The Most Advanced, Automatic,
Non-Disposable Liquid Filtration System

ZERO GRAVITY FILTERS

ADVANCES IN SELF-CLEANING FILTRATION USING VARIABLE GEOMETRY COIL TECHNOLOGY

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SUMMARY

The outbreaks of water related disease in the building services sector have spurred the development of many alternative technologies in the field of biocidal control in circulating water systems. In addition, concern of chemical handling and its environmental impact have further encouraged these developments.

New systems range from the more well known such as UV irradiation and halogenation, to more recent approaches including Ozone, Pasteurisation, and Precious Metal Ion Deposition. All these systems however have one common link; their performance can be seriously impaired when operating in water which is contaminated by undissolved solid matter.

Solid matter, both organic and inorganic has a number of deleterious effects. Mechanically, it reduces efficiency, increases corrosion and erosion, and increases maintenance. Chemically, it forms a nutrient layer which can encourage the proliferation of micro-organisms, which by increasing turbidity, seriously impairs the effectiveness of biocide regimes.

This paper examines the effect of turbidity and contamination on these new technologies, and moves on to discuss modern automatic filtration techniques for use in the building services and process sectors. The case is developed for an automatic self-cleaning filter to become as common an element in building services design as the boiler or refrigeration plant.

State of the art filtration techniques can convert an unhealthy and potentially lethal system into a clean efficient working fluid, within which new technologies can have a profound beneficial effect. It is necessary however to take this first crucial step towards good water housekeeping practice.

MECHANISMS OF WATER SIDE FOULING

Fouling in water systems takes place by one or more of the following methods:

Precipitation Fouling

The crystallisation of dissolved species from solution onto the heat exchange surface. In industry, the term most generally encountered to describe this process is 'scaling'. The most common causes of concern in building services are those dissolved species which tend to precipitate onto a heated rather than cooled surface. These are said to have an inverse solubility versus temperature behaviour and include ($CaSO_4$), ($CaCO_3$), ($Mg(OH)_2$), ($LiSO_4$), and ($LiCO_3$) and are to be found in most cooling tower waters.

Particulate Fouling

This can be defined as the accumulation of particles suspended in the liquid stream onto heat transfer surfaces. In a few cases, this deposition occurs by gravity in which case the process is called sedimentation. Suspended solids include sand, micro-organisms, insects, spores, leaves etc; and corrosion products such as iron oxides formed elsewhere in the system.

Chemical Reaction Fouling

This is the formation of solids as a result of chemical reactions within the working fluid. This kind of fouling is common within the petrochemical and food processing industries, but less common in building services where choice of materials, and water as the main constituent, restrict this type of chemical reaction.

Corrosion Fouling

In this case, the heat exchange surface itself reacts with the fluid to form corrosion products on the heat exchange surface. This is referred to as in-situ corrosion.

Solidification Fouling

As the name implies, this is fouling caused by the solidification, usually by temperature drop, of some constituent in the working fluid. Examples include ice-formation on water cooling processes and paraffin waxes in certain petrochemical applications.

Biological fouling

Biological fouling refers to the development and deposition of organic films or sludges consisting of micro-organisms and their products. This process is often temperature dependant and this is a constant concern in the treatment of water cooling applications.

THE COST OF FOULING

The cost of fouling on a system has many components, including:

- The additional cost to over-size plant and equipment due to planned efficiency shortfalls.
- Increased maintenance costs and lost production due to blocked nozzles, tube bundles, coils, and pressure tappings.
- Increased energy consumption due to efficiency shortfalls.
- Sludge build-up becomes a breeding ground for bacteria while increasing biocidal demand.
- Fouled heat exchange surfaces can lose up to 50% efficiency.
- Cleaning equipment and services.
- Speciality materials and geometric configurations.

It is estimated that the cost of fouling on the US industrial sector is over $12 billion per annum.[1]

THE EFFECT OF SOLID MATTER ON BIOCIDAL TECHNIQUES

Generally, biocidal techniques in water circuits fall into the following four categories:

a) Oxidisation
b) Thermal treatment
c) Irradiation
d) Ion deposition

The efficiency of each ultimately depends on the quality of the circulating water. The build-up of both organic and inorganic matter will hinder the biocidal activity of any of these systems.

Oxidisation Techniques

These include the conventional oxidising biocides such as Chlorine, Bromine and Ozone. The chemistry in each case is slightly different but the general requirement is to kill the 'bugs' in the water.

Unfortunately, inorganic material in water systems is relatively easily broken down and consumes the oxidising potential of the disinfectant. As a result, the undesirable matter present in dirty water streams is often oxidised first, increasing chlorine demand, and requiring dosing levels to be much higher to achieve the desired result. This can incur significant cost penalties together with the risk of exacerbated corrosion which can lead to further fouling. In extreme cases with color in excess of 70 (measured in Hazen units), the effect of oxidising biocides is virtually neutralised.

Thermal Treatments

These methods, often referred to as Pasteurisation, were originally employed in the wine industry and later adopted almost universally in milk and other food based sectors. Simply put, a proportion of the water stream is taken off and heated to around 194ºF (90°c) which destroys the vast majority of biological contamination in the circuit. The objective therefore is to systematically pasteurise the entire system by dilution. The likelihood of re-infection is greatly increased when undissolved solids are present in the system. In addition, a heat exchanger is usually employed to raise and lower the temperatures, and there is a risk of fouling the narrow water channels if water cleanliness is not maintained.

Irradiation Techniques

Excellent results have been achieved with this method on municipal drinking water, brewing, and food processing applications. The effect of ultra-violet light irradiation is to destroy the DNA of the microbial cell. To achieve this, a given intensity of radiation must be achieved through the water stream. The effective penetration depth is seriously impaired in dirty water systems. For example, a UV plant operating on clean water and achieving 100% transmission may effectively accommodate a flow rate of 2,100 gpm.

A direct correlation between water cleanliness and transmission rates states that as the water cleanliness of a system falls, there is a corresponding decrease in the transmission rate. To continue the example, if the transmission rate were to decrease from 100% to 90%, the handling capacity of the same plant would decrease by 48% to 1,082 gpm. If the transmission rate were to decrease to 50%, the flow rate would drop by 92% to 176 gpm.

The following table highlights the standard of water quality recommended for the treatment of rural supplies:

VARIABLE	CONTROL LIMITS
Turbidity	not to exceed 5 NTUs
Suspended solids	not to exceed 10 mg/l
Iron	not to exceed 0.3 mg/l
Manganese	not to exceed 0.05 mg/l
Hydrogen Sulphide	none
Colour visibility	clear
pH range	6.5 to 9.5

The aforementioned operating conditions are rarely encountered in unfiltered water systems.

Ion Deposition Techniques

The process of disinfecting a water supply by the addition of silver and copper ions is an old technology with renewed applications. Although the latest hardware and software are state of the art, the disinfection properties of these metals have been known for centuries. The ions of these metals can, in correct concentrations, disrupt the enzyme reaction of the cell and cause very effective kills. However, the effect in contaminated water circuits is that the ions will attach to the inorganic material present and their effect on the target is impaired.

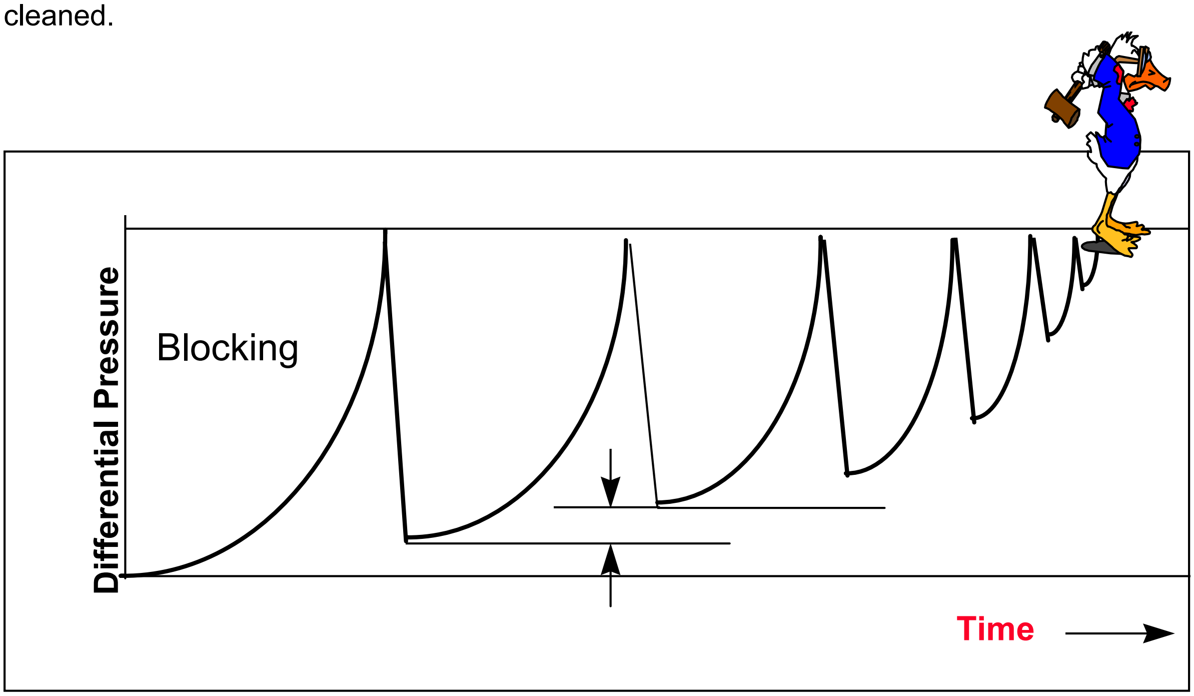
REVIEW OF EXISTING PARTICULATE FILTRATION TECHNIQUES

Many engineers with experience of water filtration carry memories of constantly blocked screens, flow starvation, and significant time and money to manually clean the filter. However, these same engineers will agree that filtration of the water is an important step in maintaining the biocidal efficiency of their systems. A filter commonly installed in the building services sector includes those of a wedge wire type design or ‘fixed screen’.

Fixed screen elements tend to become blocked very easily due to contaminants becoming ‘locked’ in the filtration gaps, particularly in cooling tower systems where scale forming particles may be present. Large quantities of backwash water are required to dislodge the debris during the cleaning process. However, over time, incomplete cleaning leads to an unacceptable pressure drop. The elements then require manual cleaning, which is not only inconvenient but extremely costly.

Systems that have tried to destabilize these particles through the use of suction, scrapping, and/or high pressure have proved ineffective at maintaining a continuously clean screen. Although the cleaning efficiency is sometimes improved, the equipment is either too complicated or requires too much maintenance.

The following chart illustrates this point by plotting differential pressure against time. As shown, over time a filter’s differential pressure will increase as debris accumulates on the filter. At some predetermined set-point, a filter will initiate a backwash. However, because particles become wedged in a ‘fixed screen’ design, the filter does not return to its clean differential pressure. This gap highlights the filter’s inability to clean itself, and is indicated by the two arrows. As this process continues, eventually the system must be taken off-line and manually cleaned.

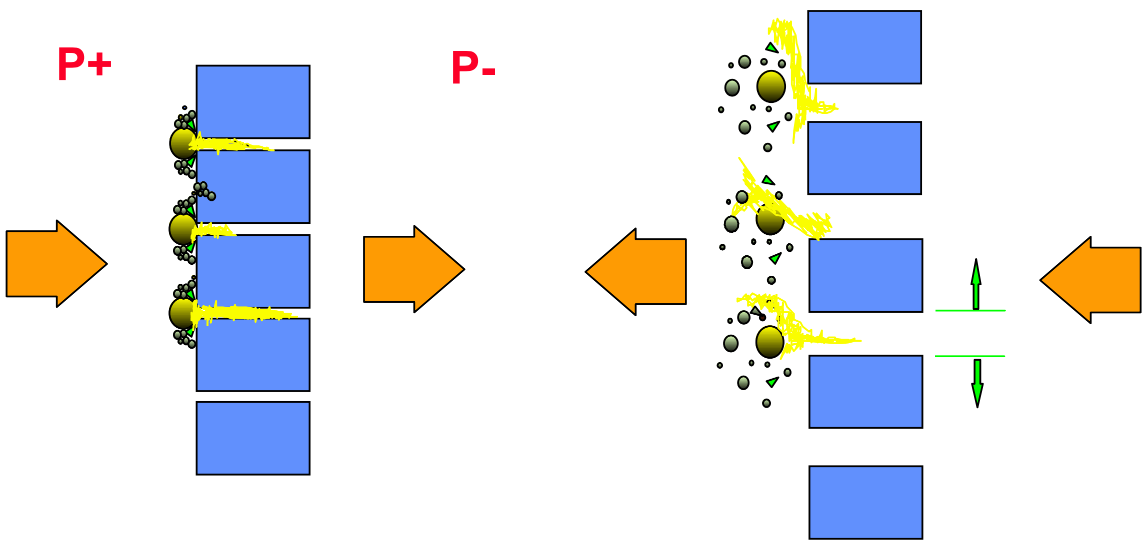


INTRODUCTION TO VARIABLE GEOMETRY FILTRATION

Research on a new element design began due to the inability of conventional filters to sufficiently clean themselves. This research has led to a breakthrough in coil spring manufacturing. Through a highly technical and patented process, a wire is wound on a mandrel with a variable pitch that allows the coil to open evenly during backwash.

This opening allows any 'lodged' or 'wedged' particles to be easily removed in that the gap which has trapped the particles has now been increased. In addition, while open, liquid flowing in a reverse direction will cause the turns of the coil to shimmer, which further enhances the backwash process. This can be achieved with very low inlet pressures and with a fraction of the water loss compared to the old fixed element design.

Variable Geometric Filter



Filtering Backwashing

Unlike conventional 'fixed screen' designs, the variable geometric filter will return to a clean differential pressure after each and every backwash. Due to its cleaning efficiency, this type of design lends itself very well to automatic controls. Complete filtration systems incorporating the variable geometric coil are designed to operate 24 hours per day, seven days per week without manual intervention. Further, the modern automatic self-cleaning filter has computer control and logging facilities and can be readily connected to the now ubiquitous Building Management System.

The coil's ability to open during backwash significantly reduces both the time and water required for backwash. For example, in a recent comparison, a 'fixed screen' element required a backwash flow rate of 555 gpm for 20 seconds or a total of 11,100 gallons for the entire backwash. The comparable variable geometric element cleaned itself back to its original pressure drop with a flow rate of 190 gpm for 5 seconds or a total of 950 gallons for the entire backwash. The variable geometric filter reduced the backwash volume from 11,100 to 950 gallons, a decrease of 91%.

REVIEW OF RECENT APPLICATIONS

Cooling Tower Application

The results of an extensive trial conducted by Dr. Dennis at the Thames Water Laboratories[2] illustrates the benefits of using the variable geometric filter on a cooling tower. By using an automatic water filter fitted with 125 micron elements, total solids loading in a cooling tower application were reduced by 99.9% after two weeks of operation. In addition, particle counts in the 2 - 3 micron range were reduced from over 900,000 before the trial, to around 700 after two weeks, a decrease of 99.9%.

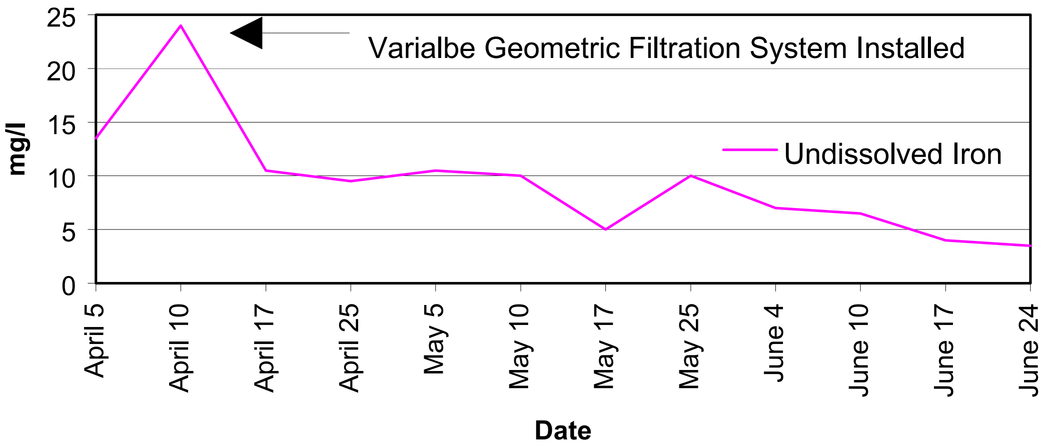
This is the effect of secondary 'bed' filtration taking place as the elements begin to blind. This effect can be highly detrimental to ‘fixed screen’ designs in that they are unable to recover from such ‘bedding’. However, due to its ability to open, the variable geometric filter overcomes this problem while enhancing the filtration efficiency. In the same trial, during which conventional biocide dosing was discontinued, microbiological plate counts were reduced by up to 50% purely due to the denial of the nutrient colonies.

Table: Summary of Results

	Pre Filtration			After 100 h Filtration			After 2 weeks Filtration		
	Tower Pond	Pre Condenser	Post Condenser	Tower Pond	Pre Condenser	Post Condenser	Tower Pond	Pre Condenser	Post Condenser
pH	8.8	8.8	8.8	8.8	8.8	8.9	8.6	8.6	8.7
Color (Hazen)	68	71	71	47	43	46	15	12	14
Micron range:									
2-10	23,872	16,084	1,936,800	-	-	-	4,522	1,660	4,522
10-25	5,690	1,625	34,000	-	-	-	840	140	840
25-120	249	88	1,080	-	-	-	45	24	45
Chloride (ppm)	1160	1100	1160	165	145	142	114	112	114
Colony Count at 22ºC for 72h (cfu/ml)	$2.2x10^6$	$9x10^5$	$1.8x10^6$	$4.2x10^5$	$4.5x10^5$	$4.5x10^5$	$3.5x10^5$	$3x10^5$	$3.5x10^5$
Colony Count at 37ºC for 48h (cfu/ml)	$2.8x10^6$	$1.6x10^6$	$1.3x10^6$	$8.1x10^5$	$1.1x10^6$	$9x10^5$	$4.5x10^5$	$5.1x10^5$	$4.6x10^5$

Chilled Water Application - Full Flow

The chilled water loop serving the European Channel Tunnel was experiencing significant pipe corrosion. To ensure the life expectancy of the pipework, it was agreed that the amount of suspended solids within the closed loop had to be reduced below 5 ppm. Further, the specification was strict with regard to backwash volume in that all makeup to the system was softened water. The variable geometric filter was chosen for the project due to its filtration efficiency as well as providing the lowest backwash volume of any filter considered. The following chart highlights the filter’s efficiency[3].



Chilled Water Application - Side Stream

Side stream filtration works by taking a percentage of the flow from the main system pipe, through a pump and filter, and then back into the system. The problem with this approach is that a majority of the larger particles will pass the side stream loop due to the system's velocity and the momentum of the particles. The combination of the variable geometric filter with a Forced Sedimentation Filtration System (FSFS) overcomes this problem.

The FSFS system is designed to lower the velocity of the particles by delivering a percentage of the flow into a large sedimentation vessel. As flow enters the vessel, the momentum of the particles is reduced and a high percentage of the particles will settle to the bottom of the vessel. From the bottom of the vessel, where the concentration of debris is the highest, water is automatically pumped through a variable geometric filter.

CONCLUSIONS

The presence of water borne contamination has a highly deleterious effect on the accepted methods of bio-control in water systems. On the other hand, modern high efficiency automatic self-cleaning water filtration can produce an efficient stream of clean water while enabling the various biocidal techniques to operate at their most efficient level.

Such equipment is now operating in a wide range of applications including cooling towers; heating and cooling; process; bulk water supply; reservoir and river systems. The modern automatic water filter has become as important to the maintenance engineer as the boiler, chiller or air handling unit, and should be seen as the Crucial First Step in the process of building water quality.

REFERENCES

[1] Bureau of Census, 1981, Annual Survey of Manufacturers - Value of Product Shipments, US Department of Commerce.

[2] Dennis, Dr. P.J.L., 1990, "High Efficiency Filtration", Building Services, pp. 67-68.

[3] Data kindly provided by TransManche-Link (Channel Tunnel), 1996.