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NOTES ON THE SEPARTING MECHANISM AND EFFICIENCY OF LARGE (12-IN.) COMPOUND WATER CYCLONES USED FOR UPGRADING COAL SLIMES.

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by

J. Visman*

It is a common problem with the densimetric separation of coal slimes in industry that the cutpoint of the particles smaller than ~50 mesh is high and the efficiency of separation relatively poor. The high ash content of these particles often affects coal quality.

It has been found from earlier work (1964-68) at WRL that the efficiency of slimes beneficiation in the primary Compound Water Cyclone (CWC) of an automatic two-stage circuit is better than the efficiency of an "open-ended" identical CWC operating without back pressure of any kind. The difference between the two CW cyclones lies in the flow-pattern of the water around the vortex and consequently, the flow pattern of the solids near the apex orifice.

There are three different patterns of interest, shown in Fig. 1, all of which can be demonstrated in the primary CWC of a Perspex model of the automatic 2-stage circuit when using an artificial particle mixture resembling a broken coal with a top size of approximately 1 millimeter.

Pattern A resembles that of an open-ended, single stage CWC where the vortex diameter approaches the diameter of the apex orifice.

Pattern B is characterized by the absence of a vortex, as happens when the circuit is operated under back pressure on both sides, without compressed air needed for maintaining a vortex in the primary CWC.

Pattern C represents the optimum condition for separating slimes, characterized by the presence of a vortex whose diameter is controlled by air pressure rather than by the apex diameter.

Early pilot plant tests (1964-68) show that the 2-stage automatic CWC circuit which uses air pressure as an operating variable for controlling the densimetric separation produces results for the slimes fraction in the primary CW Cyclone that are superior to those obtained with a reduced feed inlet or with an elongated cyclone chamber. The following explanation may

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serve to clarify these differences and to provide a working hypothesis for evaluating in advance the separating efficiency of slimes of known composition (float-sink characteristics) for design purposes.

Explanation of CWC operation

The suspension entering through the feed inlet of a CW Cyclone is first forced down a helical path and then upwards through the vortex finder. This reversal of direction means that for each particle of solids and each water molecule that exits through the vortex finder there is a turning point where its vertical velocity becomes zero as it changes from the downward to the upward direction.

For each particle there exists a locus of turning points (theoretically a circle in a horizontal plane), whose diameter and location depend on its specific gravity, size and shape, as well as on the suspension's flow pattern which can be controlled to a certain extent by the designer and by the operator.

For the densimetric separation of the smaller particles (slimes) that are carried downward through the interstices of the bed it is necessary to:

1) Have sufficient water in the lowest section of the triconical bottom to permit an upward current to form around the vortex;

2) Regulate the downward velocity of the water so that the loci of zero vertical velocity for these slimes are formed in the lower cone section where these small particles are exposed to the upward current.

When these two conditions are met, the slimes will be separated according to density by a process of elutriation in much the same manner as the coarse, light particles whose loci of zero vertical velocity are determined by the surface of the bed are washed up and discharged through the vortex finder.

The information available at this time indicates that the efficiency of sorting the slimes in large-diameter CW Cyclones can be enhanced by:

1) Reducing the feed inlet diameter. This can be further adjusted by a low back pressure on the CWC overflow discharge. Advantage: simplicity; best application when using separate single-stage CWC-12 units

for 28 m x 0 only slimes. Disadvantages: lower throughput capacity because of reduced feed inlet; relatively high cutpoint and large probable errors for the fine slimes.

2) Elongating the cyclone chamber by $\sim$50%. This means in effect that the vortex finder clearance (vertical distance between lower orifice edge of the vortex finder and the intersect plane between the top section and middle section of the CWC triconical bottom) can be doubled. Advantages: simplicity; better sorting efficiency of the fine slimes than with the reduced feed inlet; lower cutpoints for the finer particle fractions. Disadvantage: inlet pressure $\sim$50% higher.

3) Inflating the vortex in the primary CWC of a 2-stage circuit operating under back pressure. Advantages: slimes can be cleaned efficiently in the presence of larger particles; the cutpoints and probable error for the slimes fraction under these conditions are lower than for the above modified cyclones operating on 28 m x 0 only. The 2-stage circuit permits a three-product separation to be made with a clean-coal product separated at a low gravity cutpoint; a finished reject at a high cutpoint and a middlings product that can either be discharged as a product or recirculated.

Working Hypothesis for Slimes Separation Mechanism in a Compound Water Cyclone

Fig. 1A suggests the vertical-component diagram of the flow pattern in an "open-ended" CWC operating without constriction on either the overflow or the underflow. The vortex diameter is largely determined by the apex diameter. Consequently, the amount of water in cone Section 3 is insufficient and no upward current is developed to permit efficient separation of the fine slimes there.

In Fig. 1B the same CWC is operated without air pressure and under a back pressure on both overflow and underflow, sufficiently high to "squeeze out" the vortex. The flow pattern does not lend itself to proper elutriation of coarse, light particles presorted by the bed and slimes separation is adversely affected by the poor separation of these coarse light particles and by the fact that the upward current in Section 3 of the tricone is insufficiently developed, if not absent through crowding of solids there.

In Fig. 1C illustrates the flow pattern when a vortex of a small, adjustable diameter is produced by maintaining an automatically controlled air pressure in the cyclone chamber, while operating the CWC under back pressure on both the overflow and underflow. The loci of zero-vertical velocity now extend deeply into cone Section 3, while the downward water flow is controlled by the back pressure on the underflow and overflow.

COMMENTS

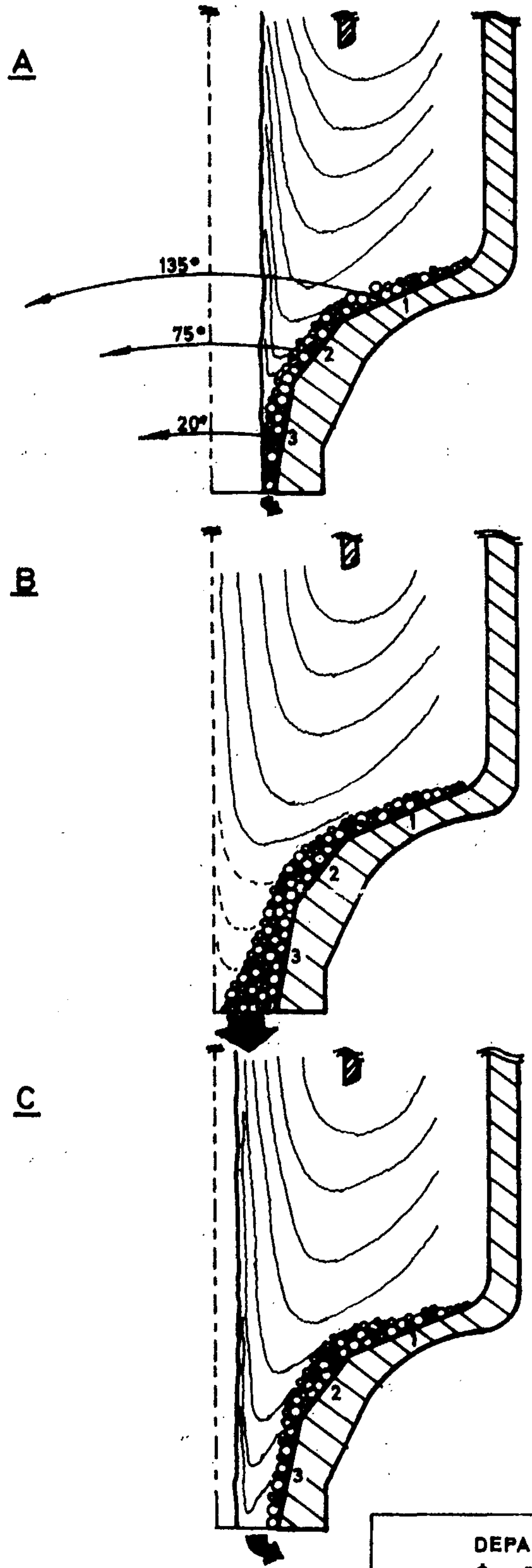
1. When a CWC with reduced feed inlet diam is operated under back pressure on the overflow, the cutpoint will be lowered at the expense of efficiency of separation of the fine slimes. The explanation suggests itself that the water flowrate through the apex is too high for an upward current to be formed for sending fine coal particles of Section 3 back up to the overflow discharge.

2. It is believed that a "doughnut" valve often used for controlling the back pressure of classifier cyclones is not advisable for controlling the apex back pressure in a CWC because it will recombine the presorted solids and water and will thus have a deleterious effect on the densimetric separation of the slimes. The air control of the vortex prevents this from happening and is believed to be the best and most flexible method available at this time for the sorting of coal slimes.

3. Single-stage cleaning of slimes may be preferred as a simple solution when the coal presents no special problems, for instance when the slimes content is small or when no large variations in the coal composition, e.g. the clay content, are in evidence.

FIG. 1

TYPICAL FLOW PATTERNS OF SOLIDS IN C.W. CYCLONES



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