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## Technical Paper Abstracts

### REAL WORLD FUEL WATER SEPARATION PERFORMANCE

M. Wieczorek, B. Verdegan and E. Quillen (pages 21-25)

Industrial test standards facilitate comparisons of fuel water separator performance for different products under repeatable and reproducible conditions. They do not, however, simulate field conditions nor do they reflect actual field performance. These standards do not necessarily provide meaningful differentiation in terms of performance among different products. In the worst case, industrial standards may produce a false sense of security for filter users. These issues are recognised by the filtration industry. Revisions to the standards at SAE and ISO are in process to enable performance assessment under more repeatable and realistic conditions. Despite this, the end of life performance of fuel water separators remains largely ignored.

In this paper, the end of life performance of several commercially available fuel water separators was evaluated using the SAE J1488 fuel water separation test method. The separators are representative of filters on the market that exhibit >95% efficiency when new. From the results, the importance of considering end of life performance, as well as initial performance, is clear. The results also suggest shortcomings of current industrial test standards for fuel water separator testing and may provide guidance to standards organisations.

### MEMBRANE TECHNOLOGY – PAST, PRESENT & FUTURE WITHIN THE WATER INDUSTRY

T. Peters (pages 26-31)

The pressure driven membrane processes of microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) have become definitively important instruments in water management and environmental engineering. Their performance has been comprehensively verified from a technical and economical, as well as an ecological, point of view. These processes can be considered nowadays to be well proven and very successful tools of chemical engineering, allowing, for example, to overcome water scarcity and to prevent water pollution, or to enable recovery and reprocessing of valuable substances. In combination with other processes the remaining water quantity can be significantly reduced by multiplied usage of the water, thus saving costs, but also facilitating the realisation of environmental sustainable zero liquid discharge (ZLD) procedures.

This development is partially based on results obtained during the operation of RO systems that were designed in the early days of the technology for the desalination of seawater (trendsetting patent 1964). Details addressing these membrane processes, examples of their area of application in the past, present and expected developments, are considered for the discussion of decision supporting criteria for the selection of these technologies.

### WATER REMOVAL APPLICATIONS OF AN INNOVATIVE COALESCER ELEMENT IN MINERAL LUBRICATING OILS

R. Chen (pages 31-39)

The requirement to remove water contamination in mineral lubricating oil is particularly stringent, since the presence of even a small amount of water contamination can cause numerous problems affecting thermal oxidation stability, lubricity, filterability, corrosion and equipment service life. To

effectively and efficiently remove water contamination dispersed in mineral lubricating oil a new coalescer element is studied in this paper. Water contamination issues are briefly introduced, the unique coalescence mechanism occurring in an innovative coalescing media SFM is proposed and the conceptual design of the new coalescer element is presented. A laboratory test stand and oil analysis procedure are also described.

The results from preliminary water removal tests with ISO 32 and ISO 68 mineral turbine lube oils demonstrate the performance of the new coalescer element. For example, within a single flow pass through the new coalescer element and then one commercial K3100 separator element at flow rates up to 10 GPM, the water content in 75ºF ISO32 mineral turbine lube oil stream can be reduced from up to 5 vol% upstream to 41 ppm or less downstream.

## EFFECT OF SILICON FINISH ON THE BEHAVIOUR OF REGENERATED SURFACE FILTERS AT DIFFERENT DUST CONCENTRATION

A. Mukhopadhyay and S.R. Swain (pages 40-47)

This paper discusses the effect of two different filter media, viz. polyester filter fabric treated with silicone finish and polyester fabric filter without treatment, and two different dust concentrations (50 and 90 g/m$^3$**)** on the performance of pulse-jet filtration. The fabrics were tested based on cleaning at fixed peak pressure drop for an equal number of test cycles during the first three phases (i.e. conditioning, ageing and stabilising) and for the same time duration during the final measuring phase. Silicone treated filter fabric showed better filtration efficiency compared to untreated fabric. At higher dust concentration, the reduction in efficiency was much lower in the case of the treated filter. A light scattering aerosol spectrometer system was used for analysing the emitted particles from the filter media. Particulate parameters like $PM_{2.5}$ and $PM_{10}$ emissions, number concentration and mass concentration of particles were less for the treated filter fabric.

After the ageing process, the silicone treated filter showed a smaller rise in pressure drop compared to the filter without treatment. The silicone treated fabric also showed more or less the same pattern of particle size distribution for emitted particles when tested at both higher and lower dust levels, but for the untreated fabric the distribution curve was much broader at the lower dust concentration. However, the difference in the particle size distribution pattern of emitted particles was marginal among the two fabrics when tested at a higher dust concentration. Experimental work was also carried out by analysing the residual pressure drop pattern with time for both fabric types, but no clear pattern was observed for the residual pressure drop. It was found that the treated fabric showed more predictable results compared to the untreated fabric.

## THE INFLUENCE OF IONIC STRENGTH ON THE LOCAL FILTRATION PROPERTIES OF TITANIUM DIOXIDE

T. Mattsson, J. Durruty, J. Wetterling and H. Theliander (pages 48-57)

Deadend filtration is an energy efficient way of achieving solid-liquid separation. It is used in a wide variety of industrial processes and for materials having very different properties. Development of accurate models describing the filtration properties of a material in terms of particle and suspension properties is important and would be of great use in, for example, process design and troubleshooting.

The aim of this study is to investigate the effects of particle interactions on local filtration properties. Titanium dioxide was used as a model material and the electrostatic interactions between the particles were altered by changing the ionic strength of a suspension. At low ionic strengths the repulsive electrostatic forces between particles prevented agglomeration, and the filter cakes formed had a low compressibility. As the ionic strength of the suspension was increased, the particles agglomerated more extensively and a more porous structure of the filter cake was obtained. It was found that the decrease in the inter-particle repulsive forces resulted in the formation of filter cakes with a lower solidosity, lower specific filtration resistance and higher

compressibility. Finally, three filtration models were applied and could successfully describe the relationship between the local solidosity and the local specific filtration resistance of a filter cake.

## COMPARING ADSORPTION OF BISPHENOL A AND SIMILAR COMPOUNDS IN AQUEOUS SOLUTION BY SYRINGE FILTERS

N. Godby (pages 57-60)

Analyte loss during syringe filtration is often overlooked in quantitative analyses. Bisphenol A, and similar compounds, are being extensively examined for their toxicity. This study serves to characterise common syringe filters and their effects on analytical results. The adsorbance of bisphenol A and similar compounds by filter media made from cellulose acetate, nylon, and polytetrafluoroethylene (PTFE) was examined using UV-Vis spectroscopy. Samples of Bis(4-hydroxydiphenyl)methane (BPF), Bis(4-hydroxyphenyl)sulfone (BPS), 2,2-Bis(3-methyl-4-hydroxyphenyl)propane (BPC), 4,4'-(propane-2,2-diyl)diphenol (BPA), 4-cumylphenol, and phenol were studied. Solutions were analysed before and after filtration. Filter composition significantly affected analyte concentrations in the filtrate solutions.

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### THE CHANGING NATURE OF DIESEL ENGINE FUEL FILTERS FOR HIGH PRESSURE COMMON RAIL (HPCR) DIESEL INJECTION SYSTEMS

B. Crook (pages 86-93)

Over recent years the world has gradually witnessed the introduction of diesel engines equipped with advanced High Pressure Common Rail (HPCR) fuel injection systems. The introduction of new designs is primarily the result of new emission regulations, which now requires these engines to improve their overall performance and reduce harmful pollutants with the culmination of requirements being 2015 when all new diesel engines shall be rated to Tier 4.

In order to reduce emissions, advanced HPCR injection systems operate at pressures in excess of 30,000 psi and in some designs, pressures approaching 40,000 psi can be achieved. These advanced systems are capable of multiple injection events per cycle and involve clearances between moving parts in the order of 1-4 µm. For these reasons, HPCR systems are far less tolerant to contamination than previous Electronic Unit Injector (EUI) designs. This increased demand on diesel fuel cleanliness presents new challenges to engine based contamination control solutions and the fuel filters that are intended to protect the injector and high pressure pump from damage or failure.

To protect HPCR components, much lower concentrations of fine particles and water need to be maintained within the fuel system than were previously accepted. This paper will discuss some of the challenges that are faced and provide recommendations to achieving the required reliability.

### EVALUATION OF THE FILTRATION PERFORMANCE OF A RAPID PROTOTYPED SINTERED FILTER ELEMENT

E. Dimla (pages 94-103)

Laser Sintering is a Rapid Prototyping (RP) technique used for the direct manufacture of solid objects layer by layer, with the aid of CAD models. In this investigation, a sintered bronze filter element was produced by the Direct Metal Laser Sintering (DMLS) process and its performance data obtained and compared to more conventional elements. The tests showed that the elements had a narrow pore size distribution, a high pressure drop and a low contaminant holding capacity compared to a random fibre element of a similar rating. The ISO 16889 multi-pass $\beta$ = 1000 rating was 12 µm which was maintained up to the maximum test differential pressure of 10 bar.

The element would be unsuitable for conventional filtration as its limited dirt holding capacity would mean a very short service life, but it could be suitable for Last Chance Filter applications or backwash and blowback applications. Further development would produce an optimum configuration.

### DEVELOPMENTS IN LARGE SCALE FILTRATION PLANTS

J. Palmer (pages 103-106)

Filtration is a well-known and effective method for dewatering slurries in the mining and mineral processing industries. Filters have principally been utilised for mineral concentrate dewatering where tonnages are moderate and the separation is targeted to producing cakes dry enough for

transport. Water as a resource is becoming scarce and there is legislative pressure to utilise desalinated water or increase the water consumption efficiency of mineral processing operations. The scale of operation has increased dramatically with the trend towards tailings dewatering, forcing equipment manufacturers to adapt and increasing the size of equipment to suit.

Tailings filtration, with a focus on water recovery and dry stack characteristics of the filter cake, has different requirements to product dewatering. Ore variability is significantly higher than the variability of products and plant reliability is essential for robust solutions in tails dewatering. Equipment scale changes have a large effect on the infrastructure required for operation and filtration plants are being developed to integrate the ancillary services required, and to facilitate safe and effective maintenance.

## STANDARDS FOR THE COMPRESSED AIR INDUSTRY

S.N. Smith (pages 107-114)

Standards for the compressed air industry are broadly divided into two categories, those for the measurement of compressed air purity specification and compressed air treatment equipment performance. The ISO 8573 series of standards for compressed air purity measurement contains 9 parts of which Part 1 enables manufacturers and end users to specify compressed air purity. Compressed air treatment equipment can be validated against ISO 7183 for air drying technology or to ISO12500 Parts 1 through 4 for the removal of oil aerosol, oil vapour, particles and bulk water, respectively.

Combined with the vocabulary standard, ISO 3857 Part 4 Vocabulary they number in total 15 published standards that have been in development since the mid 1980's under the management of ISO Technical Committee ISO/TC 118/SC4 'Compressed air treatment technology'. Over the last 18 months the working group has completed a full review of all standards in the series and set priorities for the changes required to meet environmental legislation and where appropriate to adopt new methods since they were first published. As a priority the working group has identified that significant changes are required to ISO8573-2:2007 'Test methods for oil aerosol content' due in no small part to recent EU regulations and the availability of suitable reagents to undertake the infrared (IR) analysis method detailed.

This paper discusses the changes that are being proposed and provides an overview of a timetable for their adoption.

## ASPECTS OF THE DESIGN AND USE OF SEDIMENTING CENTRIFUGES

C. Grimwood (pages 114-120)

The effects of bowl geometry on the liquor clarification and solids dewatering characteristics of solid bowl decanting centrifuges are discussed. The requirements for centrate clarity and throughput are contrasted with those required for dry decanter cakes and high solids capacity on the assumption that the solids in the decanter feed are crystalline and incompressible. The aim of this paper is to provide a basic understanding of some of the compromises necessary in the selection of decanter centrifuges.

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### A REVIEW OF SOME DEVELOPMENTS IN FILTER MEDIA

R. Lydon (pages 146-152)

It is often said that at the heart of any filter is the filter medium. It determines whether a filter process will perform adequately to give the desired separation efficiency. One of the key roles of a filter medium is to create a clear separation of particulate from a liquid or gas with the minimum consumption of energy.

Technical textile filter fabrics remain one of the most popular groups of filter media and are an essential part of countless industrial processes, contributing to product purity, savings in energy/production costs and a cleaner environment. For many years the basic structures used have remained unchanged with minor incremental improvement in fabric construction. In the past few years the development of new and improved technology combined with new measuring techniques has resulted in new filter media constructions.

This paper describes some of the recent trends and improvements in filter media and how these factors are affecting application performance.

### RESEARCH AND DEVELOPMENT ACTIVITY ON FILTRATION AND SEPARATION IN JAPAN – MILESTONES AND STATE OF THE ART

E. Iritani (pages 153-161)

Up to now Japanese researchers have been making important contributions to the developments of solid-liquid separation engineering. Modern cake filtration theory, which can elucidate the internal flow mechanism in compressible filter cakes, was developed by Shirato, together with Tiller. Several ingenious testing methods have been presented for easily obtaining compression-permeability characteristics. Properties of compressible filter cake are considered to be one of the critical factors influencing the fouling behaviour in membrane separation such as microfiltration and ultrafiltration. In clarifying filtration, Iwasaki laid the basis for deep bed filtration theory, and Shirato et al. established the generalised blocking filtration law that is also applicable to non-Newtonian, fluid-solid, mixtures. The Terzaghi-Voigt combined model which considers the creep effect of secondary consolidation, proposed by Shirato *et al.*, served as a basis for evaluating consolidation behaviour during the expression of compressible materials. Also in industry, many important contributions have been made, including the production of various kinds of membranes, submerged membrane bioreactor, fully automatic filter press, expression type filter press, and so on.

### FILTRATION AND DEWATERING IN WASTEWATER TREATMENT

M.L. Christensen (pages 162-165)

Wastewater contains organic materials, nitrogen and phosphorus that are usually removed biologically, after which solids material is separated from the liquid in a clarifier or by a membrane. A by-product from biological treatment is excess sludge which has to be dewatered by using, for example, belt filters or sludge mineralization beds. Sludge is difficult to filter and the filtration rate does not increase with pressure due to high cake compressibility. However, a large variation is observed between different wastewater treatment plants.

In the work presented here the best dewaterability is observed for sludge that contains large strong compact flocs, without single cells and dissolved extracellular polymeric substances. Calcium ions improve floc strength and dewaterability, whereas sodium ions, for example from road salt, seawater intrusion and related industries, reduce dewaterability because the flocs tend to disintegrate at high conductivity. Storage lowers dewaterability, especially when storage takes place under anaerobic conditions. High shear has a tendency to destroy the flocs and reduce dewaterability. Thus, pumping and mixing should be done gently and in pipes without sharp bends.

## THE IMPORTANCE OF PARTICLE SHAPE IN DETERMINING THE MEASUREMENT UNCERTAINTIES IN THE MAXIMUM PORE SIZES OF SAND SCREENS

K. Brocklehurst, A. Hassall, G. Rideal and A. Stewart (pages 166-174)

Unlike plain square meshes such as test sieves that can be measured directly by microscopy, the complex 3-dimensional structures of sand screens means that they are opaque to image analysis. Challenge Testing with glass beads has been used for many years but there has been some uncertainty in the results, especially when measuring maximum pore size because the penetrating beads are not always spherical.

The work presented in this paper took a 180 µm (micron) test sieve as a baseline and measured the cut point by three different methods: direct measurement by microscopy, a gravimetric Sonic Challenge Test and measuring the penetration of precision glass microspheres. Provided that non-spherical particles were removed from the analysis, excellent agreement was seen between the methods with uncertainties of less than +/-5 µm. When challenge testing a 175 µm sand screen, a cut point (D97) uncertainty as low as +/-3 µm was found. However, when looking for the Maximum Penetrating Spherical particle (D100), an uncertainty of +/-50 µm was seen making this parameter statistically unsound. The uncertainty increased to +/-68 µm if particle length rather than the Geometric Pore Size was used in the calculation.

## NON-STOCHASTIC LATTICE STRUCTURES FOR NOVEL FILTER APPLICATIONS FABRICATED VIA ADDITIVE MANUFACTURING

H. Hasib, A. Rennie, N. Burns and L. Geekie (pages 174-180)

Non-stochastic lattice structures are widely used in a variety of applications such as biomedical implants and heat exchangers. However, the utilisation of these structures for filtration applications is rather new. Additive manufacturing techniques such as selective laser melting allow lattice structures to be bespoke depending on the type of filter and its intended function. This study considers the flow characteristics and structural strength of a disc filter with a layer of repeated 1.8 mm lattice unit cell as the filter mesh. Computational fluid dynamics simulation is used to analyse the pressure and flow velocity across the filter, while finite element analysis (FEA) is used to analyse the structural characteristics of the lattice mesh under fluid load.

The results show a minimal decrease in pressure and small increases in velocity, with the mesh capable of withstanding higher loads. The ultimate failure load of the structure is also determined. These findings indicate that more layers of lattice structures could be used as filter mesh and the flexibility of AM allows the filter properties to be tailored as required for a given application.

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### THE FILTRATION OF HIGH TEMPERATURE, HIGH PRESSURE SYNGAS FROM GASIFICATION

A. Bevis (pages 202-212)

The filtration of high temperature and high pressure syngas, derived from the gasification of coal or petroleum coke, can be performed with metallic filter elements. This is a demanding filtration duty owing to the nature of the corrosive gas composition, which is significantly accelerated by the chemistry of the char contaminant retained by the filter media. There are additional demands on the system due to the quantity of char present, which can be measured in excess of 10% by mass of the gas throughput, therefore challenging the individual filter system with loads as high as 10,000 kg/hr. The filter elements are pulse-jet cleaned in-situ with previously filtered and modified (recycled) syngas, at pressures in excess of 100 bar. This presents another design and operational challenge which needs to be correctly controlled and delivered.

The paper seeks to provide an overview of the presence of filtration in gasification when specifically applied in the high temperature part of the process and where the operation is generally at a high pressure.

### A NEW TEST SYSTEM FOR THE IN-LINE MONITORING OF AUTOCLAVE EXHAUST TREATMENT: A STUDY OF UNCERTAINTY

C. Grumbach and P. Czermak (pages 213-222)

The development of test systems to monitor the filtration of exhaust gases from laboratory autoclaves is driven by emerging laboratory safety regulations. The water intrusion test is suitable for this purpose, and therefore the test was adapted to account for the risks inherent in the filter systems used for the treatment of exhaust gas. To validate the test principle, the uncertainty of calibration and measurement was investigated using two commercial test gauges (Palltronic® Flowstar XC, Sartocheck 4). The calibration data revealed a good fit ($R^2 = 0.988$) over a measurement range of 0.0-3.0 mg/mL, confirming the stability of the test system. The uncertainty of the new test system corresponds to other measurement gauges in a range of ± 0.01 (for low flow rates) to ± 0.05 (for high flow rates). These data highlight the potential of our device for the development of reliable test systems for small plants, with adjusted costs for design, integration and qualification.

### CHALLENGE TESTING – CURRENT TECHNOLOGIES AND FUTURE PROSPECTS

K. Brocklehurst, A. Hassall, G. Rideal and A. Stewart (pages 222-226)

Unlike test sieves, which have plain weaves and can be measured optically, complex 3D weaves of twilled construction do not allow light to pass and so cannot be measured optically. The apertures then have to be estimated by air flow rate studies (Porometry) or challenged by a wide distribution of particles such that those passing are measured to determine the cut point of the filter (Challenge Test). Historically, various sands such as Arizona test dusts have been used, but their irregular shapes mean that it is difficult to obtain an unambiguous measurement of aperture size. Using glass microspheres has partially solved the problem, but a small percentage of misshapes in the product can seriously overestimate the aperture size when the particle is expressed as the equivalent spherical diameter.

When an Image Analyser is used for particle measurement, it is now possible to electronically filter non-spherical particles from the size/shape distribution and thus provide much more accurate measurements of the aperture sizes. The method has been validated using plain weaves down to 20 µm, where optical measurements have been used to confirm the data, and then extended to complex twilled meshes down to 5 µm. At this size there are no other methods available to obtain unambiguous, NIST traceable results.

## METAL FILTER CLOTH AND NEW DEVELOPMENTS IN HIGH PERFORMANCE WOVEN WIRE MEDIA

Haver & Boecker, Germany (pages 227-230)

This technical note describes some recent developments in MINIMESH® metal filter media and the manner in which testing can be used to validate their performance.

## THE APPLICATION OF AEROSOL SPECTROMETERS IN FILTER TESTING STANDARDS

S.N. Smith (pages 230-240)

This paper discusses the use of aerosol spectrometers over traditional aerosol photometers when applied to filter testing in ISO 12500-1:2007 'Filters for compressed air - Test methods - Part 1: Oil aerosols'. It highlights the limitations of making measurements with traditional photometers in such an application and the importance of using the correct substance properties for refractive index and density to enable the accurate computation of the resulting mass concentration in the sampled air stream. Example test data obtained from isobaric sampling upstream and downstream of a coalescing filter is also given to provide an insight into temporal changes to coalescing filter performance due to oil saturation over time. Thus, having the ability to ascertain changes in filter performance over time provides the researcher with the potential to better understand what impact design changes or operating conditions might have on coalescing filter performance.