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Reducing pressure loss And saving energy with a Vortex finder vane system

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Reducing pressure loss and saving energy with a vortex finder vane system

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Introduction

The most important dimensional factors in centrifugal separators are the throughput volume, the pressure loss and the degree of fraction separation. Of these, pressure loss increasingly constitutes the most significant economic element, both in existing plants and newly designed centrifugal separators. In particular, the dip tube and the intake form have a decisive effect on flow behaviour. The measure of greatest importance is the use of low pressure loss dip tube designs in the intake zone, where pressure loss is by far the largest.

The reason for the economic significance of this measure is primarily because during the service life of the separator, around 90% of total costs derive from the energy required to compensate for pressure losses. Flow guidance in the intake zone must ensure that a high degree of uniformity is achieved between the intake and rotational flows in the separation chamber. Under practical conditions, deviations of up to 200% from optimum levels are to be found and these have an extremely negative effect on energy consumption and separation behaviour. Using approximation, scientists have calculated the physical connections between pressure loss, volume flow and separation behaviour for the purposes of ideal models. For practical operation, there are sufficient criteria available for an up-to-date assessment of the economic performance of centrifugal separators. Thus, on the basis of the best intake design, it is possible to concentrate fully on the main cause of exhaust pipe pressure losses.

Initial situation

Studies by Barth suggested a reduction in the overall pressure losses through the recovery of part of the velocity energy by means of a diffuse

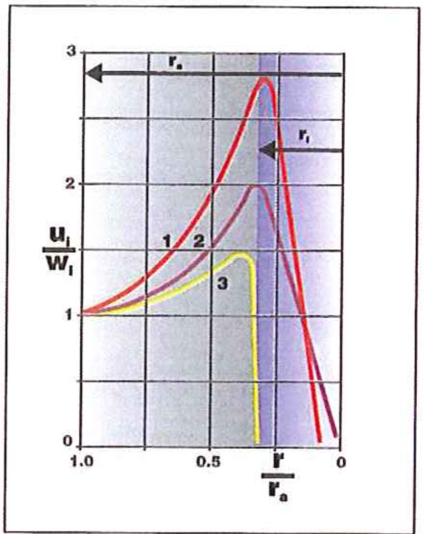

Figure 1. Curves 1 and 2 represent the theoretical and actual circumferential speeds and 3 the axial speed in the cyclone.

dip tube[1]. As his work shows, there is a considerable difference between theoretical and actual flow behaviour in the separator.

Studies by Prof. Muschelknautz, meanwhile, have demonstrated that virtually no flow losses occur in the area outside the dip tube radius[2]. The main reasons for the flow losses are the vortex or the cyclonic flow in the axial zone of the centrifugal separator. This makes clear that the cyclonic core in the separation chamber and the exhaust pipe, lead to very high acceleration and turbulence in the proximity of the axis, which can be regarded as the main cause of the sizeable flow losses. In particular, the dip tube design has a major effect on the flow configuration.

While the form of the curves 1 and 2 in Figure 1 clarify the discrepancy between theory and practice, curve 3 provides an insight into flow behaviour at the level the exhaust pipe. Here, it is evident that the central vortex in the exhaust pipe leads to extremely high acceleration near the inner surface, while a flow reversal can even occur in the core of the dip tube flow. In view of the chaotic flow behaviour within the dip tube, it is only logical to equip this area with an intake device, in order that the circumferential flow be at least partially guided into the dip tube.

Demands on the intake device

In view of the practical demands for smooth operation throughout plant service life, dip design should secure minimum pressure losses. The solution must therefore be simple, as low manufacturing costs first ensure economic application on a large technical scale.

One precondition is that the classifying capacity of the separator may not be adversely affected, as then its main function, namely good separation, would not be fulfilled. Hence, the theoretical target for a practical solution with regard to centrifugal cyclone separators can be formulated as being the use of an exhaust pipe device, which is virtually as simple as the exhaust itself (Figure 2). In more precise terms, this means:

- Generally no free flow areas smaller than around 100 mm.
- No increased operational procedure demands.

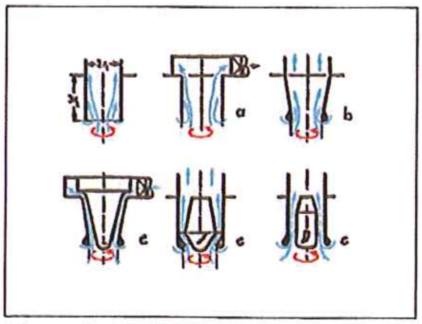

Figure 2. Air flow patterns in centrifugal cyclone separators.

Figure 3. The Hurriclon vortex finder vane system.

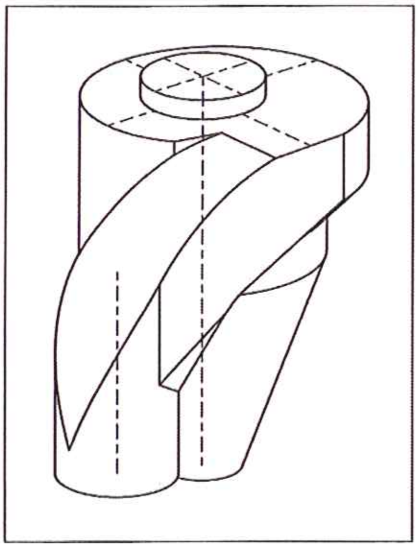

Figure 4. Cyclone with optimised entrance spiral.

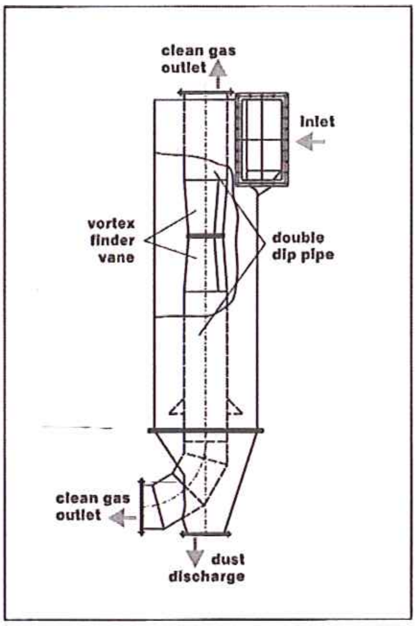

Figure 5. Hurriclon with vortex finder vane.

- The tendency to improved separation under otherwise unchanged conditions.

Known dip tube forms

Reverse exhaust air spiral

Under laboratory conditions, the reverse air spiral can provide pressure loss reductions of 25%, particularly when it has a very flat shape. However, this is frequently impossible for smooth operation, as deposits quickly have a negative effect on results. Therefore, a exhaust air spiral is more important under cramped structural conditions, where a more favourable pipe intake is possible. In current terms, the contribution to energy savings is moderate.

Conical dip tubes

Due to their simplicity, conical dip pipes are quite practical in high-performance cyclones. Their contribution to saving energy is moderate, but acceptable in relation to the costs. The actual effect in combination with the exhaust air spiral and the exhaust piping system can frequently not be assessed without model testing. Practical utilisation is therefore problematic, as energy savings are virtually impossible to prove.

Annular passage diffuser solutions with numerous guide vanes

These solutions provide good results, but due to the high manufacturing costs and their tendency to defects caused by the relatively small flow channels, are seldom used and have little meaning on a major technical scale.

In addition, to attain correspondingly good results, without precise model tests the design of such annular passage guide vane apparatus is impossible. Again, a limited effect is only apparent when the process parameters are altered.

The Hurriclon vortex finder vanes

This system is a simple tube, which takes in the gas flow just within the dip tube radius, where the flow losses are small, and creates a favourable flow path into the exhaust itself. During comparative testing, the new, low, resistance value for the exhaust flow was established and then implemented in accordance with the model laws in the large-scale sizes required under practical conditions. Operational measurements confirm the fundamental information gathered during comparative testing and are simultaneously the springboard for the new technology demonstrated under practical conditions (Figure 3).

The Hurriclon with double dip pipe and 2-unit vortex finder vanes provides up to 50% pressure loss reduction and improved efficiency (Figures 4 and 5).

Operational results summary

Three projects have been specifically studied where the Hurriclon vortex finder vane system has been installed; two at Dyckerhoff Zement GmbH's Göllheim plant and one at Perlmooser Zementwerke AG's Mannersdorf plant:

- Retrofitting of the preheater 1-cyclone stage 1 with Hurriclon vortex finder vanes at Göllheim plant.
- Optimisation of the cyclone intake situation and retrofitting of the preheater at Kiln no. 2 stage 1 with the Hurriclon vortex finder vanes.
- Retrofitting Hurriclon vortex finder vanes at raw mill cyclones in the Perlmooser Zementwerke AG Mannersdorf plant.

The findings are summarised in Table 1.

In order to ensure that the evidence was independent of varying performance data at the time of mea-

Table 1. Operational results summary for three Hurriclon system trial projects

	Before modernisation		After modernisation			
	Pressure loss mbar	Residual dust	Pressure loss mbar	Residual dust	Reduction in %	Energy savings per year (kWh)
Project 1 Göllheim plant	12	62 g/Nm^3	7	61g/Nm^3	41	350 000
Project 2 Göllheim plant	30	30-35 g/Am^3 82 g/Nm^3	14	30-35 g/Am^3	53	1.6 million 82g/Nm^3
Project 3 Mannersdorf plant	14	44 g/Am^3	7	36 g/Am^3	50	750 000

surement, the static pressure both up- and downstream of the cyclone was measured, whereby the static pressure prior to the cyclone forms the basis for consideration of the results.

Operational results at Göllheim plant

- Kiln 1: Rotary kiln with 4-stage preheater, 4 m dia. x 68 m long, capacity approximately 1200 tpd, installation 1963.

By installing Hurriclon vortex finder vanes in the winter of 1995 the aim was to reduce the pressure loss of cyclone stage 1 by a minimum of 3 mbar. When installing the system, essential attention had been given to their exact orientation and adjustment. A further essential point was the careful retouch of welding seams of the vane segments, to avoid turbulence in the flowstream. The pressure loss of preheater stage 1 had been 12 mbar before installation and could be reduced by this measure to approximately 7 mbar. Also, after one year of operation, these values can still be achieved. No wear has been discovered to date, nor could any dust sedimentation, which can influence the efficiency of the cyclone, be found.

- Kiln 2: Rotary kiln with 4-stage preheater, kiln 4.4 m dia. x 71 m long, capacity approximately 1800 tpd, installation 1965.

In 1991 the cyclones in stage 1 were modernised, but no results regarding pressure loss reduction could be achieved.

In 1996 stage 1 was modernised using the Hurriclon vortex finder vanes. The good results in the Kiln no. 1 preheater have influenced the decision to introduce the same technology in the Kiln no. 2 preheater. The pressure drop in stage 1 had been 30 mbar. The original constructor of the preheater had also performed some modernisation work on this stage.

The biggest effect in pressure loss reduction could be achieved by introducing Hurriclon vortex finder vanes in combination with optimisation of the entrance part of the cyclone. Reduction of pressure loss of more than 15 mbar could be achieved in this stage after project realisation. The pressure loss after installation had been 14 mbar, 16 mbar less than before.

Operational review

In Project 2, a cyclone intake was designed for the first time in accordance with the demand that an optimum uniform distribution of the rotation flow be achieved in the separation chamber above the cyclone level. At 23-35 mps, the intake velocity is extremely high, as the existing cyclone was relatively small.

This project demonstrates that if the flow guidance is in order, then, despite the highest intake speeds, pressure losses are not astronomic. The measured pressure loss is divided 66% in the cyclone and 34% in the offtake pipe. In case of normal intake speeds and cyclone sizes, pressure losses of half of this size can be expected, as evidenced in Projects 1 and 3. In these, the intake design was not altered, as the initial situation was perfectly acceptable.

The effect on separation caused by the retention of the dip tube diameter is negligible. Measurements taken during all applications show that residual dust levels are the same as in cyclones without the Hurriclon vortex finder vanes. Although in theory an improvement with the guide device could be anticipated due to the avoidance of peak flows in the vicinity of the dip tubes edge, the computer programs indicate the effect on separation performance can only be in the tenths of a percent range.

It has been shown in extensive laboratory testing that for optimum overall function, the design of the dip tube intake is of even greater importance than was previously thought. However, under practical conditions, it has long been established that especially unfavourable intake designs caused marked increases in pressure loss in the intake area and these were then removed by geometrical optimisation.

In Projects 2 and 3, the cyclone intake is of optimum design, whereby an ideal rotational flow is found above the cyclone level in the separation chamber. The Hurriclon vortex finder vanes ensures optimum functionality and the lowest overall pressure loss. In Project 3, a considerable improvement in separation behaviour was also established.

Conclusion

Due to the fact that the expenditure on energy for a cyclone over a period of 10 yrs constitutes 90% of total plant costs, enormous cost advantages can be achieved with a well-designed cyclone intake and Hurriclon vortex finder vanes. Under practical conditions, up to 50% reduction in pressure losses have been demonstrated by installing Hurriclon vortex finder vanes. In the case of large quantities of gas and retrofitting with the Hurriclonvortex finder vanes, this means savings of around 1 million kWh annually, and the recovery of additional costs resulting from the vortex finder vanes within a year.

Enquiry no: 37