(*g*) **Pelton Wheel.** The Pelton wheel is a special type of axial flow impulse turbine and is used for very high heads. It is the most efficient type of impulse wheel, having an overall efficiency of 84 per cent. This type of wheel has been evolved from an earlier type of water wheel used in the mines of California.

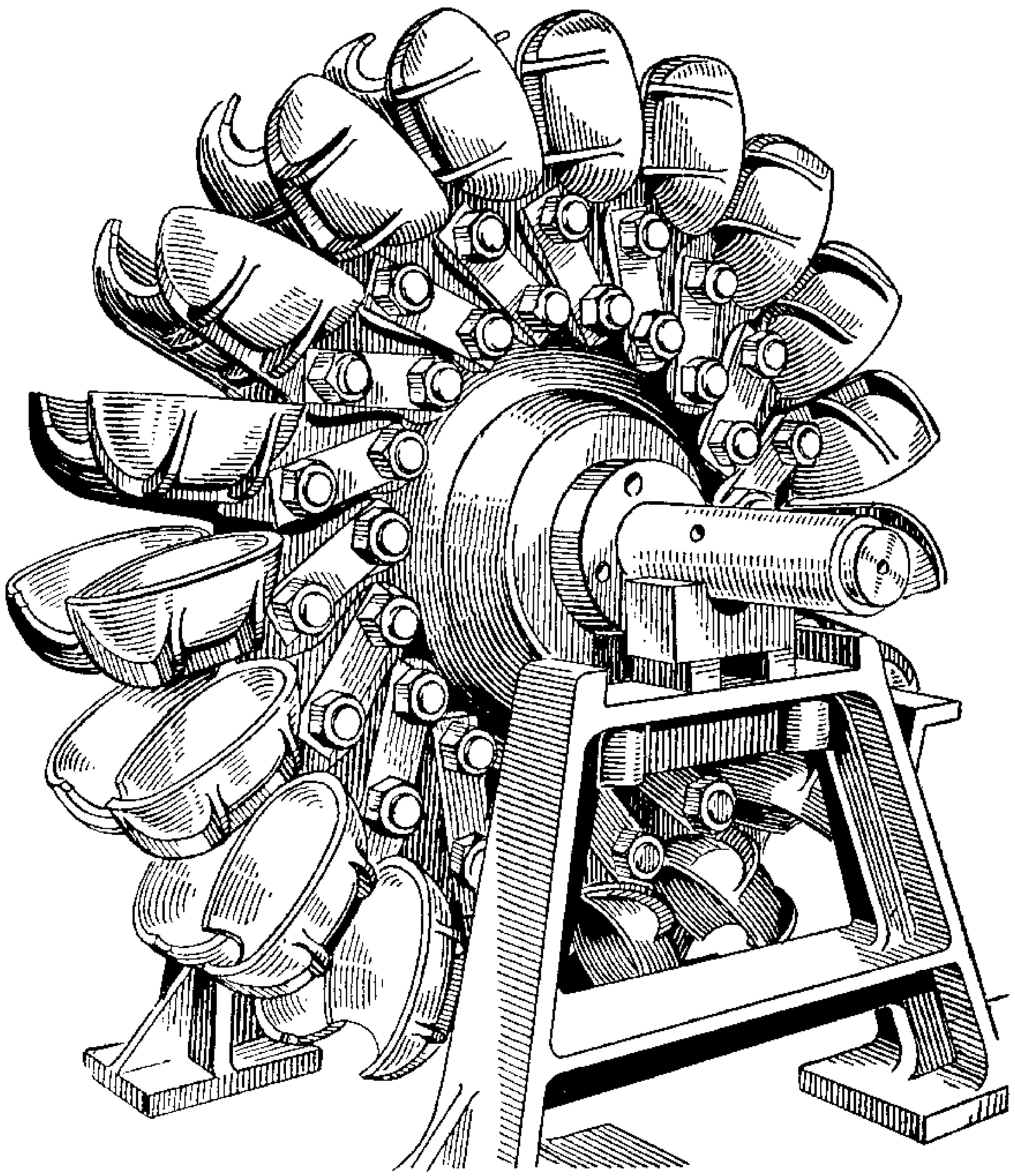


Fig. 135.—Pelton Wheel

The jet impinges on the wheel from one or more nozzles and strikes the blade at the centre (Fig. 135), flowing axially in both directions. The blades are known as buckets and consist of a double hemispherical cup (Fig. 136). As the water flows axially in both directions, there is no axial thrust on the wheel.

The flow of water through the wheel may be regulated by a throttle valve in the supply pipe or by a needle valve in the

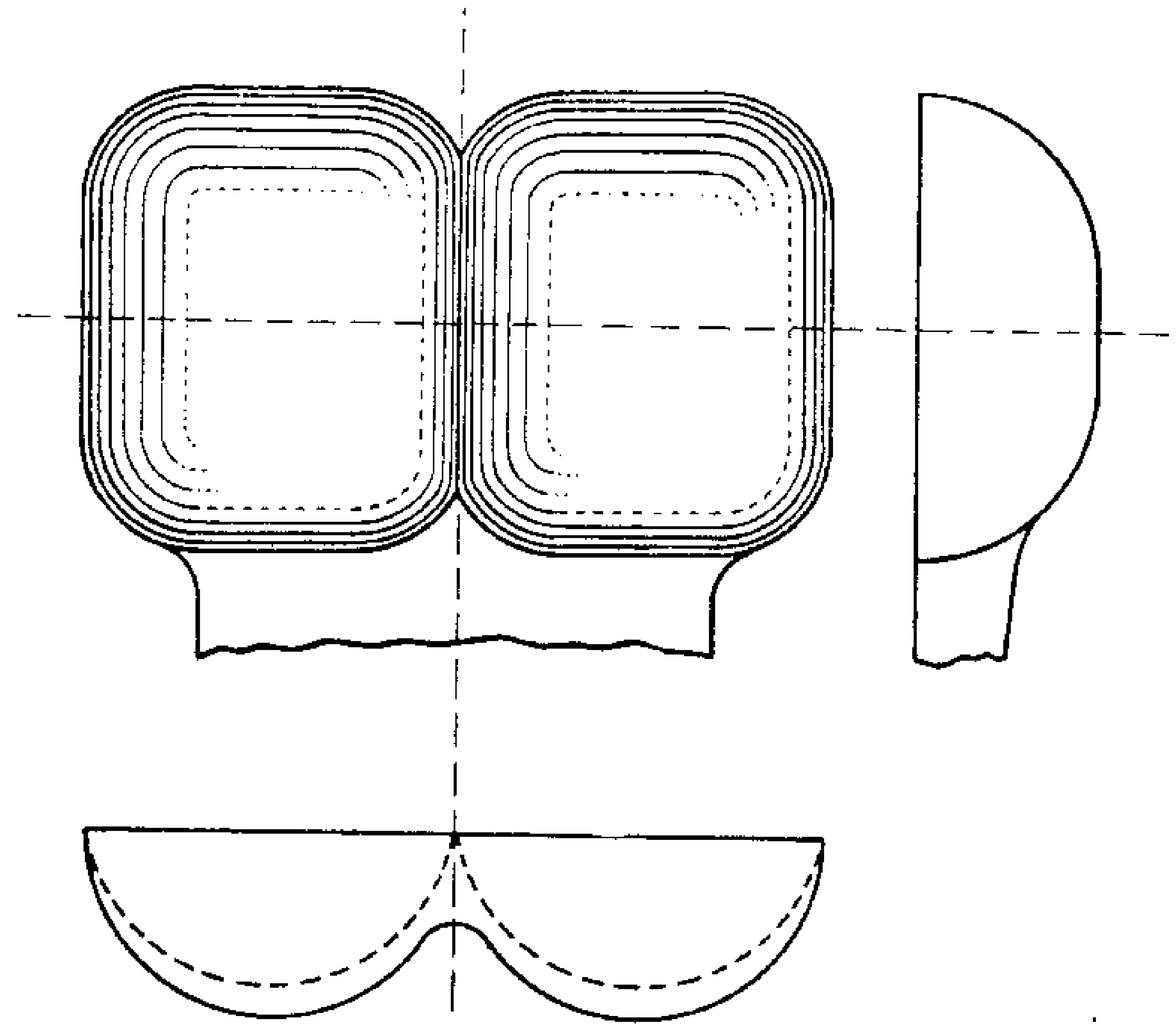


Fig. 136.—Pelton Wheel Buckets (External Views)

nozzle. The buckets are so shaped that the jet is discharged backwards. Usually, the total deflection of the bucket is 160°

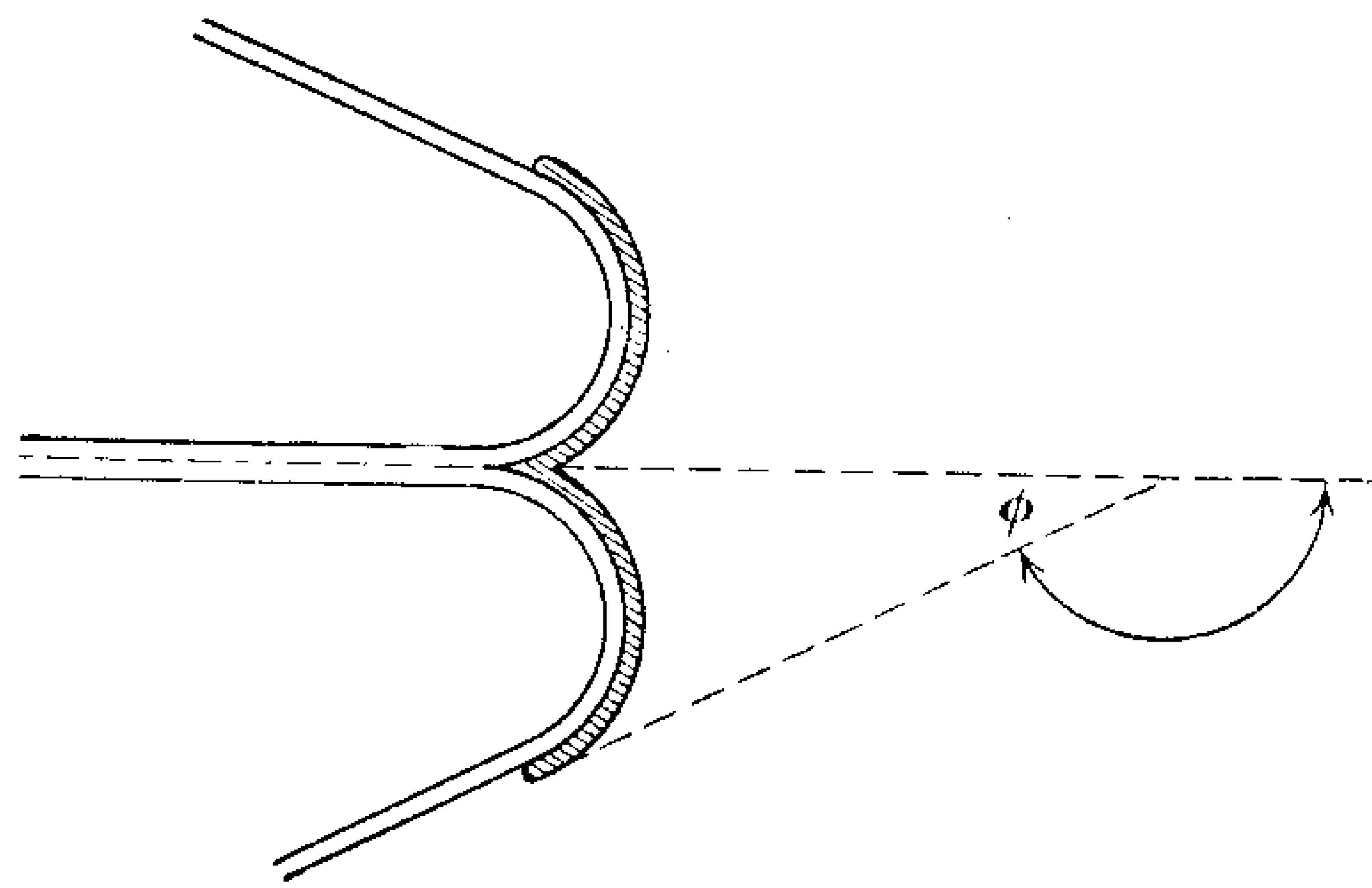
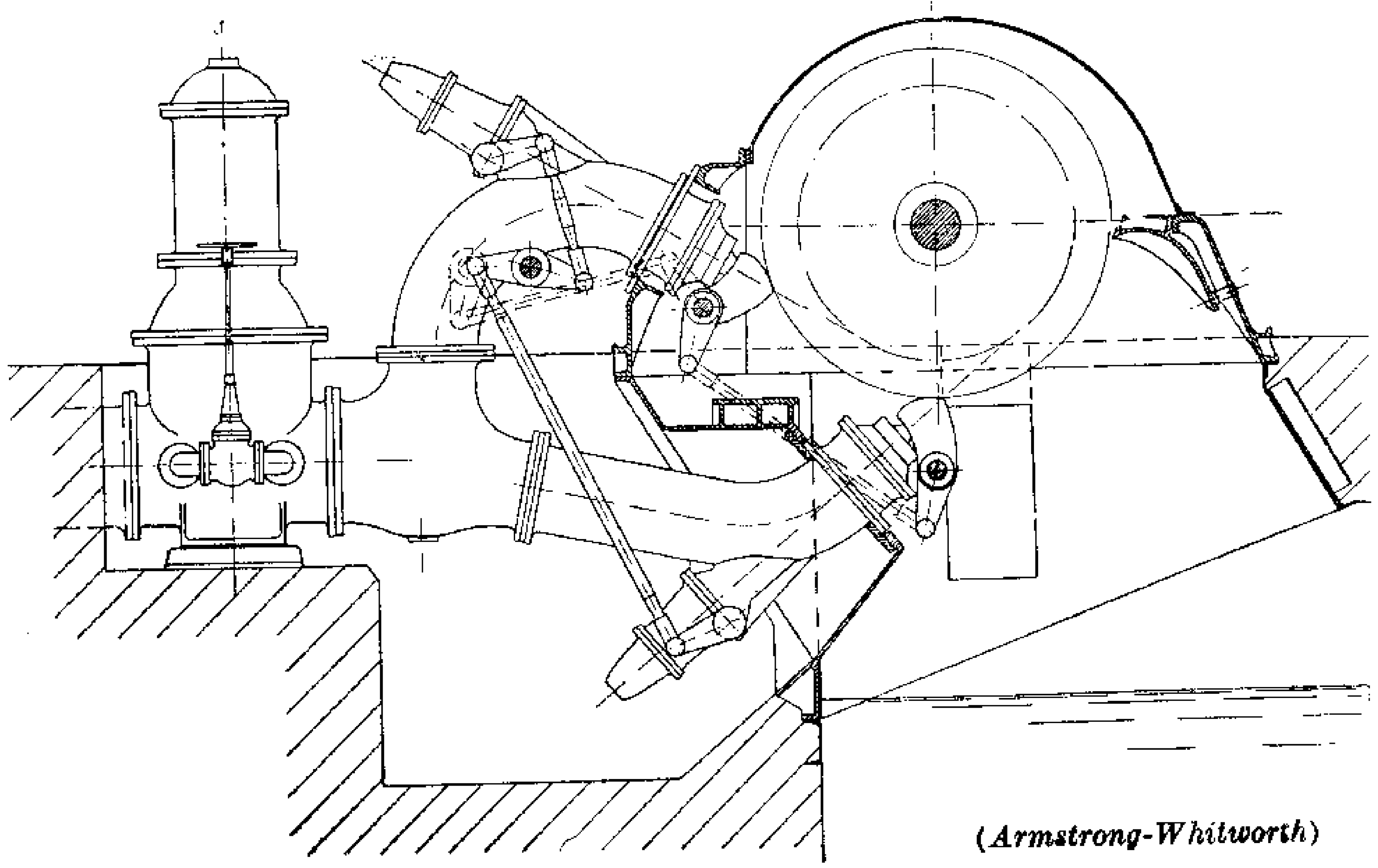


Fig. 137

(Fig. 137). An arrangement of a Pelton wheel, showing nozzles, made by Sir W. G. Armstrong, Whitworth & Co., is shown in Fig. 138.

The work done and efficiency of the Pelton wheel may be obtained from the velocity diagrams as in the case of an ordinary axial flow impulse turbine.



(*Armstrong-Whitworth*)

FIG. 138.—ARRANGEMENT OF PELTON WHEEL

For a Pelton wheel,

$$\theta = 0$$

Also, $\alpha = 0$

Then, velocity diagram at inlet is a horizontal straight line, as shown in Fig. 139.

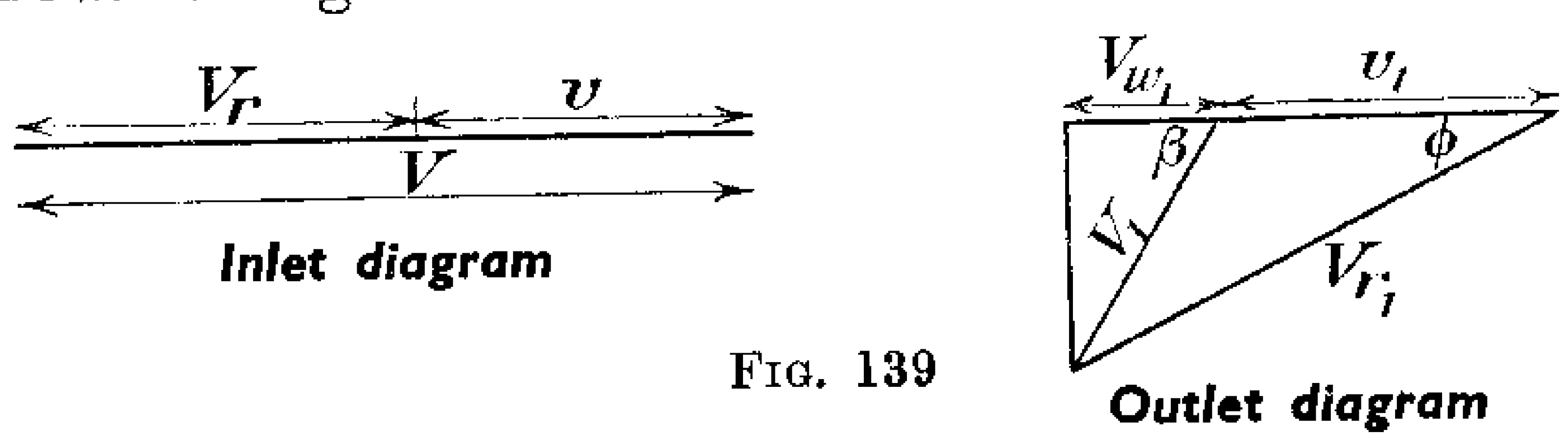


FIG. 139

Hence, $V_r = V - v$

And, $V_w = V = \sqrt{2gH}$

$$V_f = 0$$

From triangle at outlet (Fig. 139),

$$v_1 = v$$

$$V_{r_1} = V_r = V - v$$

$$V_{w_1} = V_{r_1} \cos\phi - v_1$$

$$= (V - v)\cos\phi - v$$

Work done per pound of water $\Big\} = E = \dfrac{V_w v}{g} - \dfrac{V_{w_1} v_1}{g}$

$$= \frac{V v}{g} + \frac{[(V - v)\cos\phi - v]v}{g}$$

(as V_{w_1} is negative)

$$= \frac{1}{g}[Vv + v(V - v)\cos\phi - v^2] \quad . \quad (1)$$

$$= eH$$

$$= H - \frac{V_1^2}{2g}$$

$$\text{Efficiency} = e = \frac{\frac{1}{g}[Vv + v(V - v)\cos\phi - v^2]}{\frac{V^2}{2g}}$$

The speed of the wheel for maximum efficiency can be found by differentiating this equation in terms of v and equating to zero.

$$\frac{d.e}{dv} = V + (V - 2v)\cos\phi - 2v = 0$$

From which, $V(1 + \cos\phi) - 2v(1 + \cos\phi) = 0$

Hence, $v = \dfrac{V}{2}$

Therefore, the speed of the wheel for maximum efficiency will be equal to half the speed of the jet.

In practice it is found that the maximum efficiency is when the speed of the wheel is $\cdot 46V$.

Putting $v = \dfrac{V}{2}$

$$\text{Maximum efficiency} = \frac{2\left[\frac{V^2}{2} + \frac{V^2}{4}\cos\phi - \frac{V^2}{4}\right]}{V^2}$$

$$= \frac{1}{2}(1 + \cos\phi)$$

When $\phi = 0$, the efficiency is equal to unity.

It will be noticed that the deviation of the jet is $180 - \phi$.

The following rules are used for the proportions of the buckets—

Let d = diameter of jet

Depth of bucket $= 1 \cdot 2d$

Width of bucket $= 5d$

The number of buckets may be obtained by arranging them so that the jet is always completely intercepted by a bucket.

Let R be the mean radius of bucket circle and γ be the angle subtended by two adjacent buckets (Fig. 140). If the jet is to be always intercepted, one bucket will be just about to move out of the jet as another has just moved in.

Let b, c, and e be adjacent buckets. As jet is moving at twice the speed of the buckets, a section of jet will move from c to e

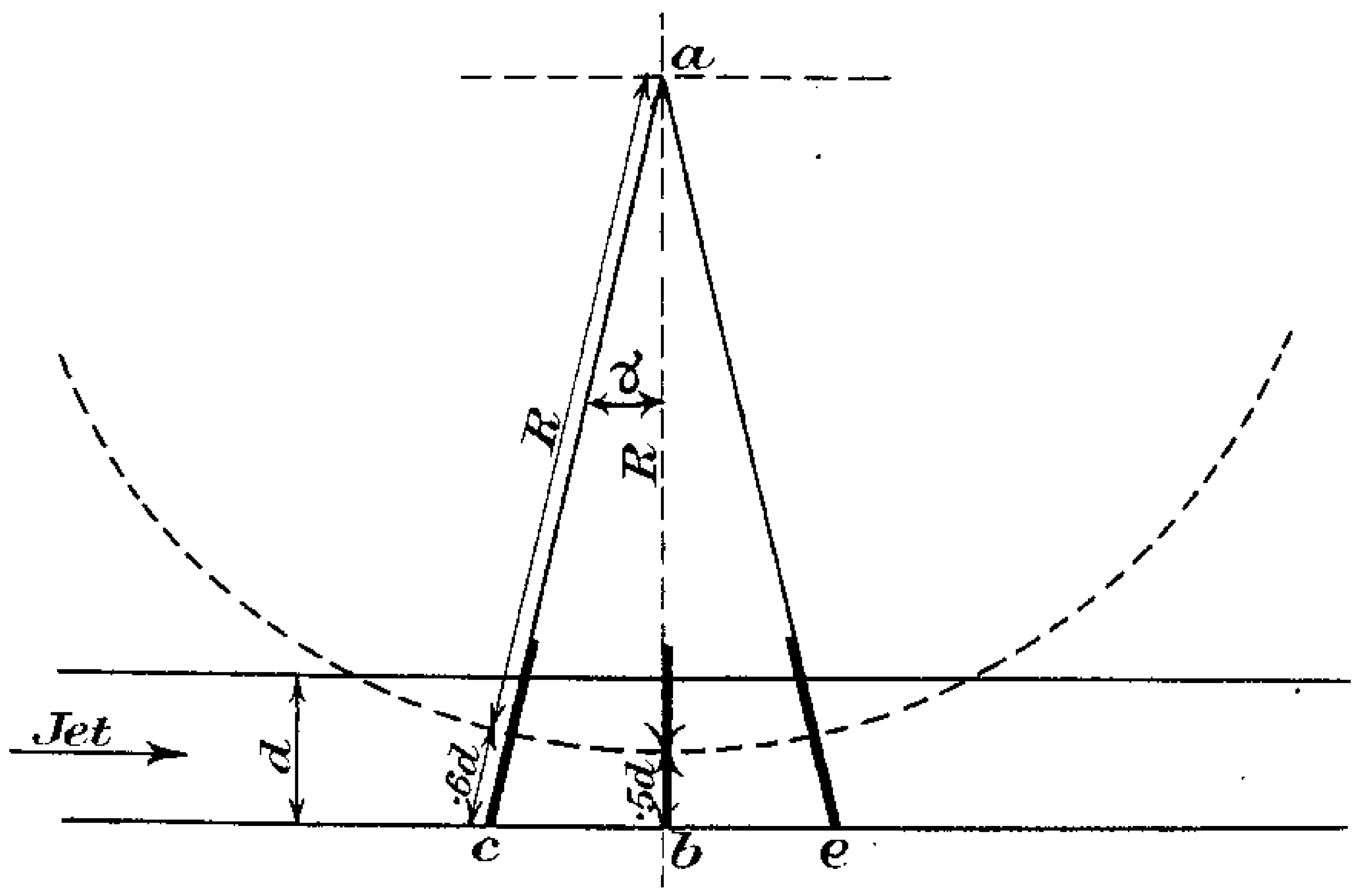


FIG. 140

in same time as bucket b moves to e. Hence, for jet to be always intercepted, the buckets will be as shown in Fig. 140.

Consider triangle abc,

$$ac = R + \tfrac{1}{2} \text{ depth of bucket} = R + \cdot 6d$$

$$ab = R + \tfrac{1}{2} \text{ diameter of jet} = R + \cdot 5d$$

Then, $$\cos \gamma = \frac{R + \cdot 5d}{R + \cdot 6d}$$

From which equation γ is obtained.

Then, number of buckets* $= \dfrac{360}{\gamma}$

Pelton wheels are in use with heads as large as 5,000 ft.

* This equation does not hold in practice as there is not sufficient space around the wheel perimeter for this number of buckets to be inserted. Actually, the number of buckets is about half of that given by the equation.

EXAMPLE 1.

A cup, similar to that in a Pelton wheel, deflects a jet of water through an angle of 120°. Determine the speed of the cup in terms of the velocity of the jet so that the work done by the jet on the cup shall be a maximum and express this work as a percentage of the energy of the jet.

Show how the speed necessary for maximum efficiency would be affected if the friction of the water in passing over the surface of the cup were considerable. (London Univ.)

Referring to Figs. 137 and 138,

$$\phi = 180 - 120 = 60°$$

$$\left.\begin{array}{l}\text{Work done per pound}\\ \text{of water}\end{array}\right\} = E = \frac{V_w v}{g} - \frac{V_{w_1} v_1}{g}$$

$$= \frac{Vv}{g} + \frac{v(V - v)\cos 60 - v^2}{g}$$

Differentiating for a maximum,

$$\frac{dE}{dv} = V + V \cos 60 - 2v \cos 60 - 2v = 0$$

Hence, $$V(1 + \cos 60) - 2v(1 + \cos 60) = 0$$

Therefore, $$v = \frac{V}{2}$$

Then,

$$\left.\begin{array}{l}\text{maximum work done}\\ \text{per pound of water}\end{array}\right\} = \frac{\frac{1}{2}V^2 + \frac{1}{4}V^2 \cos 60 - \frac{1}{4}V^2}{g}$$

$$= \frac{\frac{3}{8}V^2}{g}$$

Energy supplied $$= \frac{V^2}{2g}$$

Efficiency $$= \frac{\dfrac{\frac{3}{8}V^2}{g}}{\dfrac{V^2}{2g}} = \cdot 75$$

If there is no friction over the cup, the relative velocity at exit equals relative velocity at entrance. Let friction reduce relative velocity at exit to $k \times V_r$,