of the nozzles must be at a greater elevation than the lowest point of the bucket-pitch circle, the efficiency is somewhat lower than that of a single-jet machine, and where the power required from a unit is greater than can be obtained from a single jet, it is usually preferable to mount two single jet wheels side by side on the same shaft (Fig. 187).

Nozzles.—The modern Pelton wheel is always fitted with a circular nozzle having a needle regulator. This is a cylindrical needle or spear of tapering section fitted inside the nozzle axially with the jet (Fig. 186). Discharge takes place through the annulus between needle and nozzle, giving a solid

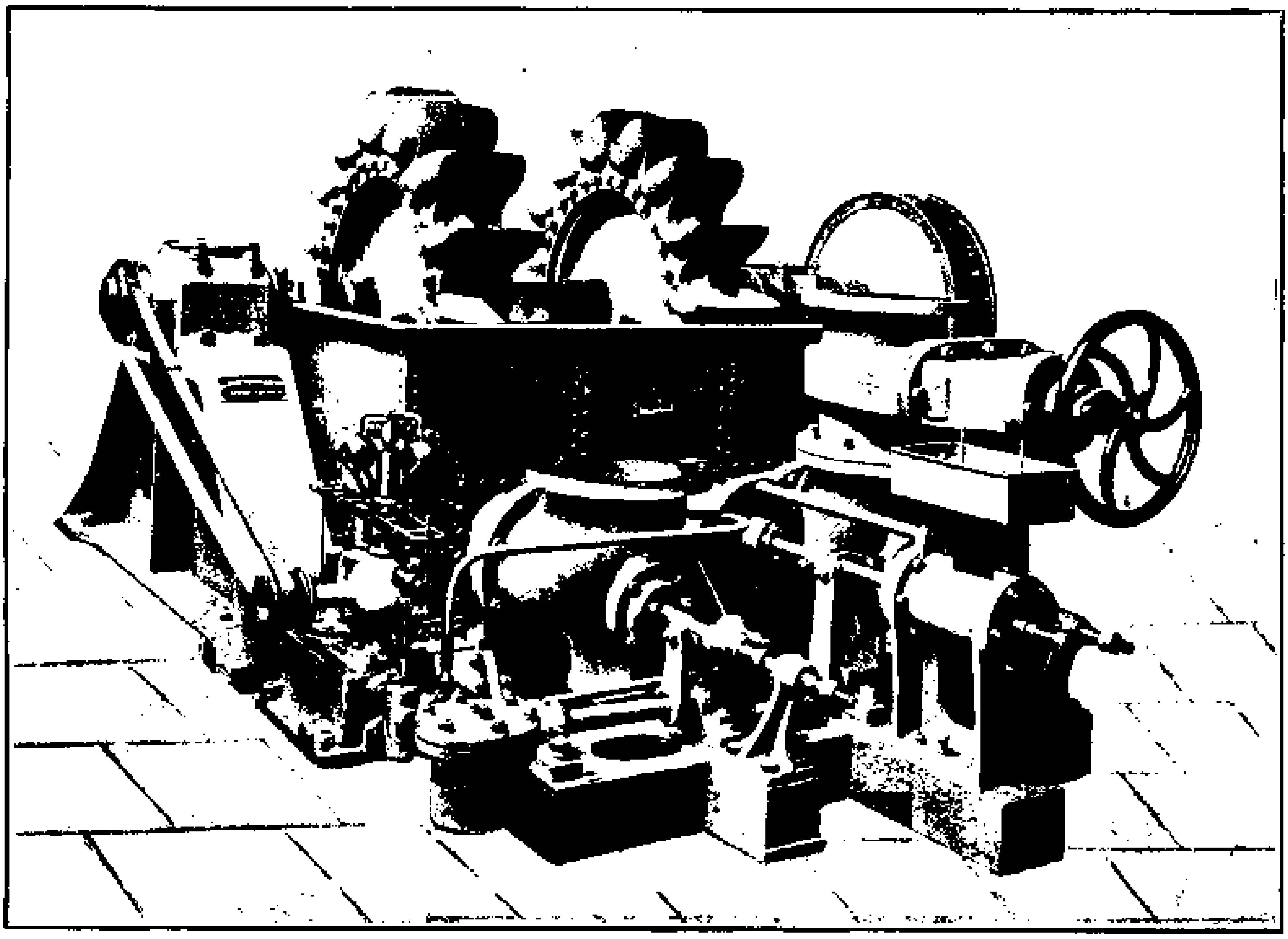

FIG. 187.—Twin Pelton Wheel with Hydraulic Relay Governor.

cylindrical jet on leaving the needle. The size of jet is determined by the axial position of the needle. This may be regulated by hand, or, as in all important installations, by the governing mechanism. It is important that the needle be central in the nozzle and be supported so as to prevent all vibration. Also it should be so formed that the least section of the annulus is in the plane of the nozzle for all openings.

Other shapes of jet have been tried, but all suffer a greater windage loss than the circular. Also all tend to become circular and to become unsteady in the process.

The maximum diameter of jet yet used in practice is about 12 inches.

Jets from Needle-Nozzle.

The presence of the central needle in a nozzle provided with needle regulation causes a reduction in the velocity of the central filament,

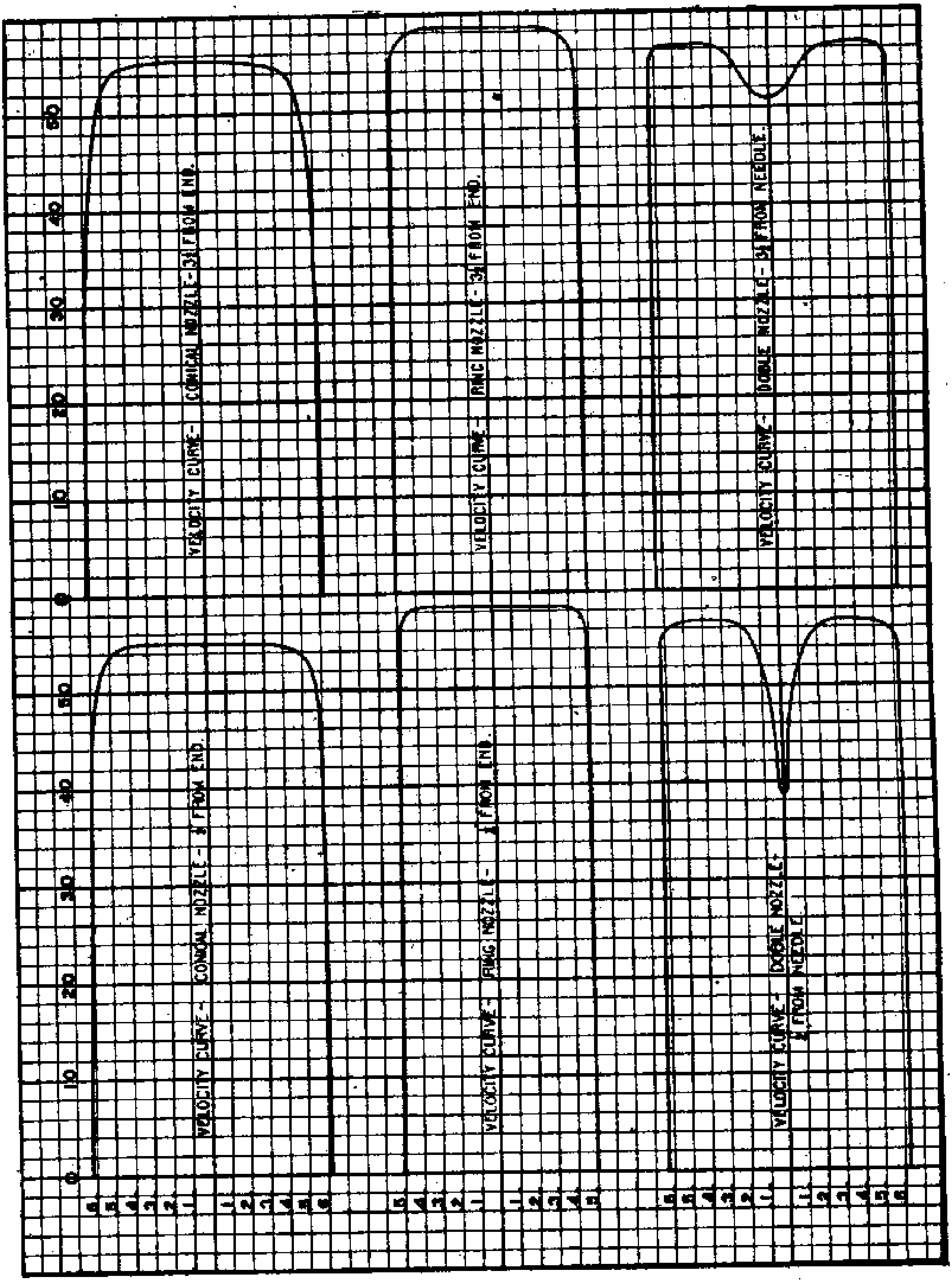

Fig. 188.

and to this extent tends to reduce the efficiency of the jet. Fig. 188 shows the velocity obtained at different points in the cross section of a jet obtained respectively from a plain conical nozzle, a ring nozzle and a Pelton wheel nozzle with needle regulator.[1] From these it appears that the central velocity at a point distant ½ inch from the tip of the needle is only ·68 of the maximum velocity. At a section 3½ inches from the tip this ratio becomes ·90, while when the distance is 9½ inches it becomes ·96.

At mid opening (diameter 1·25 inches) the coefficient of velocity diminishes slightly as the head increases, from about ·992 with 28 feet head to ·978 with 120 feet head. With a given head the velocity was slightly the

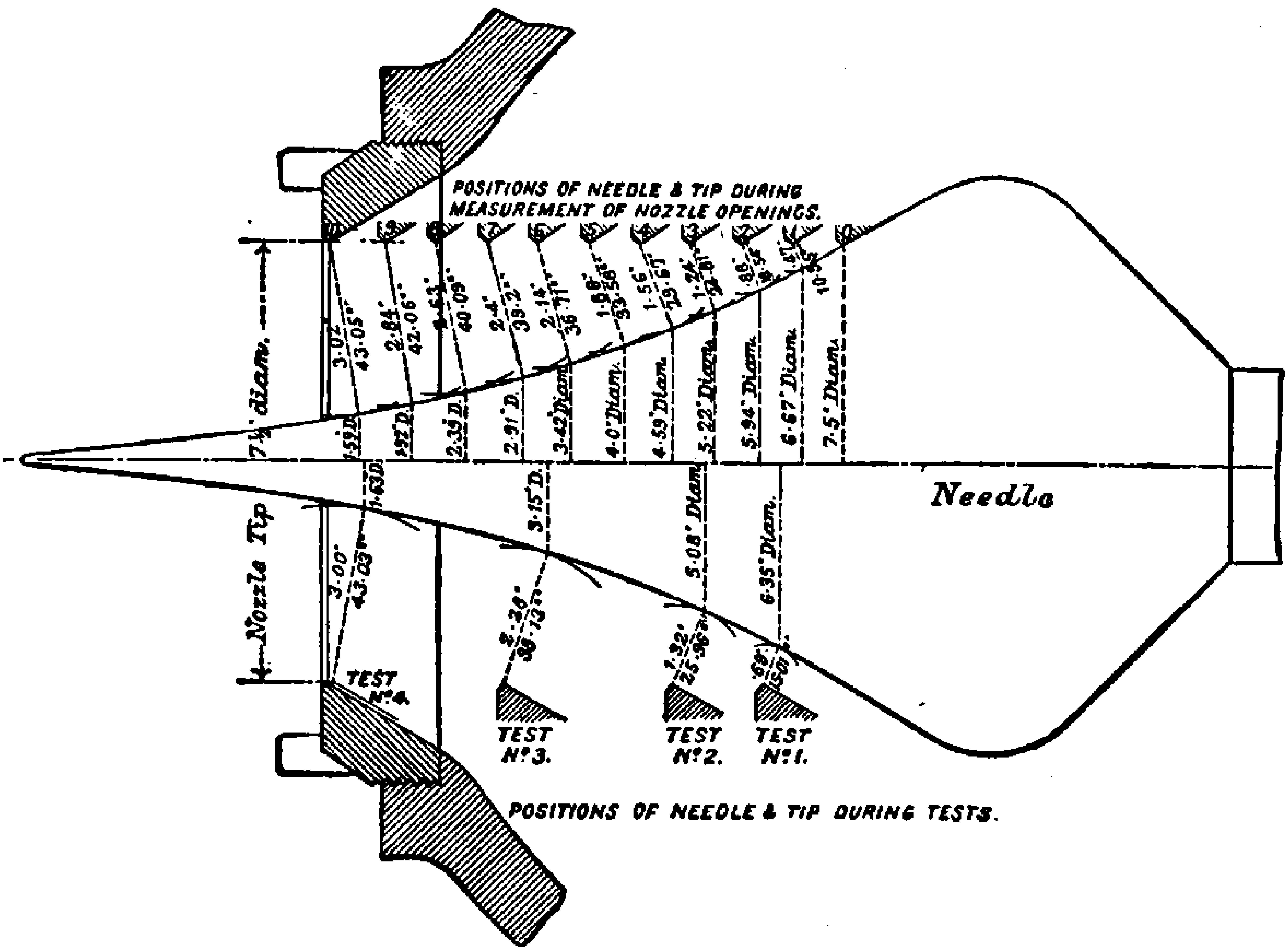

FIG. 189.

greatest with the nozzle half open. The efficiencies in these experiments varied from ·964 to ·993. The maximum jet diameter was 1·50 inches.

Experiments on a larger nozzle, giving a jet up to 7 inches diameter under heads up to 850 feet,[2] showed the following results :

Distance from centre of jet (inches).	0·0	·5	1·0	2·0	3·0
Velocity (feet per second)	212·7	228·7	229·3	229·9	227·8

[1] From a Thesis by H. C. Crowell and G. C. Lenthe (Massachusetts Institute of Technology, 1903).

[2] W. R. Eckhart, Inst. Mech. Engineers, January, 1910.

The coefficient of velocity increased from ·971 to ·989 as the nozzle area was increased, the coefficient of discharge diminishing at the same time from ·965 to ·838, and the efficiency increasing from ·958 to ·986. Fig. 189 shows the shape of needle and tip used in these experiments.

It is advisable to fit a series of guides behind the needle, parallel to the axis, so as to eliminate whirl in the water approaching the jet. Any such whirl causes the jet to spread rapidly and greatly reduces its efficiency. Also, in order to reduce windage losses, the nozzle should be as near to the buckets as mechanical considerations permit.

Buckets.—The original Pelton buckets were of rectangular section (Fig. 190 *a*). These have been superseded by the elliptical bucket (Fig. 190 *b*), in which that part of the lip in the line of the jet is omitted. The lip and ridge of the original bucket deflect the jet in two planes at right angles, and as the paths of the streams thus formed cross, a certain amount of energy is dissipated by their impact. Also, the lip tends to deflect the jet radially inwards towards the rim of the wheel, in which case some fouling of the succeeding bucket is inevitable. The sharp curves and corners of this type of bucket cause an appreciable loss in eddy formation, and tests show that the efficiency obtained with the modern form of bucket is from 6 to 10 per cent. greater than with the older form.

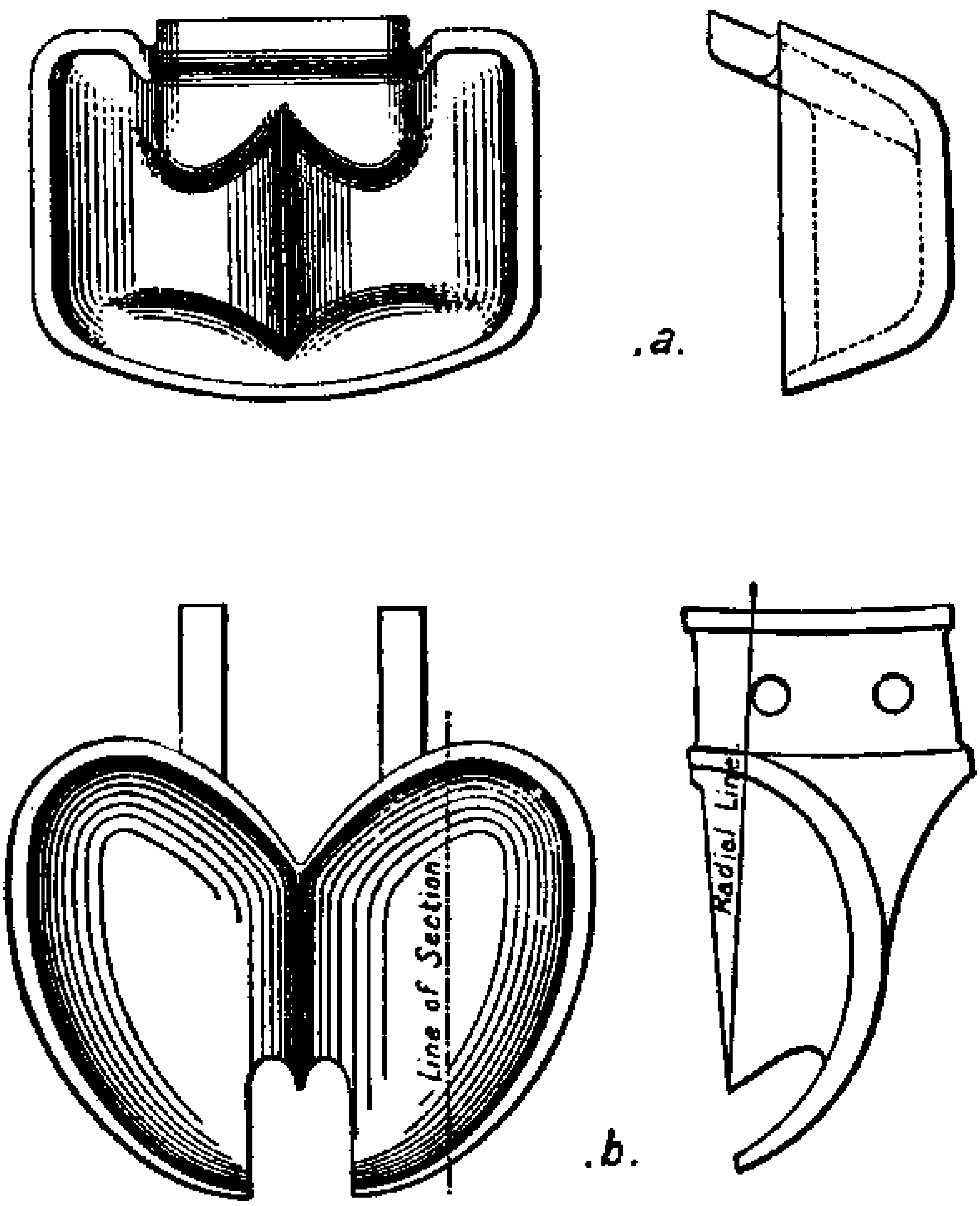

FIG. 190.

The angle through which the jet is deflected by the bucket should be as nearly 180° as possible. In order that the discharge from one shall clear the back of the following bucket, in practice this angle is limited to a maximum of about 165°.