The role of pre-filtration and it's effectiveness to remove Bulk dust

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ABSTRACT: The aim of this paper was to prove that Cyclonic separation of Bulk dust from an air stream, can be both highly effective and practical. It has the potential to reduce costs of replacement air filters and provide new opportunities for cost effective designs when dealing with bulk dust. Worldwide trends in both occupational hygiene and environmental pollution are calling for lower limits and the removal of smaller ultra-fine dust particles. Scientific evidence backs the relationship to exposure of fine dust particles with respirable lung disease. It has been widely recognized that **Multi-Stage Filtration** (see Leading Practice MVS) is required so as to remove the bulk dust from the ultra-fines. This has historically proven to be very costly in both initial cost of equipment together with the cost of maintenance (i.e. replacement filters) or usage of resources (i.e. water, electricity and man power) The answer to achieving ultra-fine filtration lies in finding practical and cost effective solutions to remove the bulk (Particles that have mass) from an air stream. This will in turn allow the focus to shift to the removal of sub-micron particles. We are not focusing on sub-micron size particle removal in this paper but rather on the removal of bulk dust.

1. INTRODUCTION

Conventional vertical / upright cyclones ***(see figure1)*** were impractical in underground applications due to the horizontal design of most shafts. Even multiple clusters ***(see figure 2)*** of vertical cyclones proved to be bulky. On intensive investigation the only "horizontal Cyclone" in operation was found to be on helicopter intakes ***(see figure 3)*** using hundreds of small vortex tubes ***(see figure 4)*** with a bleed off fan. It was the principle that let us to investigate the potential of developing a single, large, horizontal cyclone separator ***(see figure 5)***. We proceeded to manufacture and begin preliminary testing. These tests were basic but proved that separation of bulk dust was possible. We needed to proceed to the next level of testing and chose CFD (Computable Fluid Dynamic Evaluation) as it offered us the chance to assimilate and measure current results.

Figure 1. Vertical Cyclone

Figure 2. Multi Cyclones

Figure 3. Helicopter Intake

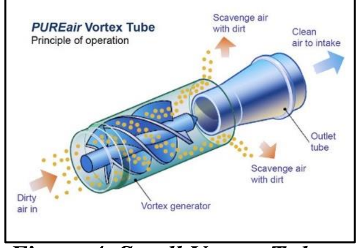

Figure 4. Small Vortex Tube

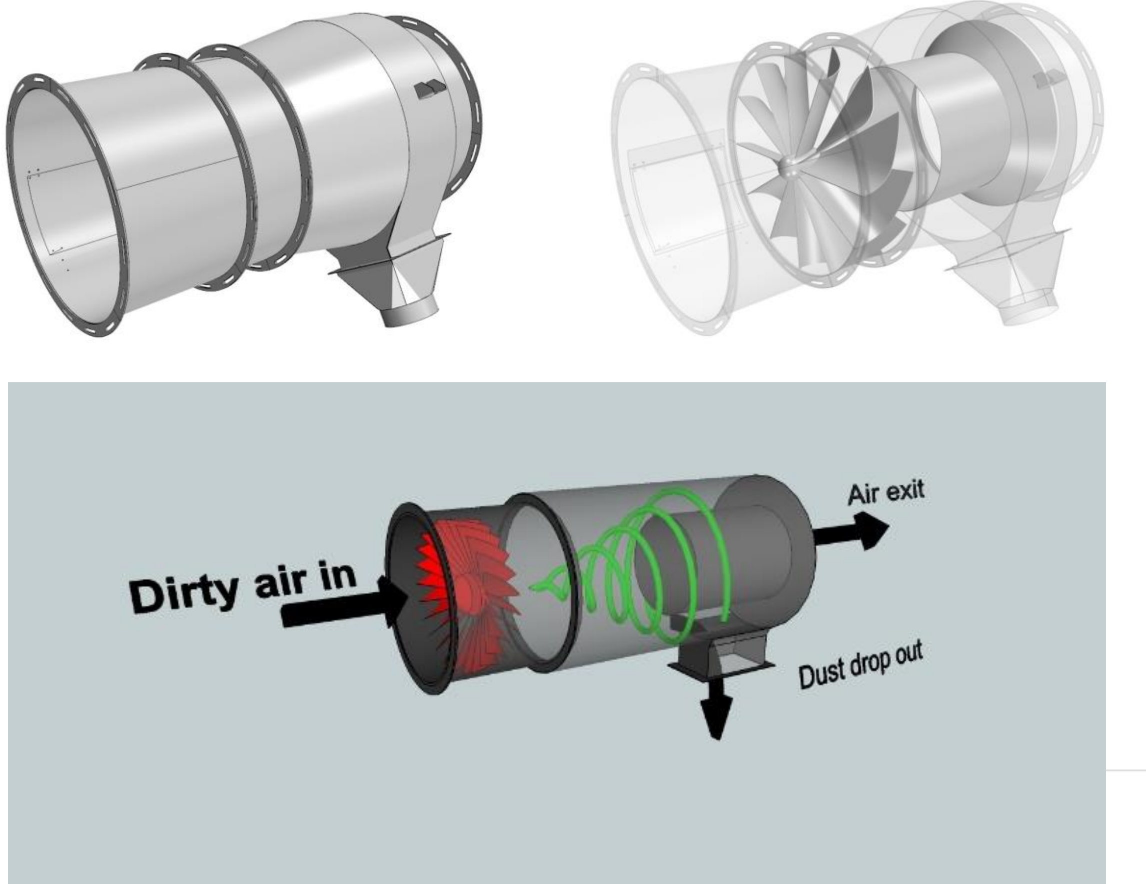

Figure 5. The basic design of a horizontal cyclone separator (Cycloduct)

A. We *needed to establish a Base case*

The Test were designed around an 850Ø Unit. which is designed to fit into an existing air duct. We used 20m/s as our inlet duct velocity. Assumed to operate in a 30˚C, 86 kPa (Highveld) environment

Figure A1.1

The initial test was setup to establish the following:

1. Optimum Approach velocity
2. Pressure differential across the unit
3. Efficiency across a broad array of particle sizes
4. All inefficiencies in geometry and dead spots
5. Make findings and suggestions to improve

Radial velocity component distribution.
Cylindrical coordinate system with Z-axis aligned with air cycloduct axis.
Positive radial flow moves radially away from the cycloduct axis. ***See Figure A1.2***

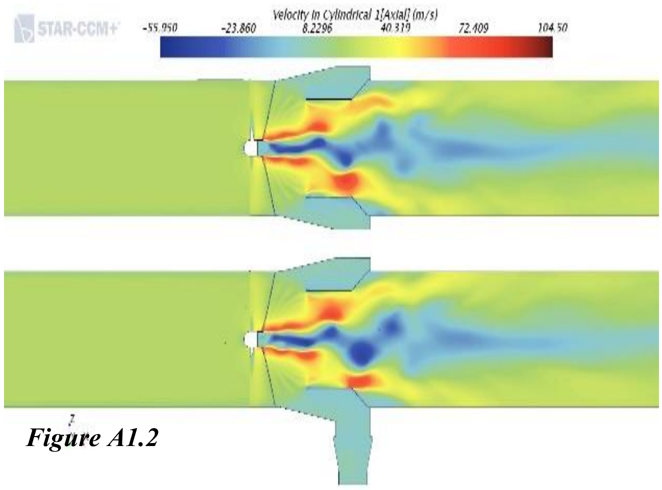

Figure A1.2

A1. Test Design Setup

Fluid volume captured, re-meshed/optimised and grown into a grid of ˜6,8 to ˜7 million polyhedral volume elements. Vol ume mesh features local refinement in areas featuring strong curvature and close proximity. The mesh also feature a prismatic boundary layer orthogonally extruded form the surface representation of the volume mesh for accurate implementation of the turbulence model. ***See Figure A1.1***

Streamlines obtained by integrating along the velocity vector field showing the flow behavior. ***See Figure A1.3***

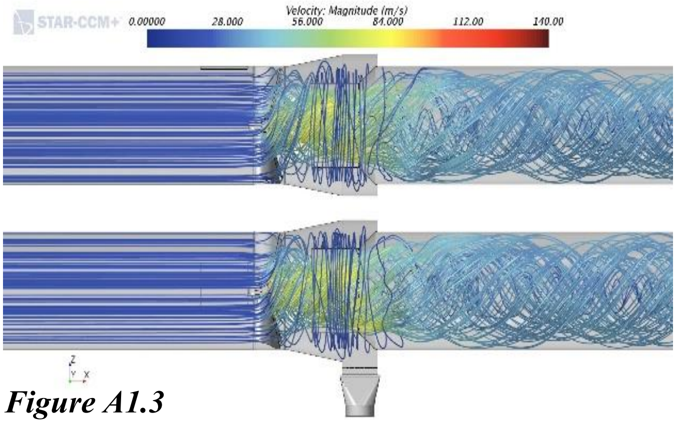

Figure A1.3

Plot reporting the total pressure at each cell on the air cycloduct surface as a function of the cells axial position. Sweeping through the domain it is clear where the losses are incurred. ***See Figure A1.4***

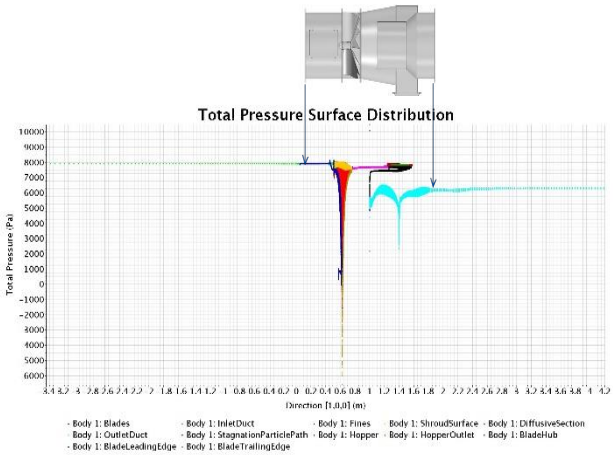

Figure A1.4

A2. Results of Base Case design

1. Approach Velocity 20m/s → (140m/s) Peak Velocity
2. Predicted Pressure Drop 1,516kPa
   - Measured from 2 Pipe Diameters
   - Upstream to 2 Pipe Diameters
   - Downstream from the Air Cycloduct
3. Efficiency Base Case

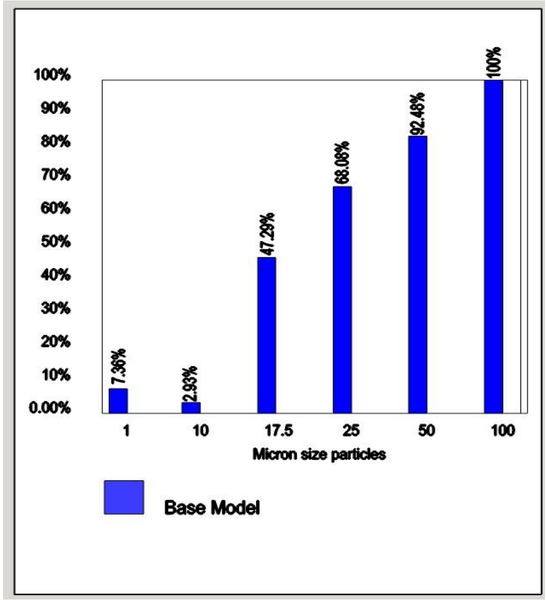

Figure A2.1(a)

Particle Size	**AC01 / Base Case**
1 Micron	7.36 %
10 Micron	2.93 %
17.5 Micron	47.29 %
25 Micron	68.08 %
50 Micron	92.48 %
100 Micron	99.95 %

Figure A2.2(b)

4. It became apparent from the CFD imaging that the Geometry needed to be adjusted i.e. Blades,(number, shape, length). Length of unit, size of outlet discharge.
5. Strong indications were that further testing would provide significant advances and improvements. We decided to continue and do further testing.

B1. (Further) TESTING

13 Subsequent tests were done to establish the following

1. The direct relationship between pressure differential / cyclonic separation and effective removal of dust particles.
2. What was the best relationship between these opposing forces of aerodynamics and efficiency?
3. How blade angles, number of blades, unit shape and length, discharge outlet, air outlet diameter and shape could be designed

4. If pressure could not be overcome and velocity maintained, was there a practical solution?
5. If velocity was lowered how would that impact performance?
6. Could the discharge be streamlined for ease of drop out and prevent any potential air reintroduction into the system?
7. What could be done to prevent buildup of dust on the blades?
8. Ultimately how efficient could we make this Cyclone?
9. Could this cyclone be installed both vertically and horizontally and would this have any negative or positive effect?

B2. Tests showed the following

1. There is a direct link between pressure and efficiency we engineered out all of the losses and aerodynamic inefficiencies. The pressure differential dropped 1516 ➔1247kPa. This could be overcome by adding a built-in fan to overcome pressure and maintain a constant velocity of 20m/s
2. 20m/s was the optimal velocity through the cycloduct. We also tested at both 10m/s and 15m/s and this lowered pressure differential and efficiency.
3. Blade angles, number of blades and the length of the blades proved to be key in generating the maximum cyclonic effect
4. The geometry became paramount to performance. The symphony of blades, outer body, outlet size and discharge shape and size all needed to be in harmony.
5. The discharge needed to be re-designed to an off-center positioning and in relationship with air direction and flow. This had an impact on results
6. A bleed off fan can improve efficiencies on the lower scale from 1 ➔ 10 micron.

C1. FINAL RESULTS

Particle Size	AC01	AC08	Improvement %
	Base Case	Mod7	
1 µm	7,36%	57,58%	50.22%
10µm	2,93%	80,47%	77.54%
17,5µm	47,29%	99,97%	52.68%
25µm	68,08%	100%	31.92%
50µm	92,48%	100%	7.52%
100µm	99,95%	100%	0.05%

Figure C.1.1(a)

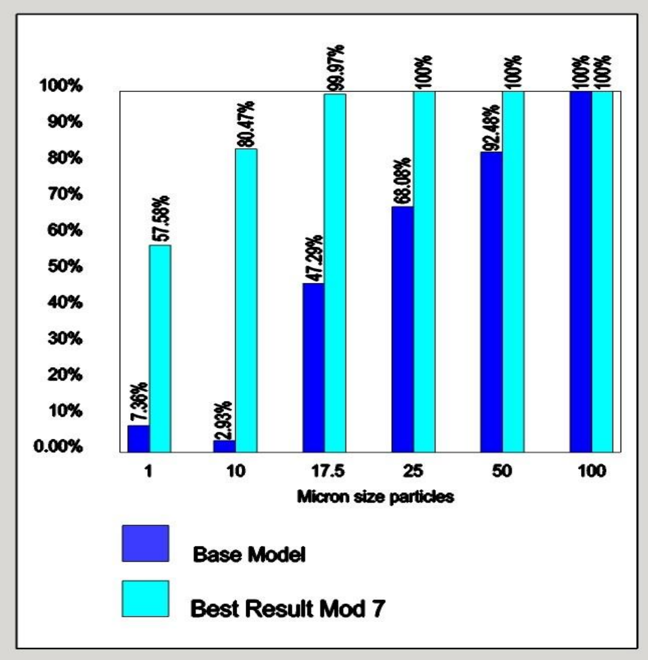

Figure C1.1(b)

2. CONCLUSION

1. The cycloduct is extremely effective at removing the bulk and surprisingly also the smaller particle ranges. Effective from 1 micron and greater. At 17,5 micron + greater it is 100% efficient.
2. A fan and VSD were added to the unit, in order to overcome pressure and maintain velocity.
3. The geometry is of paramount importance.
4. The discharge can be fitted with a sealed bin, double flap valve, Rotary Vane Feeder, conveying system or even linked to a silo and bin vent.
5. A circular ring fitted in front of the blades with compressed air nozzles, blasting intermittently may well be a way of keeping the blades from building up with dust.
6. The Cycloduct can be used for removal of mostly DRY particles of dust. We also believe that is may well be effective at removing any substance that has mass i.e. water from an airstream. This has however not been part of the scope of these tests.
7. It can be installed in a vertical or horizontal position
8. This paper shows that a cycloduct (cyclonic separator) is both practical and an efficient method to remove bulk dust from an airstream. The next step is to find real live applications and test and compare the actual flow results with the CFD results.

3. APPLICATION FOR USE

3.1 Pre-Filter to all existing:

- Filter systems
- Baghouses
- Multi-Stage Filter Systems
- Electro Static Units

3.2 Tipping and Crushing
3.3 Transfer Points
3.4 Compressor houses intakes
3.5 Winder Room intakes
3.6 Substation pressurization
3.7 Laboratories
3.8 Stack Emissions (Particle Dry)
3.9 All fresh air intakes
3.10 Bulk dust collection

4. REFERENCES

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5. ACKNOWLEDGEMENT

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