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The Investigation of the Internal Pressure Loss in Hydrocyclones

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Abstract

It is of great importance to perceive the internal pressure loss in hydrocyclones for the purpose of reducing energy consumption. The internal pressure loss in hydrocyclones with two different thicknesses of vortex finder wall and variable diameters of overflow and underdischarge outlets have been measured experimentally. A new approach to cutting down the internal pressure loss by 50% without decreasing the flow rate has been developed.

INTRODUCTION

The hydrocyclone is a widely used piece of equipment in which pressure energy is transformed into kinetic energy and the feed materials are classificated into fine overflow and coarse discharge or thickened or segregated into heavy and light fractions by the action of outward centrifugal force and inward dragging force. The pressure (or head) loss is unavoidable in the operation of a hydrocyclone. Theoretically, the total head loss across the hydrocyclone can be expressed as the sum of the internal and outlet losses (*1*), i.e.,

$$\Delta H = \Delta h_i + \Delta h_o \tag{1}$$

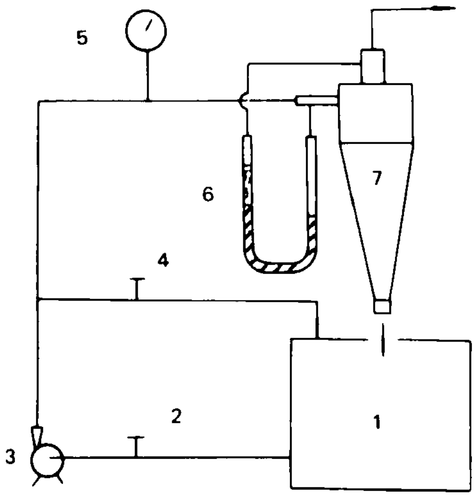

FIG. 1. Experiment device. 1: Water box. 2: Valve. 3: Pump. 4: Valve. 5: Gauge. 6: U-Tube gauge. 7: Hydrocyclone.

The outlet loss (Δh_o) is the velocity head of outflow. Some developments (*1, 2*) have been made in the recovery of this outlet loss. The internal loss (Δh_i), however, has not yet been studied fully, although Arato (*1*) stated that the internal loss at a given flow rate is determined by the surface roughness and geometry of the cyclone, as well as by the viscosity of the fluid, and cannot be altered for any cyclone performing a specific duty. But, as mentioned by the authors (*3*), there is useless energy consumption within the forced vortex of the hydrocyclone because of the viscosity and turbulence of the fluid. This consumption may be reduced by a suitable approach.

Accurate determination of the head loss across a hydrocyclone is difficult because of the presence of the underflow. Under turbulence conditions, however, the internal loss in the hydrocyclone is proportional to the square of the inlet mean velocity, i.e.,

$$\Delta h_i = \zeta \frac{V_{in}^2}{2g} \tag{2}$$

where V_{in} is the inlet mean velocity, g is the gravity acceleration, and ζ is a dimensionless drag force coefficient.

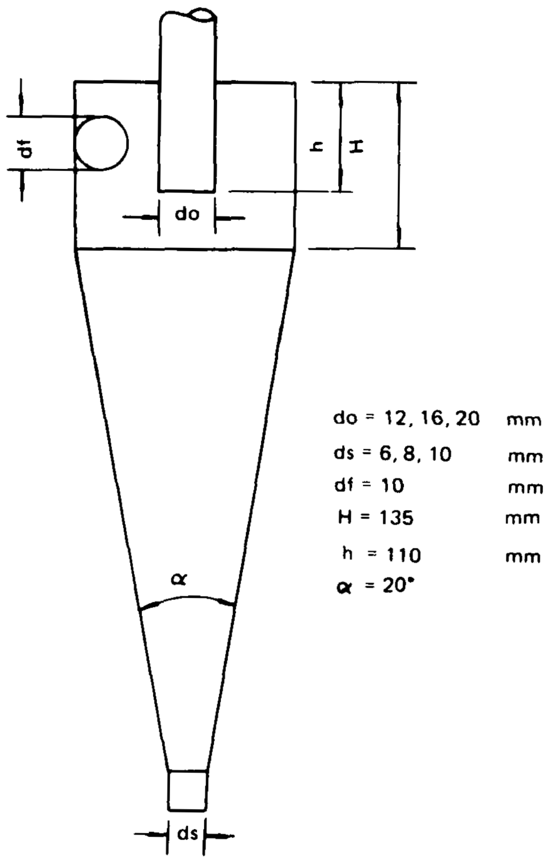

FIG. 2. 80-mm Hydrocyclone used in experiments.

EXPERIMENTAL DEVICE

As illustrated in Fig. 1, a U-tube gauge is used to measure the head difference between the inlet and outlet, and this measured value is taken to be approximately the internal loss (Δh_i). Meanwhile, the flow rates of overflow and underflow are measured to calculate the inlet mean velocity. Figure 2 is the geometry of the hydrocyclone used in our experiments. The diameters of the apex and vortex finder are variable.

RESULTS AND DISCUSSION

1. Internal Pressure Loss vs Thickness of Vortex Finder Wall

In studies (*4*) of the flow pattern of the hydrocyclone it was verified that a thicker vortex finder wall plays a beneficial role in the flow field, for example, by eliminating circular flow in the cylindrical part, widening the zero velocity zone of axial flow, and decreasing the short-circuit flow under the roof of the hydrocyclone. Therefore, the influence of the thickness of the vortex finder wall on internal loss was investigated first. Figure 3 shows the experimental results. The thickness of the thicker wall of the vortex finder is 22 mm and that of the thinner wall is 6 mm, with both having the same inside diameter and the same length in the cyclone. It is seen that there is a linear relationship between the internal loss (Δh_i) and the square of the inlet mean velocity (V_{in}^2) in a certain feed pressure range. When the feed pressure, i.e., the inlet velocity, becomes smaller,

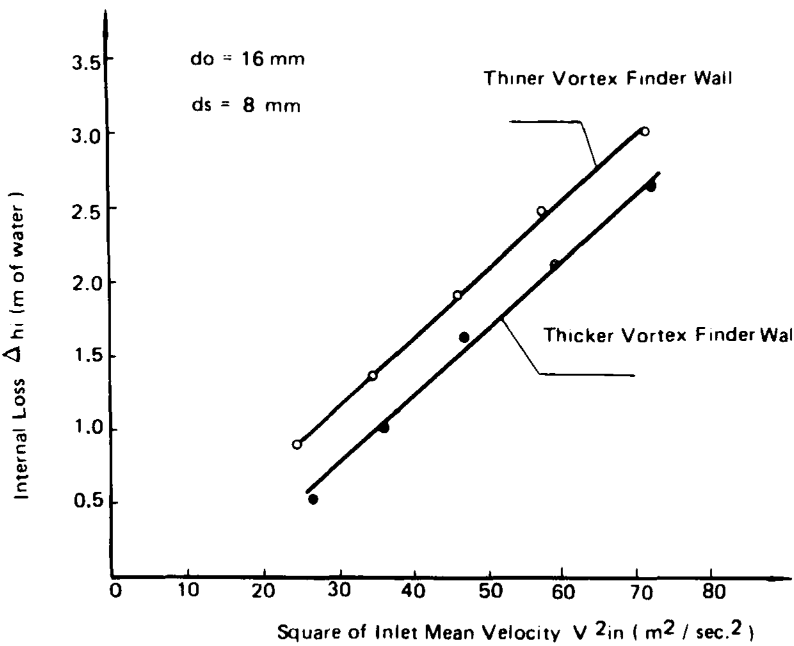

FIG. 3. Internal loss vs thickness of vortex finder wall.

however, the linear relationship disappears. In other words, the lines in Fig. 3 cannot be extrapolated to the origin. A possible explanation of this fact is that the inlet flow Reynolds number at a lower inlet velocity is not great enough to generate turbulent flow in the cyclone, therefore Eq. (2) is not applicable in this instance. This can also be seen in the following studies. Figure 3 shows that the thickness of the vortex finder wall has a certain effect on the internal loss. Under the experiment conditions, when the inlet velocities are the same, the internal loss of a hydrocyclone with a thicker vortex finder wall is smaller.

2. Internal Loss vs Size of Outlets

The sizes of hydrocyclone outlets have a large effect on the internal loss. Enlarging the outlets will undoubedtly decrease the internal loss, but the retention time of the feed in the hydrocyclone could also be shortened and the efficiency might be cut down. With the prerequisite of not decreasing the efficiency, larger outlets may not only raise the flow-through but may also reduce the energy loss.

For a given size of a vortex finder with a thicker wall, the relationship of internal loss vs the square of the inlet mean velocity for various apexes is given in Fig. 4. Clearly, the internal loss is reduced with enlargement of the apex, and the more intence the turbulence, the more distinct the reduction.

For a given apex and various inside diameters of a vortex finder with a thicker wall, the dependence of internal loss on the square of the inlet mean velocity is shown in Fig. 5, from which a tendency similar to that of Fig. 4 can be observed.

In a range of turbulence, the drag force coefficient ζ can be regressed from the experimental data by Eq. (2). Figure 6 shows the curves of ζ vs the diameters of two outlets. The coefficient ζ is lowered with an increase of outlet diameters but is independent on whichever of the outlets is used; the reason for this is that the two curves of Fig. 6 are almost parallel.

A plot of ζ vs total outlet area is presented in Fig. 7, in which the total outlet area of the hydrocyclone with a vortex finder diameter of 12 mm and an apex diameter of 6 mm is regarded as unity. The figure indicates that the drag force coefficient is a function of the total outlet area regardless of an enlarged vortex finder at a fixed apex or an enlarged apex at a fixed vortex finder. It is reasonable to assume that the drag force coefficient ζ is only dependent on the total outlet area. In addition, the coefficient ζ decreases more quickly with a smaller outlet area and

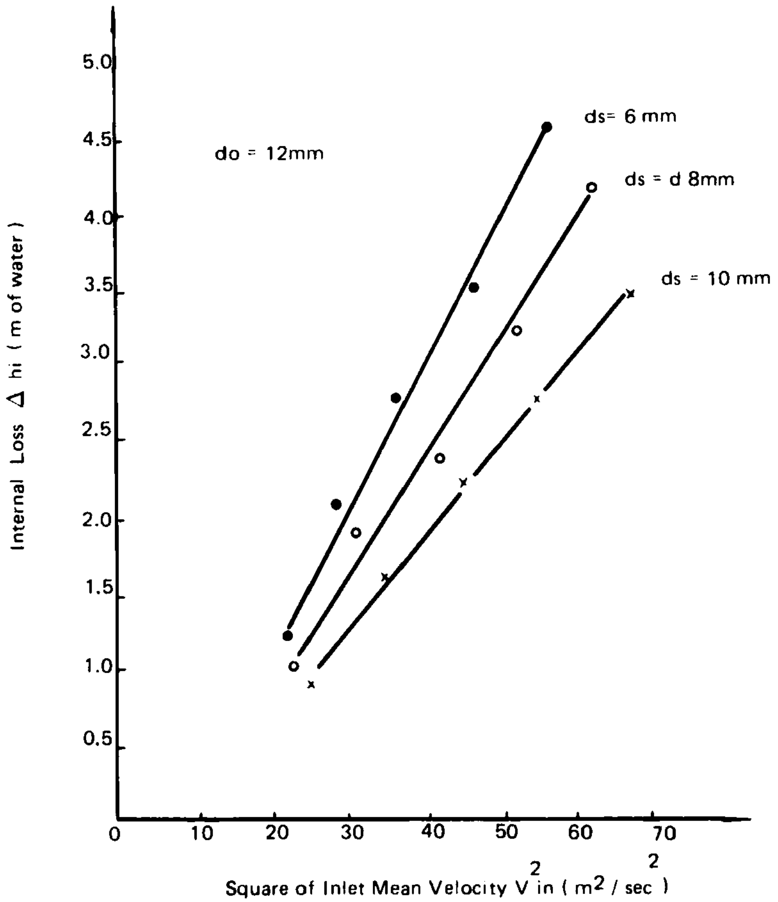

FIG. 4. Internal loss vs apex diameter (thicker vortex finder wall).

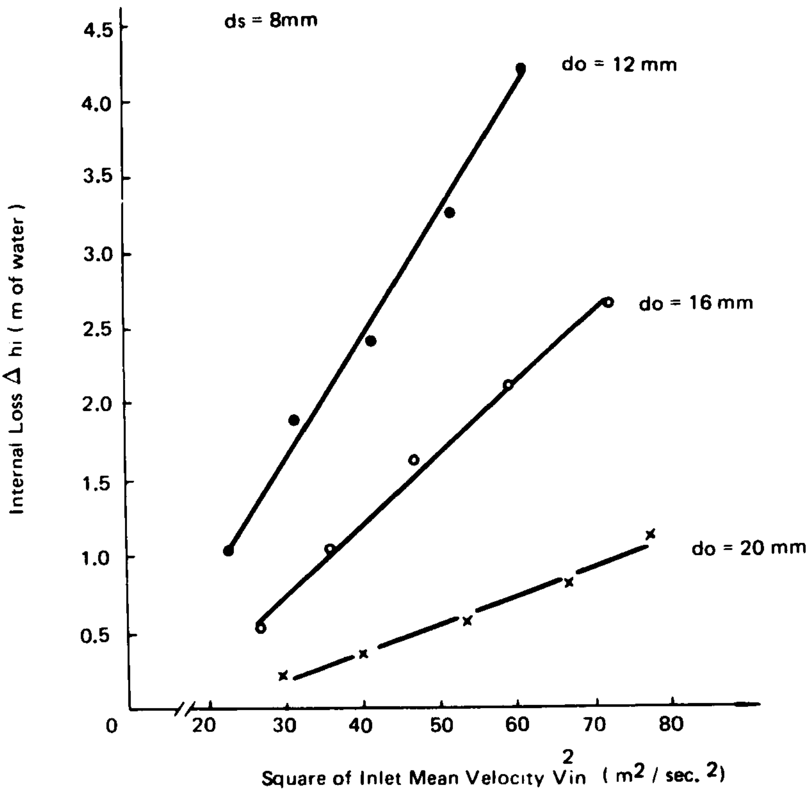

FIG. 5. Internal loss vs vortex finder diameter (thicker vortex finder wall).

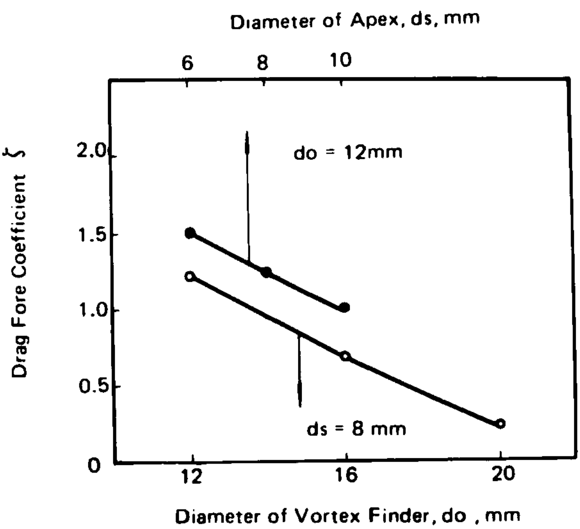

FIG. 6. Drag force coefficient ζ vs outlet diameters.

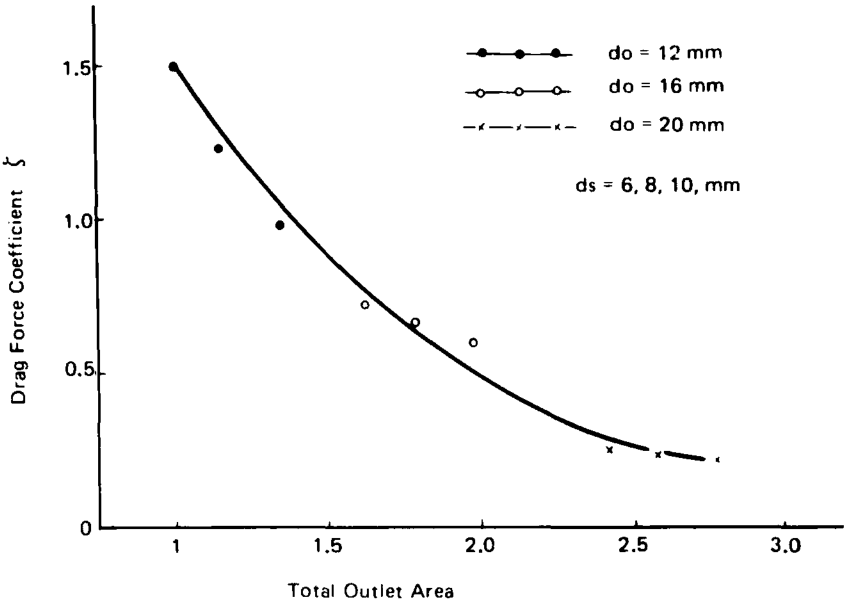

FIG. 7. Drag force coefficient ζ vs total outlet area.

changes smoothly when the outlet area is greater than a threshold value.

3. A New Approach to Reducing Internal Loss in Hydrocyclones

There is a compound action of forced vortex and free vortex in a conventional hydrocyclone. During the performance of classification or other processes (such as thickening, separating), the treated mineral generally cannot enter into the forced vortex, but some fines are drawn into it because the unstability of the liquid-gas interface lowers the efficiency of the hydrocyclone. Considerable energy consumption occurs in the forced vortex mainly due to the existence of an air core.

A new approach to eliminating the forced vortex and reducing the internal loss by substituting a solid core for the original air core was tested. In the new hydrocyclone, the energy loss due to the viscosity and turbulence of the forced vortex found in a conventional hydrocyclone was eliminated. Of course, frictional loss due to the additional solid–

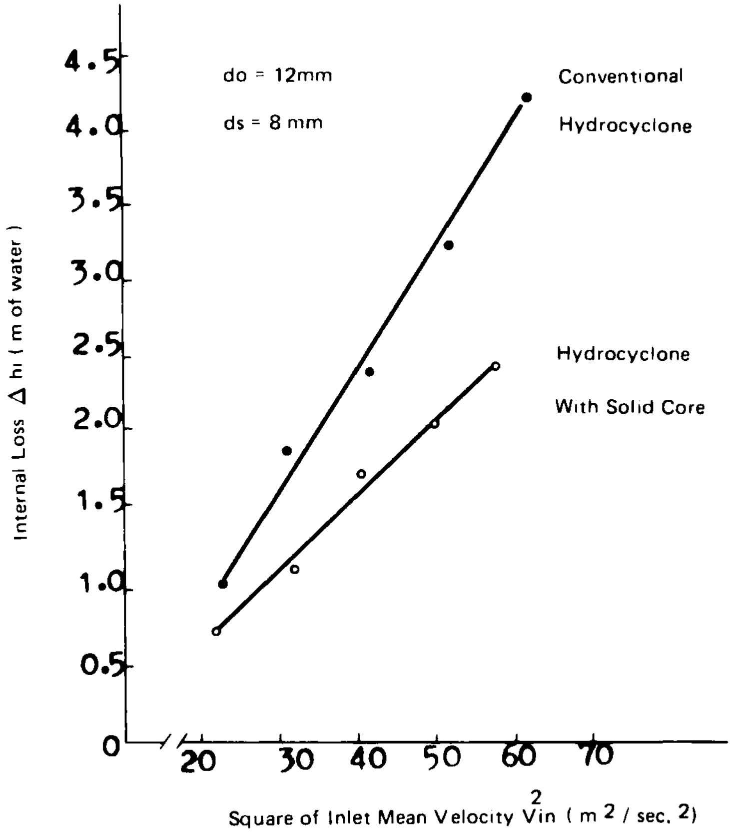

FIG. 8. Internal loss vs solid core.

liquid interface was increased. As indicated by our experiments, however, the net effect is the marked decrease of the internal loss.

Figure 8 shows the relationships of internal loss Δh_i vs the square of the inlet mean velocity in hydrocyclones with a solid core and an air core, respectively. The solid core had a diameter of 7.45 mm. In Fig. 8, the internal loss of the hydrocyclone with a solid core decreased markedly, and the higher the inlet velocity, the greater the decrease.

The experimental results of various solid core diameters are presented in Fig. 9 in which the diameters of cores I, II, and III are 7.45, 6.75, and 5.00 mm, respectively. Figure 9 shows that the intenral loss becomes larger when the solid core is too big or too small. The possible

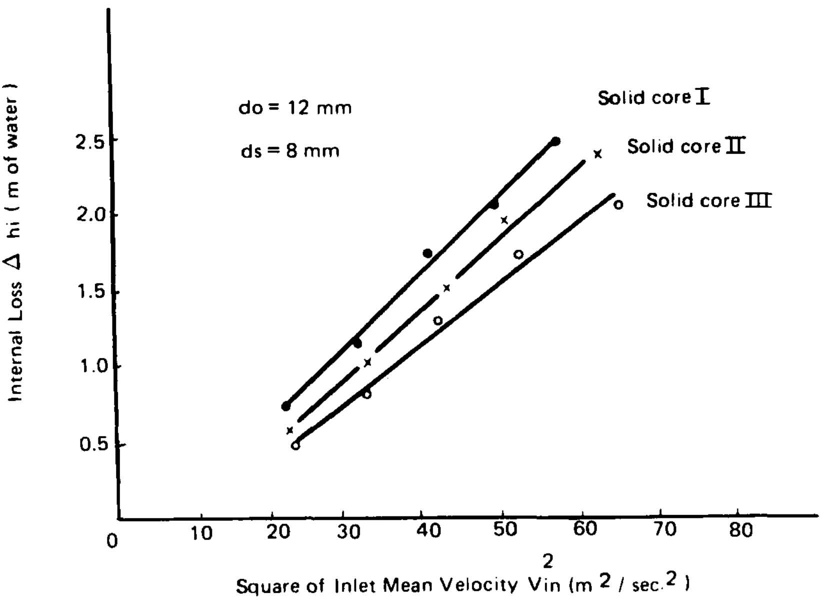

FIG. 9. Internal loss vs various solid cores.

explanation for this is that a thicker solid core is big enough to engage the forced vortex completely, but the friction loss of the solid-liquid interface is maximum. On the other hand, a thinner solid core does not occupy the whole forced vortex zone although the friction is smaller. Only when the solid core has a suitable diameter does the net effect of eliminating the forced vortex and decreasing the friction become optimum. Experiments indicate the optimum diameter of the solid core is about equal to or slightly less than the diameter of the air core.

The drag force coefficients and relative internal losses of conventional hydrocyclone and hydrocyclones with different diameters of solid core at 1.8 atm feed pressure are given in Table 1, from which a significant result can be seen: the internal loss in hydrocyclones with a solid core is only 42–52% of the conventional one.

It is necessary to investigate further the flow rate of hydrocyclones in which the forced vortex is engaged by a solid core. Tables 2 and 3 present the measured results of the flow rate and the percentage of underflow, respectively. The results show that a solid core does not decrease the total flow rate but does increase the underflow somewhat. When the diameter of the solid core is 7.45 or 6.75 mm, the underflow increases 10% on the

TABLE 1
Drag Force Coefficient (ζ) and Relative Internal Loss (Δh_i) vs Solid Core (d_s = 6 mm, d_0 = 12 mm, thicker vortex finder wall)

	No solid core	Solid core I	Solid core II	Solid core III
ζ	1.23	0.80	0.59	0.70
Δh_i (%)	100	58	48	56

TABLE 2[a]
Influence of Solid Core on Flow Rate

	Feed pressure (kg/cm)				
	0.60	0.90	1.20	1.50	1.80
Q0 (mL/min)	22.4	26.3	30.4	34.0	37.1
Q1 (mL/min)	22.1	26.5	30.1	33.4	35.8
Q2 (mL/min)	22.7	26.9	30.4	34.3	38.4
Q3 (mL/min)	22.6	27.1	31.0	33.9	37.5

[a]Q0, Q1, Q2, and Q3 are the flow rates of hydrocyclones with solid core diameters of 0, 7.45, 6.75, and 5.00 mm, respectively.

TABLE 3[a]
Influence of Solid Core on Distribution of Flow Rate

	Feed pressure (kg/cm)				
	0.60	0.90	1.20	1.50	1.80
r0 (%)	41.8	41.7	41.1	40.2	39.0
r1 (%)	54.3	52.8	50.2	49.4	50.1
r2 (%)	52.6	50.2	48.8	48.8	48.1
r3 (%)	41.5	46.1	44.5	42.8	42.2

[a]r0, r1, r2, and r3 are the ratios of underflow to total flow in hydrocyclones with solid core diameters of 0, 7.45, 6.75, and 5.00 mm, respectively.

average; if the diameter is 5.00 mm, the increase is only about 3%. It is reasonable to conclude that a solid core does not significantly affect the flow rate and its distribution.

CONCLUSION

The investigation of internal loss in a hydrocyclone is important for the reduction of energy consumption by the hydrocyclone.

A thicker vortex finder wall in a hydrocyclone cannot only improve the flow pattern (*4*) but also decrease the internal loss.

The internal loss of a hydrocyclone is closely related to the total outlet area. Outlets should be as large as possible while not reducing the efficiency of the cyclone.

Eliminating the forced vortex in conventional hydrocyclone is a useful approach to decreasing internal loss. When a solid core engages the forced vortex zone, the internal loss of a hydrocyclone can be cut down by approximately 50% without decreasing the flow rate.

REFERENCES

1. E. G. Arato, "Reducing Head or Pressure Losses across a Hydrocyclone," *Filtr. Sep.*, *21*(3), 181–182 (1984).
2. J. D. Boadway, *A Hydrocyclone with Recovery of Velocity Energy*, Presented at the 2nd International Conference on Hydrocyclones, Bath, England, 1984, Paper D1.
3. Xu Jirun, *The Forced Vortex and Hydrocyclone* (in Chinese), To Be Published.
4. Xu Jirun, Luo Qian, and Deng Changlie, "The Research of Flow Field in Two Kinds of Hydrocyclones," *Nonferrous Met.*, *37*(3) (1985) (in Chinese, with English abstract).

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