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**Technical Paper Abstracts****QUICK AND RELIABLE FILTER TEST ACCORDING TO PREN-779 OR ASHRAE 52.2 WITH A NEW WHITE LIGHT SCATTERING SENSOR SYSTEM**

G. Lindenthal and L. Mölter (pages 19-21)

In order to characterise filters according to EN 779 or ASHRAE 52.2, the grade efficiency curve has to be determined. Therefore the particle size distribution by number of the test particles (e.g. DEHS or KCl) in the upstream and downstream positions must be measured exactly. To realise this task two experimental set-ups are generally possible, using one or two measuring devices.

In this paper we first point out the basic principles for quick and reliable filter tests to the above standards. So a constant and reproducible aerosol generation, isokinetic sampling without losses of particles in the transportation tubes from the sampling point to the measuring volume and an unambiguous particle sizing and counting system are needed.

**EVALUATION OF THE SCREEN PERFORMANCE IN A WET GRINDING CIRCUIT**

M. Oja, T. Knuutinen, P. Mörsky and H. Lehto (pages 22-24)

The purpose of this study was to find out the way to minimise the amount of fine material in a screen overflow. The experiments were carried out in the wet milling circuit that had a Derrick single deck screen after a rod mill. The tests showed that increasing load on the screen increased the recycle load so much that the feed size distribution changed considerably. The current results suggest that the grade efficiency curve of the test screen depends on the feed size distribution.

**CYCLONE DESIGN - AN INTEGRATED APPROACH**

K. Morris (pages 25-28)

Cyclones are widely used in industry as a cost effective means to remove relatively coarse particulate material (>25 µm) from gas flows. They are capable of much more sophisticated and fine grade separation and classification, but suffer from a lack of simple and convenient design procedures. This problem comes about, in part, from a lack of information about the problem species, but more fundamentally, from the interaction and interdependence of the physical and operational parameters, which describe the geometry and operations conditions in a cyclone.

**COMPARATIVE METHODS FOR THE PORE SIZE CALIBRATION OF FILTER MEDIA**

G. Rideal, E. Mayer and R. Lydon (pages 29-33)

For many years the main method of calibrating filter media has been via the 'Frazer' air permeability measurement. In more recent years the use of pore size has become more acceptable as a backup method of further calibration.

Pore size measurement has been traditionally performed by the Bubble Point measurement whereby the maximum aperture size present can be related to the pressure at which a bubble appears on the top side of a wetted filter medium pressurised from below. Changes in flow rates are used to estimate the pore size distribution, while the efficiency in an actual filtration process is calculated by using a 'tortuosity factor' to estimate the retention properties of the filter medium.

The limitation of this technique is that it is a second order method and only gives 'equivalent' or theoretical pore sizes often dependent on the pore structure within the filter medium.

An alternative method is the so-called 'Challenge test'. In this method standard test dusts or glass beads are presented to a filter medium and the size distribution in the downstream flow analysed. The method gives a more absolute measurement of pore size because it measures real particles but, because the size distributions involved are often broad, there is a significant uncertainty in the measurement of the largest particles passing the filter medium.

A new set of narrow size distribution glass microsphere standards recently introduced has been used to accurately determine the filter efficiencies of double layered woven filter media of nominal pore sizes from 20 to 200  $\mu\text{m}$ . The results are compared to the more traditional method of bubble point testing and air or water permeability measurements.

### **PRODUCTION AND USES OF METALLIC SURFACE MICROFILTERS WITH SLOTTED AND CIRCULAR PORES**

R.G. Holdich, I.W. Cumming and S. Kosvintsev (pages 34-38)

The filtration mechanism of a surface microfilter is simple rejection of suspended particles at the surface of the filter, in a similar way to sieving. Hence, the surface pore size of the microfilter, as viewed under a microscope, is the pore size rating of the filter. Conventional microfilters have pore sizes considerably in excess of the pore size rating of the filter; they rely on depth filtration mechanisms to retain the suspended solids – leading to internal membrane fouling and poor long term flux performance. A method of production of surface microfilters is described in which the pore size of an existing filter is reduced by selective deposition. Methods of characterising the pore sizes of these filters include: image analysis, the bubble point test and experiments where the filters are challenged with a very low concentration of solids in suspension and analysis of the feed and permeate, to provide the rejection efficiency for each particle size, or grade.

The method of production is applicable to commercial membranes for process scale use, as well as laboratory applications. The filters are reusable, in most applications, and their use is likely to become widespread in separations involving particles within the microfiltration range. Backflushing is usually effective in keeping deposited material off the surface of the filter and fluxes in the 1000's  $\text{L m}^{-2} \text{h}^{-1}$  result.

### **INVERTING FILTER CENTRIFUGES – ADDING A SIPHON EFFECT AND AN IMPROVED CLOTH INVERSION MECHANISM**

F. Deshun and R.J. Wakeman (pages 39-43)

The inverting filter centrifuge has a special solid transport structure. In order to improve this kind of centrifuge, two designs are put forward and discussed here. One design concerns the basket of an inverting filter centrifuge that leads to the siphon inverting filter centrifuge. The other is concerned with the solid transport mechanism of an inverting filter centrifuge. A more dependable and lower cost solid transport structure is described.

### **WASTEWATER RECYCLING STUDIES**

S. Judd and B. Jefferson (pages 43-48)

This paper describes trends in wastewater recycling and highlights the potential benefits of membranes. Three case studies are used to illustrate what can be achieved with current technology.

### **EVIDENCE FOR SWELLING INDUCED PORE STRUCTURE IN DENSE PDMS NANOFILTRATION MEMBRANES**

J.P. Robinson, E.S. Tarleton, C.R. Millington and A. Nijmeijer (pages 50-56)

A dense polydimethylsiloxane (PDMS) membrane was used to assess the flux and separation performance of a range of solutes (e.g. poly-nuclear aromatics and organometallics) and organic solvents (e.g. heptane and xylene). Solvent flux was modelled with the Hagen-Poiseuille equation and found to fit well with the degree of swelling influencing the effective pore size and porosity of the membrane.

The rejection mechanism for low polarity solutes was found to be predominantly size exclusion. The rejection varied with solvent type and rejections were higher in poorer swelling solvents. For instance, the rejection of 9,10 Diphenylanthracene was 2% in a pure heptane solvent compared with 15% in xylene. It is postulated that dense PDMS membranes exhibit the characteristics of a porous structure when swollen with solvent, and that the degree of swelling impacts on the separation performance of the membrane. A comparison between the Hildebrand solubility parameters for the PDMS membrane and the challenge solvent was found to be a good indicator of flux/rejection behaviour.

### CHARACTERISATION OF THE RESISTANCE BEHAVIOUR AND SEPARATION EFFICIENCY OF PRECOAT LAYERS BUILT UP DURING CROSSFLOW FILTRATION

H. Hess and W. Höflinger (pages 57-64)

In precoat filtration the filter aid layer can be built up by a crossflow technique. Due to selective particle deposition the structure and characteristics of the precoat layer built up by the crossflow essentially differ from a precoat layer obtained by deadend filtration. Thus, the filtration resistance, the area mass and the separation efficiency of crossflow precoat layers are greatly determined by the operating conditions (filtration pressure, crossflow velocity) during the cake build-up.

In the first part of the paper a model for the characterisation of the resistance behaviour of crossflow precoat layers is presented. Using this model the resistance behaviour can be described by two process specific parameters, the filter medium resistance,  $\beta$ , and a dimensionless resistance coefficient,  $K$ . Both parameters can be determined from experiments at different operating conditions and their dependency on the filtration velocity determines the resistance behaviour.

The second part of the paper describes a model proposal for the estimation of the separation efficiency of crossflow precoat layers. Based on the process specific parameters  $\beta$  and  $K$  a critical 'cut-off' diameter can be calculated for precoat layers built up at various operating conditions. Combining both models a new method was developed to determine the optimal crossflow velocity for the build-up of a precoat layer with given separation efficiency and area mass with a filter aid with given particle size distribution.

### LOCAL FILTRATION PROPERTIES OF KAOLIN FILTER CAKES

P. Sedin and H. Theliander (pages 65-73)

Simultaneous measurements of the local solid compressive pressure and local solidosity using  $\gamma$ -ray attenuation have been performed on kaolin during filtration. Based on these measurements, constitutive relationships for solidosity, specific filtration resistance and permeability were determined. Four different methods were used in the estimation of the parameters in the constitutive relationships. The empirical relationships fitted the data well, within the experimental error, and it was found that the estimates differed. The exponents in the relationships, on the other hand, were estimated to be almost identical and independent of the method used. The transition time between the cake build-up and expression phases was determined using three different methods, the agreement between the three methods was good. The pressure profiles at the

transition were found to deviate from the assumed pressure profile used as initial condition in the commonly used expression models, e.g. Terzaghi and Terzaghi-Voigt models.

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**Technical Paper Abstracts****EVOLUTION OF FILTER TEST STANDARDS**

C. Peuchot (pages 99-103)

Liquid cartridge filters are used in many processes and on many machines working on, or using fluids, where particles in suspension may reduce the performance. This creates a huge market in which a lot of suppliers operate with a broad variety of products, the quality of which can fully, or on the contrary not at all, comply with the user specifications or requirements.

Standard test methods are necessary to evaluate the behaviour and performance of the filter in conditions that represent as closely as possible the actual working conditions. This is expected to make the preliminary choice of filter, before a validation on the real process, the right one. The performance and ability for use of filtering cartridges can be divided into three classes: Hydraulic, Compatibilities and Performance.

The standard methods on which all industrial relationships should be based are drafted by experts from the three 'partners' involved: the manufacturers, their client end users and testing laboratories, each one bringing to the discussion their own requirements and know-how to reach the best compromise possible. Because of the constant evolution in market needs, the products offered and testing know-how and equipment, standards must be regularly updated and new ones drafted.

**TREATING COMBINED SEWER OVERFLOWS: PERFORMANCE OF HIGH RATE CLARIFIERS AND CONTINUOUS SAND FILTERS**

G. Glasgow and B.J. Morrow (pages 103-108)

During wet weather conditions, wastewater flows in combined sewers systems can be enormous, resulting in untreated spills from combined sewer overflow structures to the receiving water. Where such intermittent discharges are judged to be unsatisfactory, the conventional solution has been to either increase the pass forward flow or store the wet weather overflow in large tanks for later treatment. An alternative to this storage solution, known as Equivalent Treatment, is to treat the overflow to a desired standard and discharge it as and when necessary directly to the receiving water.

Process technology including clarifiers, filters and ultra violet disinfection is being trialled by United Utilities to assess this approach to solving unacceptable intermittent discharges. Results have shown that suspended solids concentrations, ultraviolet transmission levels and faecal coliform concentrations can be improved to a level where ultraviolet disinfection becomes viable for the destruction of microorganisms. United Utilities are actively pursuing this approach to storm water management for a number of intermittent discharges across the North West of England.

**ELECTROCHEMICAL METHODS FOR COOLANT OIL REGENERATION**

T. Yamamoto, C.-L. Yang, T. Nagaoka, M. Okubo, T. Kuroki and M. Okamoto (pages 109-113)

Coolant oil (an oil-in-water emulsion), widely used for machining metal pieces from various industries, needs to be clean before being disposed of or reused. The used coolant oil contains not only fine metals but also sludge, grease and other compounds which are the source of odours

as time elapses. The conventional methods are to use the filters, and gravitational and centrifugal separation methods to remove those compounds but these have practical limitations in terms of maintenance, removal efficiency, and coolant oil quality for regeneration.

In the present study, electrochemical methods were investigated to remove these compounds and to regenerate the coolant oil - this led to development of a maintenance free and innovative coolant oil treatment process. The other advantage was to suppress bacteria generation by controlling pH in the coolant oil, being considered the main cause of the odour problem. More than 90% by weight of fine aluminium particles, grease and oil were removed by the filter. The coolant oil can be used for regeneration and its characteristics did not deteriorate when the treatment time was less than 20 s at 20 V.

### **APPLICATION OF THE OPTICAL SENSING ZONE METHOD TO FILTER MONITORING**

T. Wharton (pages 113-116)

This paper presents some recent developments in optical sensing and its use in filter monitoring. The operating principle of the Accusizer is described and methods for incorporation within filter test environments is shown.

### **USE OF STANDARD TEST DUSTS IN FILTER CHALLENGE TESTING**

R. Buxton (pages 116-118)

Standard test dusts have a wide variety of uses in a range of industries. They are used as secondary calibration materials for measuring instruments, testing the integrity of enclosures and packaging, the reliability of components and equipment in dirty atmospheres and in the testing of filters and filtration systems. There are many test dusts - Particle Technology Ltd manufacture dusts to over 70 different specifications. This paper concentrates on the filtration uses of standard test dusts.

### **MOLASSES PURIFICATION BY INTEGRATED MEMBRANE PROCESSES**

P. Pinacci, M. Radaelli, A. Bottino and G. Capannelli (pages 119-122)

Molasses represent an important waste stream in the sugar manufacturing process but their value is very low because of the presence of impurities ranging from suspended materials to inorganic salt and colour substances. This paper deals with the possibility of purifying molasses by two consecutive membrane processes, i.e. microfiltration and electrodialysis, and to recycle them back to the sugar manufacturing process.

The results of laboratory feasibility tests indicate that, by feeding the electrodialysis with microfiltered molasses at a concentration of 30 Brix, it is possible to remove up to 80% of salts, thus obtaining a stream suitable for sugar crystallization. Fouling phenomena are negligible due both to the beneficial effect of the microfiltration pretreatment and to the intrinsic characteristics of the ion exchange membranes. Preliminary economic figures indicate potential benefit due to the use of integrated membrane processes but crystallization tests of purified molasses are necessary in order to evaluate the actual yield of the crystallization process and determine the quantity and quality of recovered sugar.

### **CONSOLIDATION BEHAVIOUR OF GEL EMULSION CAKE IN THE FILTRATION OF O/W EMULSIONS WITH AND WITHOUT SOLID PARTICLES**

E. Iritani, Y. Mukai, N. Katagiri and I. Yoshii (pages 124-129)

A method has been developed for preparing highly concentrated gel emulsions by the filtration-consolidation of O/W emulsions using an unstirred batch filtration cell. The cake was highly

consolidated without cake cracking or the coalescence of oil droplets by applying the pressure longer after completion of filtration for the whole emulsion. A compressed cake formed by this method has a porosity much smaller than the value of 0.2595, which corresponds to the hexagonal close packing of undistorted spheres. During consolidation, the oil droplets separated by thin stable films of continuous water in the compressed cake lose their sphericity and increasingly deform.

By considering cake compressibility, the properties for the filtration period were evaluated on the basis of the cake filtration equation. This revealed that the highly compressible filter cake formed on the membrane surface during filtration. Moreover, the properties of the consolidation period were analysed using the modified Terzaghi model. The variations over time of the average consolidation ratio and the average porosity in the compressed cake during the consolidation process were well described by the model.

Filtration-consolidation of O/W emulsions containing fine solid particles is also important from the practical viewpoint. It was found that a cake with two distinct layers, comprising gel emulsion and fine solid particles respectively, was formed, and that the properties of the cake in both the filtration and consolidation periods can be well described by the model proposed.

### **DEVELOPMENT OF NOVEL MEMBRANES WITH CONTROLLED POROSITY FROM FLUORINATED POLYMER**

A. Bottino, G. Capannelli, A. Comite and M. Oliveri (pages 130-135)

This paper deals with the preparation and characterisation of a new class of porous membrane made from a fluorinated polymer (polyvinylidene fluoride) supported on various types of porous nonwovens. Flat sheet membranes were prepared from polymer solutions, initially cast at room temperature on the nonwoven, and then exposed for a given period in air before being immersed in water. The effects of some of the preparative parameters (i.e. polymer concentration, type of nonwoven, exposure period of the cast solution) on the membrane properties (air permeability, ultrafiltration performance, structure and morphology) were investigated.

The stretching action of the nonwoven on the nascent membrane during immersion in the water bath was found to play an important role in the formation of membrane pores. The action was strictly connected to the penetration depth of the polymer solution into the nonwoven matrix that in turn was controlled by wetting the nonwoven, or by varying the polymer concentration (i.e. the solution viscosity), as well as the exposure time of the solution before being immersed in water. Proper operating parameters were then defined in order to prepare membranes with controlled pore size and distribution in the range of tenths of micrometres.

### **COMPUTER MODELLING OF PLEATED CARTRIDGE FILTERS FOR VISCOUS FLUIDS**

W.R. Ruziwa, N.S. Hanspal, A.N. Waghode, V. Nassehi and R.J. Wakeman (pages 136-144)

The primary aim of this study is to develop and validate a software package for the design of pleated cartridge filters for aeronautical applications. This package is intended to develop into a cost effective, robust and reliable design tool to enable engineers to appraise the operation of a filter. A 2-D computer code has been developed to simulate both Newtonian and non-Newtonian flows in the filter. The model is based on the flow and mass transport models described by the Continuity and Darcy equations and the Convective-Dispersion equation for the porous flow region. These equations are solved by the weighted residuals finite element method. First order Taylor-Galerkin and implicit time stepping schemes were applied for temporal discretization of the Darcy and the Convective-Dispersion equations, respectively.

The streamline upwinding Petrov-Galerkin technique was chosen for the solution of the Convective-Dispersion equation to overcome the numerical problems caused by high Peclet (convection dominated) transport. Preliminary numerical experiments were based on simple

geometries and the domain complexity was increased in steps to examine the model flexibility in dealing with various situations. The overall model was validated against experimental data. Domain variables of interest are velocity, pressure and concentration profiles, which are obtained through the solution of the governing equations taking into consideration the changes in the rheological properties of fluids being filtered.

### **A STUDY OF THE INFLUENCE OF THE COLLECTOR ON PHOSPHATE FLOTATION IN A COLUMN**

G.M. Queiroz, M.S. Oliveira, D.R. Cioqueta, C.H. Ataíde and M.A.S. Barrozo (pages 145-149)

The purpose of this work is to analyse the influence of some important operational variables of the flotation column. An apatite ore sample taken from the flotation circuit of the company Bunge, Araxá, Brazil, was used as test material. A laboratory flotation column was operated in discontinuous mode in order to examine two different types of fatty acid collectors, and the effects of their dilution, conditioning time and dosage. The effects of these variables on the content and recovery of  $P_2O_5$  was evaluated through a factorial design.

Recoveries between 32 and 55% were obtained in flotation with rice oil soap collector. This range was greater than the one observed in flotation with the soy grape oil collector (38 to 50%). The dosage of the collector was the variable that exerted the greatest influence on the recovery.

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**Technical Paper Abstracts****CHARACTERISATION OF NANOFIBRE FILTRATION MEDIA BY CAPILLARY FLOW POROMETRY**

A. Jena and K. Gupta (pages 176-180)

Comparison of the capabilities of pore characterisation techniques suggests that liquid extrusion techniques are most appropriate for the characterisation of nanofibre filtration media. The extrusion techniques, Capillary Flow Porometry and Liquid Extrusion Porosimetry, were used to successfully measure all the pore structure characteristics of through pores.

Pore throat diameter, bubble point pore diameter, mean flow pore diameter, flow distribution and gas permeability were measured by capillary flow porometry. Through pore volume and volume distributions were measured by extrusion porosimetry. It is shown that through pore surface area and liquid permeability are measurable by both techniques. It is concluded that techniques based on liquid extrusion are suitable for characterisation of nanofibre filtration media.

**PERFORMANCE OF DIFFERENT PRIMARY FILTERING MEDIA IN ROTARY VACUUM DRUM FILTERS FOR SUGAR CANE MUD**

W. Polonio (pages 181-185)

This study aims to evaluate the development of 13 different types of primary filter media. These were developed for use in the vacuum filtration of sugar cane mud to simulate the cake formation and dewatering operations in the rotary vacuum drum filters employed in sugar and alcohol mills in Brazil. The primary filtering media tested were divided in perforated boards by mechanical process and chemical photo corrosion, with round bores, different procedures, open areas, superficial types of finish, thickness and chemical corrosion attack of the boards. Other types were also built with trapezoidal bars to form a metal grid having rectangular openings of different open area.

All the experiments were made in a pilot plant attached to the real filter that aimed to reflect the truthfulness of the operational variables of the sugar cane mud in a rotary vacuum drum filter. For each experiment, the analyses of the mud, cake and filtered juice were made at the mill's own laboratory, raising quantitative and qualitative data that was contrasted with the standard filtering element commonly used. The results are presented graphically, comparing the filtering indices obtained in the formation and cake dewatering steps, for variations in vacuum, temperature and concentration of the filtering auxiliary.

As a conclusion, the user is shown a new way to significantly improve the performance of vacuum filtration through low investment, without the need to increase the area of the filtering unit.

**THE WHIRLPOOL SEPARATION SYSTEM AND ITS INDUSTRIAL APPLICATION**

H. Nirschl and V. Denk (pages 186-189)

The whirlpool is in general a device for solid-liquid separation. The physical phenomenon is also known as the so-called teacup effect: tea leaves in a tea cup which has been stirred do not move to the outside, in accordance with centrifugal force, but contrary to the direction expected they move towards the centre of the bottom of the cup where they settle. The separation of the particles takes place in the bottom boundary layer of the vessel. The equilibrium forces arising

from fluid rotation are disturbed there so that resulting eddies force the particles to move to the centre of the vessel.

Various undesirable secondary flows arise in the system. A so-called torus eddy with a shape of a car tyre tries to whirl up the settling trub in an undesirable manner. As a result the entrance velocity may be limited to a special inlet velocity which makes sure that the shear stresses on the trub particles are not too high and no destruction can occur. The limitation of shear stresses is of high importance because not just in the whirlpool but also in the surrounding parts, for example in pumps and pipes, a degradation of the particles is possible. Besides, there are constructive ways to get rid of undesirable secondary flows.

The torus eddy can be 'sliced' by means of suitable inserts. The inserts can consist of concentric rings installed near the bottom. A work programme has been developed to ensure the separation system for use in the brewing industry. The system has now been installed and approved in several breweries.

### **NEW TEST SYSTEM FOR PRACTICAL FILTER TEST OF CLEANABLE SURFACE FILTER MEDIA AT TEMPERATURES UP TO 250°C AND IN RELATIVE HUMIDITY UP TO 80%**

M. Schmidt and L. Mölter (pages 189-193)

Cleanable surface filters are used in many different applications in the field of industrial dedusting such as the building material industry, metal processing, the chemical industry and the food industry. They are also used for exhaust gas cleaning of combustion processes and in many other applications. As there are so many different fields of application, a large number of different types of surface filters with different structure and surface conditions have been developed by media manufacturers.

A close-to-reality evaluation of these filter media under practical conditions concerning temperature, relative humidity, different types of dust and service life is not possible in test systems according to VDI 3926. Palas® provides a test system which allows practical, fast and reliable filter tests to be carried out. The system basically consists of two components:

- Advanced Test Rig according to VDI 3926 Type 2 MMTC-2000
- Ageing Chamber for filter media and small complete filters.

### **FILTER MEDIA TESTING FOR STARCH FILTRATION SYSTEMS**

N. Salmela and M. Oja (pages 194-198)

Pressure filtration of starch slurries in starch production is increasing. Because the filter medium is a keystone of any filtration system, it is important to find the best possible medium for a certain process. The change of the medium can significantly alter the economics of the starch filtration process. Every starch type has its own special mean particle size and particle size distribution. The differences between sizes of different starches are quite large: from a couple of micrometers to one hundred micrometers. However, different starch types are filtered in the same filter press. The filter media used has to be as suitable as possible for all starch types.

In this work, different types of filter media used in commercial starch production processes were tested. The aim was to find the most suitable medium for wheat starch filtration. The resistance of the clean and used medium was measured before filtration and between the filtration runs by flowing water through the medium. The medium resistance was measured with the same test filter as the actual filtration tests, but using special water piping. Clean and used media were also compared microscopically.

Because every starch type has its own special properties, it is important to find the media most suited to each application. North European starch production consists mainly of wheat and potato

starch production, whereas American and Southern European starch production consists mainly of maize starch production. This sets different demands for the filter media.

### **METALLIC FILTER ELEMENTS: DETERMINING AN ELEMENT'S SUITABILITY FOR REUSE AFTER CLEANING**

R.A. Smith (pages 198-202)

There are a number of metallic filter element configurations and media used in liquid/solid as well as gas/particle separation. Their high cost requires that they remain on stream for a long time or are cleaned on/off-line and subsequently returned to service. At some point, some sort of cost effective non-destructive test must be applied to assess suitability for continued service.

There are a number of tests used to define the largest pore in an element, mean pore size, permeability, tortuosity, etc. when new. The picture becomes cloudy once an element has been used. This is due to subtle changes in the media as a result of a multitude of possible causes. Changes could be minor with no measurable or minor increase in largest or mean pore size to significant changes that compromise an element's integrity from a performance or product quality perspective. It may also be necessary to determine the effectiveness of cleaning. It is important that the end user be able to determine if an element is suitable for reuse or must be replaced. What tests, criteria and limits does he /she use to make this determination?

It basically becomes a risk assessment for the end user. Standards or limits set too high will result in higher operating costs due to element replacement. Limits set too low may result in process upsets, productivity or product quality issues. This paper addresses the test methods and criteria commonly used today and provide some insight into the significance of test results relative to minimising the risks associated with setting these limits.

### **CHARGE EFFECTS OF DISPERSED SYSTEMS AND MEMBRANE SURFACE ON CROSSFLOW MICROFILTRATION**

D. Smidova, P. Mikulasek, R.J. Wakeman and P. Velikovska (pages 204-209)

The influence of particle size and  $\zeta$ -potential of the feed particles ( $\text{TiO}_2$ ) and a membrane surface ( $\alpha\text{-Al}_2\text{O}_3$ ) with changes of pH on permeate flux during microfiltration using a tubular ceramic membrane have been studied. The properties of alumina tubular membranes and the aqueous titania dispersions were measured and related to the filtration characteristics. The experimental system is also described.

It was found that permeate flux was dependent on the surface charge of the suspended particles and to some extent dependent on the surface charge of the membrane. This phenomenon was especially pronounced during microfiltration of a dispersion around its isoelectric point, when permeate flux increased significantly.

### **INFLUENCE OF ADDITIVES ON THE SEDIMENTATION BEHAVIOUR OF FINE GRAINED SOLIDS IN THE CENTRIFUGAL FIELD**

M. Beiser and W. Stahl (pages 210-215)

The influences of solids concentration and additives on the sedimentation behaviour of quartz and limestone suspensions in centrifugal fields are described. These solid/liquid systems showed similar physical properties (e.g. particle size distribution, particle shape, density) but different physicochemical properties. Quartz/deionised water suspensions were inherently stable, that is the quartz particles did not tend to coagulate, whereas limestone suspensions were destabilised in their natural state.

Within this paper, the influence of electrolyte concentration ( $\text{AlCl}_3$ ) and pH value (HCl) on the sedimentation behaviour of quartz particles is discussed. Both additives induced coagulation of the quartz. Additionally, the influence of dispersing agents on the sedimentation of limestone particles is presented. The comparison of the settling behaviour of these two products revealed both similarities and differences.

The experimental results show how the sedimentation behaviour of fine grained solids can be readily influenced by additives. The well-directed control of physicochemical parameters implies the possibility of adapting the sedimentation behaviour of particles to a particular process in an optimal way.

## **FILTRATION AND WASHING CHARACTERISTICS OF CONCENTRATED COBALT HYDROXIDE SUSPENSIONS**

H. Saveyn and P. van der Meeren (pages 216-219)

Cobalt hydroxide  $\text{Co}(\text{OH})_2$  suspensions were made by a precipitation reaction and the suspensions were consequently adjusted to different pH values, ranging from about pH 6 to 10. It appeared that the suspension viscosities showed a maximum at pH 8.8 because of strong interparticle attractive forces, leading to bridging as was confirmed by the high sediment volume upon prolonged sedimentation.

The rheological behaviour of the suspensions was reflected in their filtration behaviour, indicated by the fact that suspensions with the highest apparent viscosity were the easiest to filter, with the lowest filter constants and shortest filtration duration times. The porosity of the cake structure was demonstrated through the filter cake thickness and the water content, which showed maximum values around pH 8.8. It appeared, however, that the good filterability at pH 8.8 was compensated by an increased retention of sodium in the filter cake, because of the large pore liquid volume.

Upon washing, it appeared that the filter cakes formed from suspensions at pH 8.8, were washed out most quickly. The mixing of pore liquid with wash liquid was more pronounced in these cakes, due to high wash liquor velocities in the larger pores. It is discussed how this optimum pH is related to the point of zero charge of two cobalt (hydr)oxide compounds.

## **LABORATORY, PILOT AND INDUSTRIAL SCALE VALIDATION OF NUMERICALLY OPTIMISED REVERSE FLOW GAS CYCLONES**

R.L.R. Salcedo, V.G. Chibante and I. Sôro (pages 220-225)

This paper addresses the experimental validation of the optimum design of reverse flow gas cyclones, obtained through the solution of a numerical non-linear optimisation problem, viz. maximizing cyclone collection. The simulation model is based on the predictive properties of a finite diffusivity model, where the particles' turbulent dispersion coefficient is estimated through an empirical correlation between the radial Peclet and Reynolds numbers. The optimisations were formulated with constraints on pressure drop, saltation velocity and geometrical considerations, such that feasible cyclones could always be obtained.

The optimum geometry, named RS\_VHE, is different from the available high efficiency designs, and represents reverse flow cyclones with a significantly improved predicted performance. An innovative partial recirculation system within a collector first arrangement further reduces emissions with only a moderate increase in pressure drop. The generally observed, but unexpected, high collection of sub-micron particles is attributed to capture by larger particles in the turbulent flow field due to turbulent dispersion, much like what occurs in re-circulating fluidised beds.

Results obtained for the RS\_VHE cyclones with partial recirculation at laboratory, pilot and industrial scales, for temperatures ranging from 300 to 600 K, gas flow rates from 1 to  $10^4$   $\text{m}^3/\text{h}$  and

inlet loads from 15 to  $10^4$  mg/m<sup>3</sup>, show them to perform significantly better than equivalent diameter HE cyclones, or smaller diameter multi-cyclones. Under certain circumstances, with recirculation the proposed system shows better performance than on-line pulse-jet bag filters.

Overall, the results show that the numerically optimised RS\_VHE cyclones, when coupled with a partial recirculation system, open the applicability of these simple devices for fine particle collection which is typical of more expensive devices, such as venturis and on-line pulse-jet bag filters.

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**Technical Paper Abstracts****CORRUGATED HIGH EFFICIENCY FILTER MEDIUM VILEDON FE 2507 SINE – RESULTS FROM LONG TERM FIELD TESTS AND A COMPARISON WITH LABORATORY TESTS**

M. Waldenmaier (pages 249-252)

Filter cartridges equipped with modern synthetic filter media are increasingly used for the separation of airborne particles. The need to separate particles from a carrier gas occurs in dust removal applications as well as in the case of recovering special products, e.g. in pharmaceutical industry. Particularly for the filtration of very fine particles (less than 5 µm down to the sub-micron range) the requirements on the filter media are still growing with respect to the capability of separating these particles and to the cleanability when cleaned by pulse-jet.

**INFLUENCE OF CLEANING PARAMETERS ON PULSE-JET FILTER BAG PERFORMANCE**

X. Simon, D. Thomas, D. Bémer, S. Callé, R. Régnier and P. Contal (pages 253-260)

The aim of this study is to characterise pressure drop and acceleration profiles along a filter bag subjected to different conditions of pulse-jet cleaning. A flow of clean air is imposed on the 24 bags of a pilot scale dust collector. Pulse-jet cleaning can be achieved either on the single instrumented filter bag, or on the 24 bags simultaneously.

Various parameters (initial bag tension, filtration velocity, compressed air tank pressure, impulsive flow duration and geometry of the nozzle or tube injector) were investigated and their influences on the cleaning performances of a filter bag are discussed and compared. Results permit better understanding of the effects of pulse-jet cleaning and identification of the areas where cleaning seems to be most effective. Choice and combination of those parameters (compressed air pressure, geometry of injector nozzle and number of bags cleaned simultaneously) seem to be crucial stages for the optimisation of bag cleaning in pulse-jet filters.

**THE TURBO MAGNETIC OIL FILTER 'URAGAN-M'**

A. Karabach and I. Dun (pages 260-261)

A key problem of the technical-scientific progress in engine manufacture is an improvement of the quality of motor oil cleaning, and the importance of this problem will increase. During each minute of operation of any internal combustion engine, especially during a cold start and warmup, the engine oil is contaminated with some quantity of foreign metallic and other particles which are produced as a result of friction between parts of the engine and fuel combustion (soot and carbon deposit).

About 75% of engine wear is brought about during the first 10 minutes of operation after a cold start. Modern high power augmented engines – both gasoline and diesel engines equipped with precision units (hydraulic compensators, hydraulic tensioning devices, etc.) - require application of a new oil filter which would provide a high quality of oil cleaning in any extreme condition (especially during a cold start, or when the filtering elements are heavily contaminated, or during motor race driving).

**EXTENDED AREA FILTRATION IN NONWOVENS POLYMER PROCESSING**

R.A. Smith (pages 262-266)

As the application of nonwoven materials into more critical end uses such as filter media has evolved along with a highly price competitive market, manufacturers have been increasingly interested in ways to distinguish their product in the market or improve their economic position. Many of these manufacturers have development efforts aimed at reducing fibre diameters, improving fibre/web physical properties and consistency while maximizing process efficiencies.

Given the capital and operating cost impact of filtration requirements on a process, not to mention potential product quality or market position issues, it is extremely important that the right decisions are made relative to filter medium, size, and design. Without a fundamental understanding of filtration concepts and technologies, including an understanding of the end users own basic filtration needs, knowing the strategic questions to ask of a supplier or how to interpret their answers is difficult. In the absence of this knowledge, they must find an unbiased company or consultant that can provide them with the necessary guidance and direction.

### **OPTIMISATION OF SLUDGE MANAGEMENT IN LEISURE PARKS BY LOW PRESSURE REVERSE OSMOSIS**

D. Kunz, E. Schmidt and T.A. Peters (pages 267-270)

Water treatment has become more and more important due to increased costs for municipal water and wastewater during the past few years. The membrane processes have been developed continuously during recent years. Increasingly they have replaced approved processes like adsorption and reverse osmosis is already established for sea water desalination and other applications. In the 'Bergische Sonne' leisure park in Wuppertal, the so-called project 'SAMRO' has been developed.

In this project, a specific vibration screen is used to separate the solids material in addition to a low pressure reverse osmosis membrane process. By using this combination, the filter backwash water, which is accumulated during the backwashing of the filters, is purified by a low pressure reverse osmosis so that it can be used as filling water for the basins again. The filter backwash water is pre-cleaned over a Sweco vibration separator to separate particles which are bigger than 60 µm. The filtrate flows over a police filter (a bag filter) afterwards and then over the flat membrane modules of the low pressure reverse osmosis system. The results show that the drinking water and sewage quantity has been reduced by 80%.

The savings made are also based on the lower energy demand required to heat the potable water. It contains a credit of 0.40 €/m<sup>3</sup>. The hygienic conditions are improved since sludge storage is avoided.

### **USE OF ANALYTICAL CENTRIFUGATION FOR EVALUATION OF SOLID-LIQUID SEPARATION IN DECANter CENTRIFUGES: APPLICATION TO SELECTION OF FLOCCULANTS FOR SLUDGE DEWATERING**

T. Sobisch and D. Lerche (pages 270-274)

The paper reports on a new laboratory method for the evaluation of solid-liquid separation in decanter centrifuges based on analytical centrifugation. The method allows determination of the two critical parameters for sludge dewatering – separation rate of sludge flocs and the compressibility (dewaterability) of the sludge cake. The initial separation rate gives information on whether or not the sludge flocs are separated fast enough from the bulk liquid. This relates to the maximum throughput performance at which the decanter can operate. The content of total solids after centrifugation measures the extent that the separated sludge cake can be compressed further. This is proportional to the total solids, which can be obtained if the throughput rate is not critical.

The action of high shear stresses during mechanical processing was modelled by adapting the sample pretreatment, so that similar changes take place in the sludge samples as in practice. The performance of the newly developed method was demonstrated by investigations of the effect of the initial total solids of a sludge, of mechanical stresses on sludges before flocculant addition, by an example of flocculant selection and by comparison with results obtained under field conditions.

### OPTIMISATION OF CANDLE FILTERS USING THREE-DIMENSIONAL FLOW SIMULATIONS

K. Velten, M. Günther, B. Lindemann and W. Loser (pages 276-280)

A model has been developed to compute 3D quasi-stationary flow patterns in candle filter systems. It is based on the Navier-Stokes and Brinkman flow equations and a shape optimisation procedure to estimate the filter cake shape in 3D. Finite elements and an iterated grid search algorithm are used to solve the mathematical problems.

Since an unnecessary detailed modelling of the process is avoided, the approach is particularly efficient in terms of computation time and memory requirements. It allows for a scenario based optimisation of the filtration process. Among the results, the 3D flow pattern in a particular candle filter system (FILTROjet 2300®) has been obtained. Also, the dependence of the filter cake's shape on its thickness has been derived, which will be used for experimental validation.

### EFFECT OF AEROSOL CONCENTRATION ON THE ELECTROSTATIC PRECIPITATION OF NANOPARTICLES

A. Marquard, J. Meyer and G. Kasper (pages 281-286)

This paper presents experimental data on the relevance of particle space charge effects during electrostatic precipitation of SiO<sub>2</sub> nano-aerosols in a cylindrical ESP. The influence of particle concentration on the ESP operation is characterised by measurements of voltage (*U*) - current (*I*) characteristics, particle collection efficiencies and mean particle charges at the ESP exit. Variation of particle concentration between 5x10<sup>6</sup> and 1.8x10<sup>8</sup> #/cm<sup>3</sup> was achieved by diluting the aerosol without changing the particle characteristics (size and morphology) and gas conditions (temperature and humidity). With increasing concentration a decrease of the voltage-current curve was observed, but for the highest voltage applied, precipitation still remained high (total number collection efficiency 98% for 45 nm aerosol and 96% for 75 nm aerosol).

The transition from low to the high particle concentration regime where particle space charge effects start influencing the ESP operation was determined. Derived from the *U-I* curves, the threshold concentration lies between 5x10<sup>6</sup> #/cm<sup>3</sup> and 9x10<sup>6</sup> #/cm<sup>3</sup> and derived from the measured collection efficiencies, it is located around 1.5x10<sup>7</sup> #/cm<sup>3</sup>.

For the low concentration regime a theoretical analysis of the charge and grade efficiency measurements based on two migration models and a charging model was performed. Whereas the charge calculations based on measured grade efficiencies and the Deutsch model showed good agreement with the direct charge measurements, the charge calculations based on the established Fuchs model at the measured electrical conditions resulted in a significant underestimation of the particle charge.

### DURABILITY VALIDATION OF SYNTHETIC FILTER BAGS

S. Tanaka and C. Kanaoka (pages 287-294)

The use of filter bags as high temperature air cleaning media is one of the most promising methods for preventing the release of hazardous emissions such as dioxins from incineration exhausts. High temperature and chemical resistant fibre felts are preferable for filter media to establish high collection efficiency and strong durability. The felt shape materials must have quite different durability compared with bulk polymer material because there are so many factors related to

polymer morphology and felt structure. However, no systematic method to evaluate the durability of filter materials has been established. The dominant degradation mechanisms of filter bags (FBs) is also unclear.

In this study, a systematic evaluation method for high temperature application is proposed and validated on an experimental basis. Commercially available synthetic FBs for high temperature operation made of polyfluoroethylene, polyphenylene sulphide, polyimide, and poly-methaphenylen isophtalic amid showed excellent durability and high application potential in municipal incinerators at temperatures of less than 210°C. Not only temperature, but also oxygen and water content, significantly affect the durability of FBs by a mechanism of oxidization or hydrolysis. PTFE showed strong durability against all acid gases tested but its tensile characteristics are significantly affected by temperature change. The degradation mechanism was investigated by a comprehensive chemical analysis.

### **HIGH PRESSURE EXPRESSION OF COCOA SUSPENSIONS: AN OVERVIEW OF THE BUTTER EXTRACTION MECHANISM**

J.-L. Lanoisellé, G. Piar and E. Vorobiev (pages 295-303)

Expression is a unit operation that is very widespread in food industries, and is used in particular to extract oil from a plant. This process is important for the first transformation of cocoa (54% fat) as a prelude to the manufacture of chocolate. The objective is to obtain cocoa butter (fat), which will be added to the cocoa mass (liquor) and sugar to form chocolate.

Classically, expression is performed at 100°C in high performance hydraulic presses that work with pressures of 80 MPa. The cocoa expression operation is considered complete when the cake butter residual content is 10%. The operation takes place within 20 minutes to produce a cake butter residual content of 10%, and may be divided into five phases with regard to recordings of pressures, variation of thickness of the pot and extracted mass of butter:

- i) Feeding phase, including an over-filling stage, which corresponds to a filtration with constant pressure
- ii) Filtration phase characterised by a constant butter outflow and a linear increase of pressure with time
- iii) Constant rate compression phase with a rapid increase of pressure
- iv) Compression phase with a decreasing rate of deformation of the pot limited by the forward movement of the piston resulting from the performance of the hydraulic pumping unit
- v) Constant pressure compression phase due to the pressure regulation of the hydraulic pump unit.

For each of these phases, an empirical model is proposed, which allows the calculation of the volume of butter extracted according to time.