CHAPTER 4 : SUMMARY AND CONCLUSIONS

4.1 Summary

The primary objective of this research project was to develop a bench-scale triboelectrostatic separation (TES) process that could overcome deficiencies of existing techniques. In accordance, a bench-scale triboelectrostatic separation unit was designed and constructed here at Virginia Tech. The TES unit developed was a semi-continuous processing unit. When scaled up to a full size industrial unit with a few modifications, this could serve as a fully continuous unit. The actual design of the unit evolved a long way from the original conceptual design. The ideas for these changes came with experience and with a view to improving the TES process. The salient features of the unit developed include:

1. Design of drum shaped electrodes to increase the electric field gradient and also help in the continuous cleaning of the electrode surface during the operation of the apparatus.
2. Construction of a chamber that could provide a laminar air flow pattern inside.
3. Addition of flow-straighteners or collimators to further reduce the turbulence of air and prevent eddies.
4. Improvements in the charger designs (described in detail in the earlier chapter) that substantially improved charging and hence separation efficiency. The turbocharger design that was the last in the series of charger designs made a significant impact in the separation efficiency. The charging efficiency of the turbocharger is being evaluated as a part of the objectives of this project but not included in the scope of this research work.
5. Addition of a heat source which increased the temperature of air that was being sent into the chamber for better flow of solids. Increasing the temperature increased the charging efficiency owing to the following reasons-
    - Reduced the inherent moisture of the solids and helped in better particle-particle and particle-wall interaction.
    - Changed the surface properties of the solids which facilitated free flow electrons from particle with lower work function to that with higher work function.

Three samples of coal were tested. These samples were chosen based on their basin reserves and their application in the Utilities plant. The Pittsburgh No.8 Clean Coal and Sewell Seam Clean Coal are known to have extensive reserves and can be used as representative samples for the corresponding areas. The tests were originally conducted on Pittsburgh No.8 ROM coal samples. It was decided later to conduct tests only on clean coal samples because of their applicability to the Utilities plant. The separation efficiency was best in the ROM coal sample because of its inherent high ash and sulfur contents. All the test results have been discussed in detail in the earlier chapter.

- In a series of tests conducted on the different samples at varying electrode potentials, it was observed that 40-50 kV was found to be the optimum operating range. This judgement was based on the behavior of the three samples used, this could very well be a property common to these coal samples.
- Also, the TES unit developed in this work was found to have a maximum throughput of 30kg/hr. The charging and separation efficiencies were best at the above feed rate.
- At the above mentioned feed rate, the pyritic sulfur rejection was high and could serve well in the power plants in sticking to the environmental regulations.
- A model which could predict the trajectory of the particle was developed and the simulation results of the model concurred with the experimental data, in particular the concept that fine particles separate better than coarse particles. This however disagrees with the experimental results that coarse particles separate better than the finer particles.

The drawbacks of this system were:

1. Coarser particles (+100 mesh) separated better than finer particles or even composite mixtures that comprised coarse and fine particles. From this, one may tend to arrive at a conclusion that coarser particles charged better than the finer ones. Mathematically, the opposite was proved. The fine particles unlike the coarse particles travel in a cloud and as proved mathematically the maximum deviation was of the order of less than an inch. Comparing this deviation macroscopically with the size of the separator, the deflection from the original path is very small. When the fine particles travel in a cloud there is a greater chance of

entrainment which results is ash particles being trapped in a cloud of coal and coal particles in a cloud of ash. This reduces the recovery even if the particles were charged correctly. The coarser particles travel in thinner clouds or more independent paths. This substantially reduces the chance of entrainment and hence misplacing particles in the wrong stream. This theory possibly explains the contrasting results mathematically and experimentally.

2. Entrainment was found to be an inherent problem with this technique. In the case of the fine samples too, it can be said that entrainment of unfavorably charged particles reporting to the opposite electrode was the reason for poor separation.

4.2 Recommendations for future work

As an on-going effort to increase the efficiency of separation for a triboelectrostatic process, it would be necessary to constantly modify the design parameters and operating conditions. The idea of drum shaped electrodes was the first of its kind and provided an open-gradient or a non-uniform electric field. The electrodes themselves were bulky and scaling up would be a problem. A major factor in a TES process is to increase the surface area of the electrodes. This gives the fine size particles greater area of interaction with the electric field. It would be practically impossible to increase the surface area of the electrodes at the bench-scale stage. One way to overcome this difficult proposition is to reduce the diameter of the electrodes and increase the number of electrodes. This could perhaps reduce the entrainment of particles and give more time for the entrained particles to report to the correct stream.

Some of the other ideas that were discussed during the course of this research work were -

1. To switch back to plate electrodes but increase the length of the plates. This could increase the residency time of the particles under the influence of the electric field.
2. To introduce a recycle stream which could recycle the middling particles back to the charger. The middlings may have arisen due to insufficient charging of the corresponding particles, entrainment of even well charged particles.

The above two techniques are being currently experimented and preliminary tests are being conducted. Another recommendation that could be made at this stage of the dissertation is, to run different methods for the different size fractions. The coarse fractions as seen from tests conducted, charge better and could probably separate well in two or three stages of recleaning. The finer fractions may need a more efficient charging and more stages of cleaning than the coarse fractions. The two streams of coarse and fine fractions may be fed in different units to improve the separation efficiency.

As a final note, experience is a valuable factor in TES processes. More knowledge is gained from conducting tests and working with the apparatus than understanding from books.