CASE STUDIES IN THE APPLICATION OF AXIAL FLOW CYCLONES

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Whilst the original mission of Flosep was the perfection of the process of centrifugal separation of ^{235}U and ^{238}U isotopes for uranium enrichment, a wealth of experience has been gained in the understanding of strongly rotating flows. Over the last few years in which Flosep has been established as a commercial group, our experience and technological developments have been adapted towards the more conventional needs of industry.

The specialized Flosep team now offers a total service to industry in the field of gas/solid separation. We specialize particularly in dust separation for applications ranging from the reduction of stack emissions and other dust suppression projects to the recovery of fine product in process applications.

AXIAL FLOW CYCLONES - AN EFFECTIVE SOLUTION TO DUST PROBLEMS

Flosep have developed and perfected an axial flow cyclone system with an efficiency of separation well ahead of that which could be achieved by conventional cyclones. These cyclones are manufactured from a variety of materials and are available in different sizes to suit most applications. In many instances this development in cyclone technology is able to compete with conventional bag houses and electrostatic precipitator systems. Axial flow cyclones can even replace some existing installations due to their low maintenance and capital cost.

Axial flow cyclones separate particulate matter from air or gas streams by centrifugal action similar to that achieved in conventional cyclone separators. Almost 4 years of advanced R & D at the AEC has resulted in perfection of a unidirectional axial cyclone of extremely high efficiency. These units demonstrate outstanding separation characteristics combined with low pressure drops. Other benefits of using axial flow cyclones for dust separation include:

- Compact design
- Minimal maintenance and wear
- Simplicity of installation
- Flexibility in size and design according to process requirements
- A variety of construction materials to suit most applications.

TYPICAL CYCLONE PERFORMANCE

Material	Nominal diameter	Efficiency
	mm	%
SAE COARSE: SG=2,46 Median size = 30 μm	18 25 100	96,3 95,5 89,0
SAE FINE: SG=2,65 Median size = 7 μm	18 25	87,0 79,0
Mil-E: SG 2,65 Median size = 287 μm	18 25	98,0 99,5
Alumina: SG=3,37 Median size = 86 μm	100	98,7

APPLICATIONS

Two case studies are now presented. They serve to illustrate the versatility of FLOSEP's problem solving capabilities.

COAL GASSIFIER FLY ASH REMOVAL

At ALUSAF's carbon plant, coal is gasified to produce a combustible gas which is used as an energy source. In the process, the bottom gas line is excessively contaminated with fly ash having a median particle size of between 140 and 200 microns. This fly ash can present serious problems to the gas reticulation system, particularly when it mixes with the oils and phenols present in the top gas of the gasification plant. The maintenance costs involved with these problems are considerable.

In order to assess the extent of the contamination, as well as the efficiency with which FLOSEP axial flow cyclone technology could deal with the problem, a pilot two-stage system was proposed by FLOSEP. This system was duly installed in a bypass line using a representative stream from the bottom gas line of the No 1 gas producer. Results of this test demonstrated:

1. That the original cyclones were performing poorly, allowing 8 000 - 10 000 kg per month of particulate matter to be discharged in the pipelines downstream of the 3 gas producers.

2. That the efficiency of the pilot scale axial flow cyclone system installed by FLOSEP was such that installation of full-scale equipment was warranted.

A full-scale two stage FLOSEP axial flow cyclone unit, custom designed for the purpose, has been installed and commissioned on the No. 1 gas producer at ALUSAF, operating at temperatures of up to 700°C. Extensive tests on the new system have shown that, should similar systems be installed on all 3 gas producers, the discharge of particulate contaminant into the pipelines would be 180 kg per month. This represents a 50-fold reduction over the original system.

A LONG LIFE HIGH EFFICIENCY FERROSILICON RECOVERY PLANT

Until recently a leading producer of ferrosilicon has used a gas cyclone for the recovery of the lean phase pneumatically conveyed underflow of the cyclones downstream of their furnaces. The performance of the cyclone was not as efficient as desired and wear necessicated relining of the cyclone once or twice a year. FLOSEP was approached to investigate the possibility of improving this situation.

A plant was installed by FLOSEP comprising of a single 350 mm axial cyclone with a single two blade swirl generator as the primary separator or prefilter, followed by a bank of twelve 100 mm axial cyclones, using standard four blade swirl generators, as the secondary separator. As the operating temperature was ambient, all units were constructed from polyurethane to give maximum wear life.

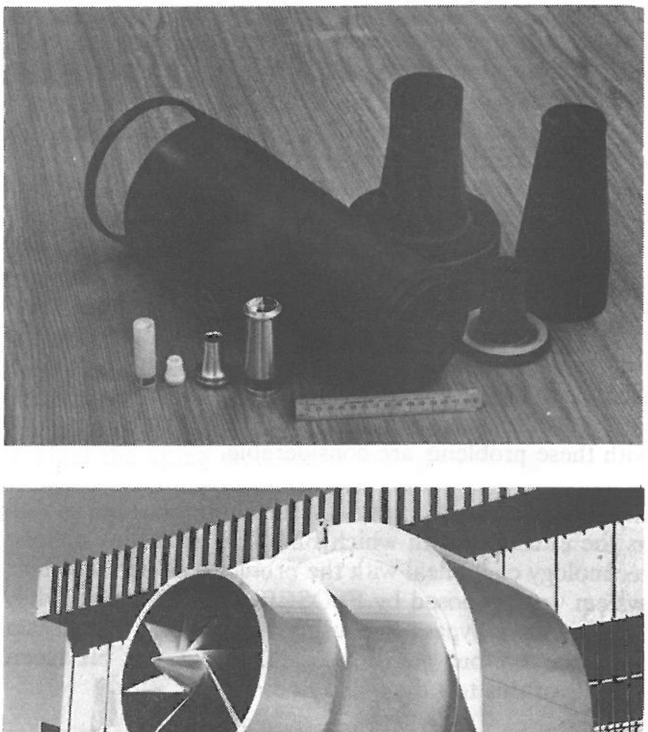


Photo 1a & b - Axial cyclones are made in a wide range of sizes: from 18 mm to 1 m in diameter.

Not only did the addition of a primary separator effectively remove all large objects, hence eliminating the problem of cyclone blockage and subsequent down-time for cleaning, but it raised the total system efficiency to 99,4%. The dust emission was reduced by a factor of six relative to the previous system. The above effiency was achieved at the expense of a pressure drop of only 1,4 kPa.

Recently, 18 months after commissioning, no significant wear on the vortex generator blades of the cyclones could be established during a routine inspection.

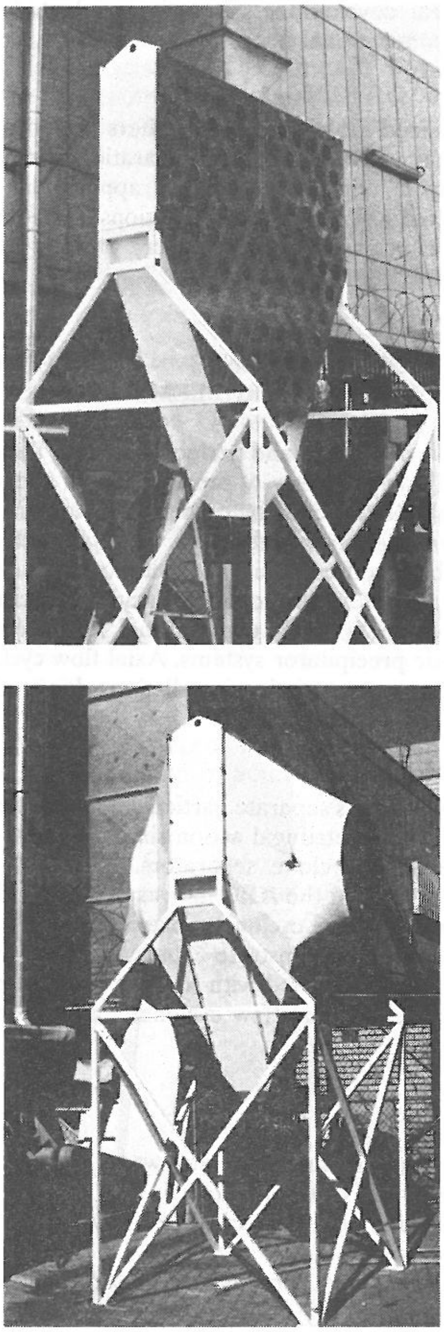


Photo 2a & b - A bank of 96 100 mm polyurethane axial cyclones, fitted with flow and dust dispersion vanes, capable of handling up to 15 m^3 per second. A water spray nozzle system was fitted subsequently to improve its coal dust handling efficiency from 90% to about 99%.

TECHNICAL NOTES:

No 2: Estimation of acid dew point in combustion flue gas

Method

1. On fig 1, connect % excess air to the hydrogen content of the fuel and find volume % water vapour in flue gas. For this figure, the moisture content of the fuel is assumed to be 1%.

2. Conversion of SO_2 to SO_3 is between 1% and 2%.

3. On fig 2, read vertically from the sulphur content of fuel to 1 or 2% conversion, move horizontally to find SO_3 concentration and connect that point to water vapour content. Dew point is found on middle scale.

Sources:

1. Verhoff, F H & J I Branchero: Chem. Eng. Progress, Vol 70, p 71 (1974).

2. Pierce, R R; Chem. Engineering 11.4.1977, p 125.

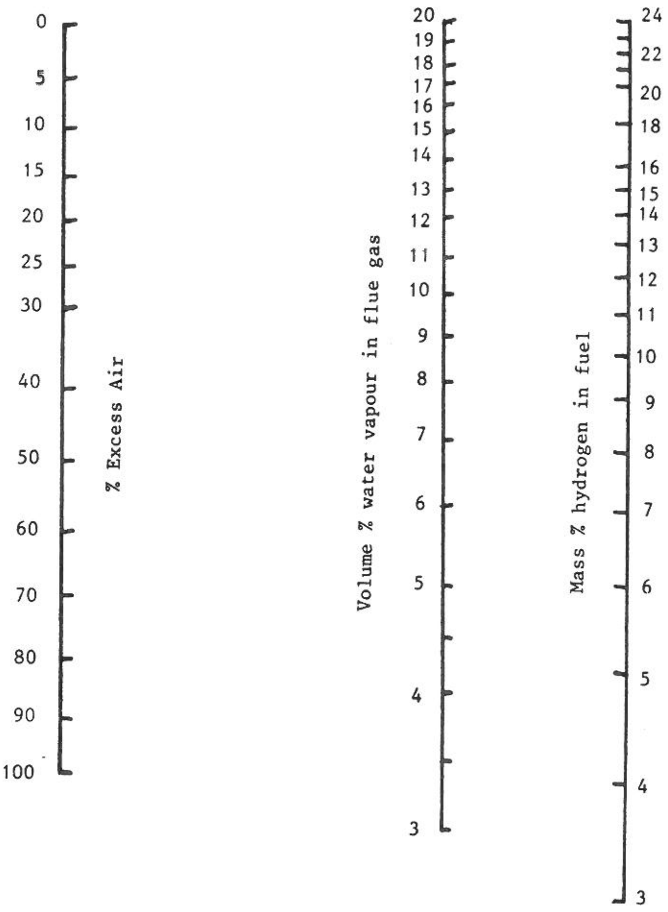


Fig 1

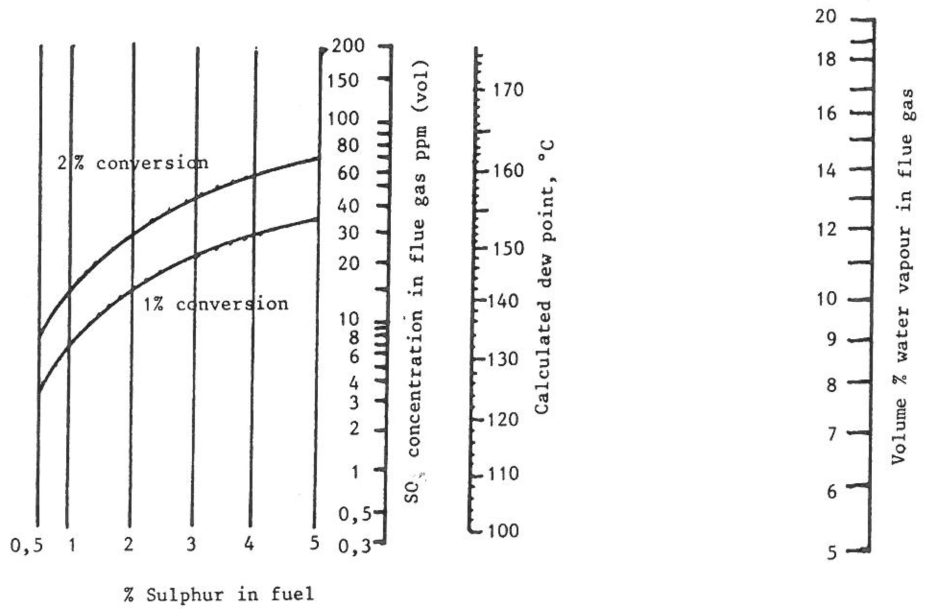


Fig 2

He has extraordinary endurance to live in all climates on earth, everywhere requiring carbonaceous resources (ie carbon) for his cooking, heating, lighting for most of his activities. Nowadays he requires carbonaceous resources for his transport and for air conditioning. These resources are drawn from fossil fuels - coal and oil - and timber. The latter can fortunately be regarded as renewable but not the former two.

Because of his ingenuity and resourcefulness he has found enough food and fuel for living and there has been little or no break in his increase in numbers. He has over the centuries and in the past few decades particularly, been able to extend his life span and reduce infant mortality. The well known world population graph is alarmingly steep.

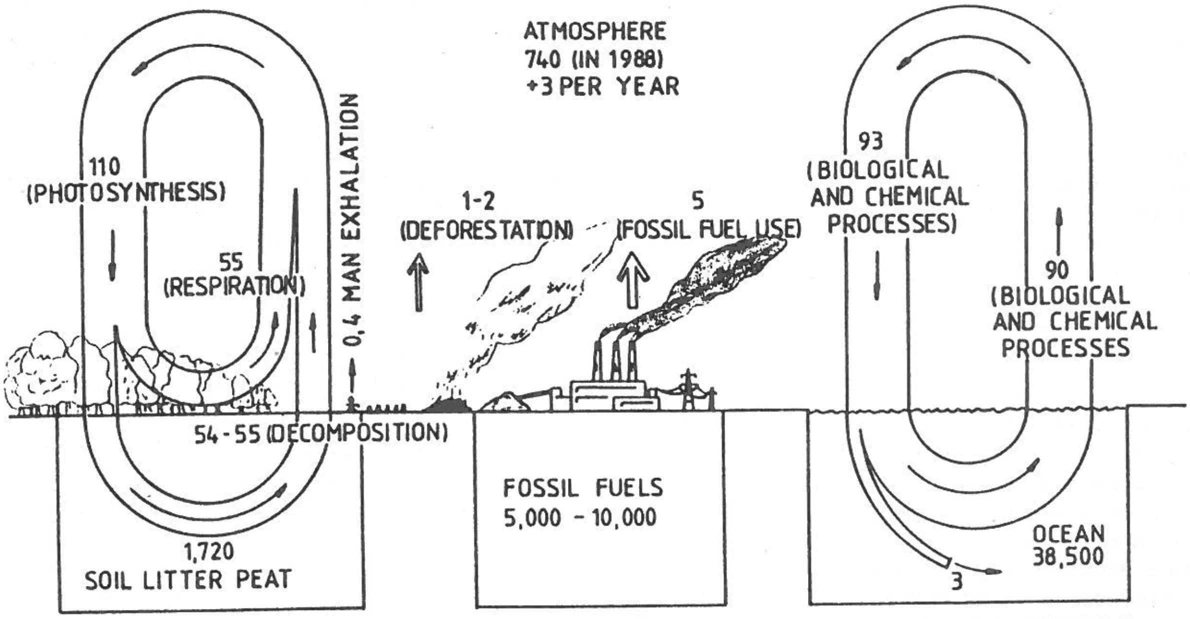
Now the waste gases from his fuel for living, industry and transport are comprised essentially of carbon dioxide, methane and carbon monoxide, all of which enter the air around us. Some remain in the atmosphere. Others are dissolved or absorbed in rain and return to the earth as acid rain. Carbon dioxide and methane are the principal contributors to the greenhouse effect, whilst carbon monoxide contributes towards the destruction of stratospheric ozone.

The increase in the carbon dioxide and methane content is the result of burning of fossil fuels, the reduction of CO_2 absorption following the clearing of forests and from vegetation burnt or decayed. A slight compensation is that the bare earth that remains following deforestation reflects back more of the sun's heat than did the dark forest - the albedo effect.

4. Consequence of Atmospheric Changes - Pollution of the Air

4. Global warming - Greenhouse effect

The signals of global warming are becoming clear, but not necessarily as clear as some would have us believe. At the end of an Ice Age some 130 000 years ago, the earth was as warm as it is today. It is now at its warmest since that time.



NUMBERS IN BILLION TONNES CARBON PER ANNUM

AFTER SCIENTIFIC AMERICAN SEPT. 89

Exhalation by man, all 5 billion of us, contributes about 0,4 billion tonne of carbon per annum to the atmosphere.

The planet's carbon balance is worthy of examination. Some 750 billion metric tonnes of carbon in the form of CO_2 are held in the atmosphere and are increasing at a rate of about 3 billion metric tonnes per annum. Against such figures photosynthesis accounts for the absorption of 110 billion metric tonnes per annum and respiration and decomposition a similar amount. The oceans release some 90 billion metric tonnes per annum into the atmosphere and absorb about 93 billion metric tonnes. If the sea became warmer, this absorption would decrease. Thus in the vast exchange of carbon on earth and in oceans, somewhat more carbon, about 3 billion metric tonnes per annum, is absorbed from the atmosphere than is generated. On the other hand de-forestation accounts for 1-2 billion metric tonnes, and fossil fuel burning 5 billion metric tonnes of carbon.

Thus the net gain of carbon in the atmosphere is about 3 billion metric tonnes per annum compared with the 750 billion metric tonnes of carbon already there, i.e. an increase of about ½% per annum. By comparison 1720 billion metric tonnes of carbon are held in the earth's soils and 36 000 billion metric tonnes in the oceans!

As mentioned earlier, global warming is probably due to the increase in greenhouse gases and water vapour in the atmosphere. These gases trap heat by absorption of infrared radiation much like a transparent overcoat permitting heat through the atmosphere but preventing or delaying its escape. Obviously the higher the concentration of these gases the greater the heat trapped and the warmer the climate.

There is remarkable consensus amongst geographers and climatologists that global warming is with us - the point of discussion and difference of opinion being the rate of change; and possibly the cause of such change.

The natural variability and complexity of the earth-atmosphere system are such that the temperature variations which have occurred during the last 150 years cannot be unequivocally ascribed to an enhanced greenhouse effect and there may be compensatory cooling mechanisms operating to stabilise the climate which are not yet completely understood. (J. Lindesay)

The warming could be driven by the accumulation of heat-trapping gases. A doubling of the CO_2 content would result in a temperature rise of between 3 and 6°C: as a consequence there would be an increase in the melting of snow, ice and glaciers. A 1°C rise in sea water temperature would result in a 0,2 metre level rise. A 1 metre or more rise in 100 years is a likely occurrence, the consequence of which is already now starting to receive attention. We on the Witwatersrand have a little longer to ponder the problem!

Temperature rise however would have other important effects on CO_2 balance. The importance of the biotic feed mechanisms should not be overlooked for it is there where by far the greatest interchange of carbon takes place.

Photosynthesis is not overly sensitive to temperature change but affected more by availability of light, water, and nutrients.

Respiration by plants on the other hand depends largely on temperature: 1°C temperature change would alter plant respiration rate by from 10 - 30%.

Global warming would increase the decay of organic matter without change in photosynthesis; so CO_2 in the atmosphere would increase. Warming would also increase atmospheric methane and it has already been noted that methane is increasing by at least 1% pa. This is significant because methane is some 20 times more effective in trapping radiated heat than CO_2.

In Southern Africa global warming would cause increased evaporation and decreased rainfall with the result that water for urban, industrial and agricultural uses would be more difficult to come by.

5. Health Hazard

Increased CFC's in the atmosphere will result in less ozone in the stratosphere which in turn will result in a higher concentration of ultra-violet rays reaching the earth with consequential damage to man, particularly those of light skin, who may have to retreat to the more temperate zones of the earth!

6. What preventative measures?

Man, by some of his senses, such as sight and smell particularly, is at last reacting to ugly earthly scenes of pollution. I believe that his belated reaction to the despoliation of mother earth and his awakening to the problems he is inflicting upon his environment and himself, is born not only from self preservation but from a deep seated realisation that the earth is or was beautiful and should remain so.

A parallel look at water may help us. With water pollution, the real dangers lie not in the visible, but in the invisible constituents that makes it unsuitable, if not poisonous, for imbibing. So too with the atmosphere. Man's senses are unable to detect the insidious poisonous matter that is emitted into the atmosphere to cause adverse global changes. We react aghast when we see chimney stacks discharging plumes of ugly smoke into the sky; such is our natural reaction, thanks to sight and smell, but we cannot be expected to react to that which is not detected by our senses. Against this, man with his higher intelligence, must realise that he should no longer rely only on his natural senses - there are many scientific tools at his disposal. It is the invisible gases that are claiming the attention of climatologists and scientists throughout the world, gases which could cause incipient but serious changes to our atmosphere and inevitably to our precious planet.

We must however be wary of over-reacting to short term changes. Monitoring of the globe's temperature and sea levels has only recently been embarked upon seriously and incorrect interpretations from short term monitorings can be expected. One warm or cold decade does not make an ice age - nor does it even presage an ice age.

Earth is due for an ice age about every 100 000 years and we should be starting one soon, but the greenhouse effect may delay the ice age's advent and even result in it never coming.

We should also be reminded that mother earth, although her atmospheric mantle is relatively thin, is inherently rugged and tough and will adjust to certain changes without unduly upsetting life on its surface. James Lovelock's Gaia theory gives certain encouragement in this regard, but man is unable to accommodate too much change and in the end, somewhat selfishly, man's future is our prime concern.

It is probably true that our future is not as good as it looked before. The fact that we are observing the situation, and hopefully reacting correctly to it now, is encouraging.

One notes with encouragement that major chemical companies and organisations are active in producing ozone friendly CFCs and in recycling CFC gases.

However man continues to perpetrate follies. As an example let us consider the feasibility of reducing the quantity of fossil fuel that is consumed here in Southern Africa, and what the consequences are.

Major technical practical decisions have had to be made in the political and other circumstances that prevailed. Had there been political statesmanship and accord amongst the nations south of the Equator over the past few decades, all the electric power required for Southern Africa could have been generated by harnessing the mighty Zaire (Congo) River in a great hydro electric generating installation. It is solar energy that lifts water from the seas and deposists it as rain on higher lying areas thereby providing the water with enormous potential energy. Such is the energy and volume of water in the Zaire, and at a particular site, that enough electrical energy could be generated for all of Southern Africa to meet the expected demand well into the 21st Century.

Such a plant would be pollution free and not consume any water, merely use its potential energy. Instead we have had to burn coal and bear the atmospheric consequences.

Our precious coal, the accumulation of carbon during millions of warmer years, could be left for the future and used judiciously for better purposes than heat generation. The Eastern Transvaal could have had far clearer skies. But man stupidly has not yet learned to work together for the common global or even sub-continental good.

Not only we, but the world will have to move away from fossil fuel usage, and utilise other sources of energy including atomic energy. We read with concern that China is proposing doubling its burning of coal by the year 2010!!

7. What else should be done

More attention will have to be paid to the air and what we discharge into it. The immediate future demands such attention. There is certainly cause for concern and no room for complacency. Tree planting should become a world wide prime occupation. We should travel less - certainly less in our cars, reduce population growth rate and add to our skills or habits that of moderation.

In Genesis Chapter 1, God entrusted and instructed man to multiply, occupy the earth and subdue it - tame it - manage it : that man has multiplied and occupied is not in doubt, what remains solely his prerogative and responsibility is to manage the earth. Man's folly has dimmed his vision of his God given responsibility.

References

Scientific America : September 1989

James Lovelock : Gaia : A New Look at Life on Earth

Frank W Lane : The Violent Earth

Andrew Goudie : The Nature of the Environment

Hicklas G Pisias : Orbital Geometry, CO_2 and Pleistocene Climate

Physics Today : May 1989, V Ramanathan, Barkstons & Harrison

J A Lindesay : Mechanisms of Climatic Change - a Review