develops from a parabolic outline, it being known that the evolute of a parabola is another parabola. But, as the oscillation of the valve is short, the parabolic arc described by C can be considered approximately as an arc of circumference having for its centre the mean centre of curvature of said parabolic arc; and this centre be considered as point of suspension of the valve.

Now, as the co-ordinates of this point are

$$\text{Abscissa} = c + \frac{3y^2}{2c}; \quad \text{Ordinate} = -\frac{y^3}{c};$$

it is evident why the axis of suspension I, I , of the valve, is situ-

Fig. 2.

ated, as shown in Fig. 1, in reference to the centre of gravity of said valve and the axis of rotation of the valve chamber.

But this disposition is not at all arbitrary, as it seems to be, because the axis of suspension I , in reference to its position and its distance from the centre of gravity C , can be determined by calculation so as to obtain the equilibrium of the valve in all its positions with the smallest variation of N ; that is, with the smallest variation of speed in the engine.

In fact, let IC , IC^1 (Fig. 2) represent the extreme positions of the valve; φ and φ^1 their respective angles with the horizon; and let

$$ID = a; \quad IC = IC^1 = R;$$

$$\therefore \quad y = CB = R \cos \varphi - a$$

$$y = C^1B^1 = R \cos \varphi^1 - a.$$

Substituting successively those two values of y in the equation (5), observing that $\varphi = \theta$, $\varphi^1 = \theta^1$, will be found, after reductions,

$$\left. \begin{aligned} N^2 &= \frac{C}{R \sin \varphi - a \tan \varphi} \\ N^2 &= \frac{C}{R \sin \varphi^1 - a \tan \varphi^1} \end{aligned} \right\} \quad (6)$$

Now, it is easily seen, that if

$$R \sin \varphi - a \tan \varphi = R \sin \varphi^1 - a \tan \varphi^1; \quad (7)$$

or,

$$R = a \frac{\tan \varphi - \tan \varphi^1}{\sin \varphi - \sin \varphi^1}$$

the valve will be absolutely in equilibrium at its extreme positions without any variation in the number N , or of speed in the engine.

For the intermediary positions of the valve, theoretically, the number N is not constant; but its variations are so small that it can be considered practically as constant.

The members of the equation (7) represent, respectively, in Fig. 2, the distances AB , A^1B^1 , that is, the projections of AC , A^1C^1 on the axis xx ; therefore, those two projections must result equal to each other in the drawing.

Gallium Battery.—J. Reynauld has succeeded in making a battery of liquid and solid gallium by means of a metal solution of gallium sulphate. The liquid metal takes the place of zinc; the solid, of copper; the former being negative in relation to the latter.—*Fortschr. der Zeit.* C.