AFM®

ACTIVATED FILTER MEDIA

Instructions for Use

Water Treatment

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Dryden Aqua Ltd. Bonnyrigg, Scotland

Dryden Aqua Distribution AG Büsserach, Switzerland

Dryden Aqua is one of the largest manufacturers of glass filtration media, operating two sophisticated & fully automated glass processing facilities.

OUR PRODUCT - ACTIVATED FILTER MEDIA - AFM®

Activated Filter Media - AFM® is a soda-lime-silica glass based filtration media. AFM® is verified to at least double the performance of sand filters without the need for additional investments in infrastructure. AFM® is used in industrial and municipal water and waste water treatment for single or dual media filtration in Rapid Gravity Filter (RGF), Pressure Filters and continuous backwash filters (such as Dynasand style).

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1. AFM® Introduction

Research & Development

AFM® (Activated Filter Media) is the product of more than 40 years of research and development by Dr. Howard Dryden and the company Dryden Aqua. AFM® was developed to address the inherent performance limitations of conventional filter media, including quartz sand.

AFM® can be used in any type of media filter application, including drinking water treatment.

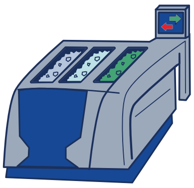
AFM® improves performance, reduce risk, and stabilizes systems by providing predictable repeatable and sustainable results.

AFM® is a high-performance filtration media engineered from green and brown soda-lime-silica glass. It is processed to achieve optimal particle size, shape, and distribution. Critical parameters such as particle size distribution, sphericity, and uniformity coefficient are tightly controlled to ensure consistent product quality as well as consistent filtration and backwash performance across applications.

Manufacturing process

We optimise every part of the process to make the best material available, with consistent shape, size and surface properties.

1



CAREFULLY SELECTED

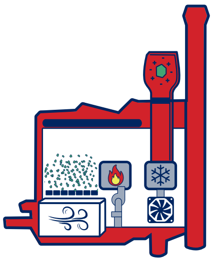
We use green and brown soda-lime-silica glass in the manufacturing of AFM® to provide for the bio-resistant and superior filtration properties.

2

OPTIMUM SIZE & SHAPE

AFM® is highly engineered to obtain a precise consistent particle size and shape. The sphericity and uniformity coefficient are crucial for the outstanding hydraulic properties of AFM®.

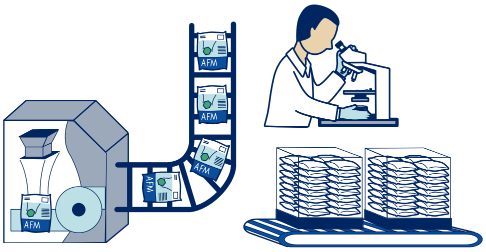
3



UNIQUE ACTIVATION PROCESS

AFM® undergoes a surface activation process that increases the specific surface area, imparts resistance to biofouling, and provides superior filtration properties.

4



PACKAGING & QUALITY CONTROL

Dryden Aqua's fully automated AFM® packaging system delivers 25 pallets per hour. An integrated quality control and management system guarantees a consistently high quality product.

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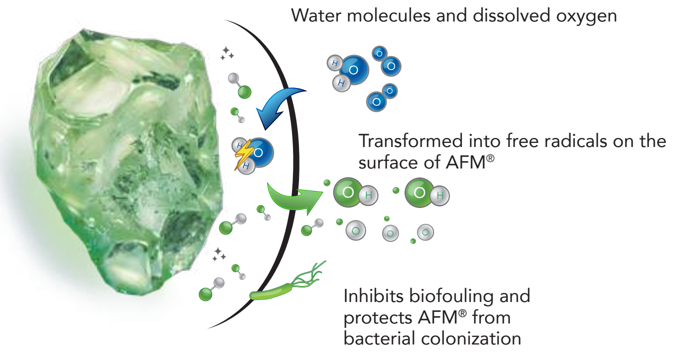
2. AFM® Properties and Specification

AFM® Type & Surface Properties

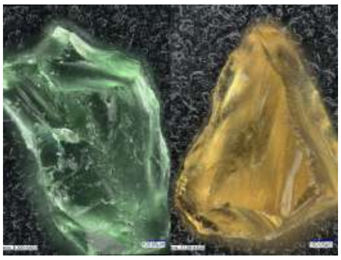
1 ▸ Biofouling-resistant surface



- ✓ Does not support bacterial growth, eliminates clumping, channeling and passage of unfiltered water.
- ✓ Reduces backwash water up to 50% providing a quick ROI, usually within 2 years.
- ✓ Improves and provides predictable, repeatable and consistent nominal filtration performance up-to 98% and a life cycle >10 years.

2 ▸ Increased surface area

AFM® Grade 1 = 50.000m^2 / 1'000kg*
Sand 0.4 - 0.8mm = 3.000m^2 / 1'000kg*
* Surface Area by Langmuir Isotherm Method

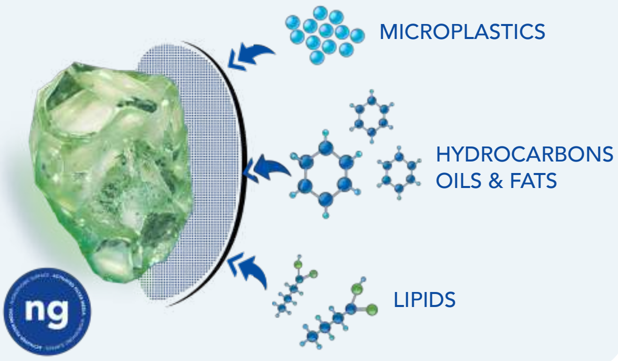


- ✓ High surface area with superior mechanical filtration properties for adsorption of fine particles.
- ✓ Precise, consistent particle size distribution, shape, sphericity and uniformity coefficient for outstanding hydraulic properties.
- ✓ High surface area amplifies catalytic reaction, generating free radicals to avoid biofouling on media surface.

3 ▸ AFM®ng and AFM®s Advanced filtration properties

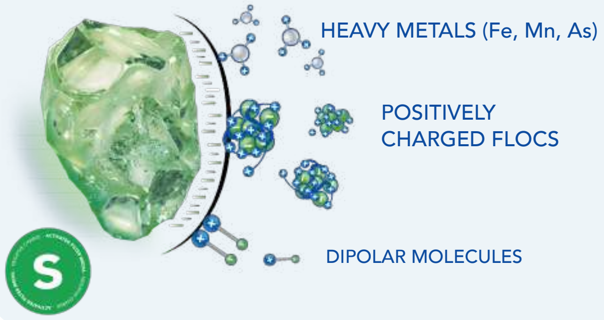
AFM®ng: HYDROPHOBIC SURFACE

- Hydrophobic & non-polar
- Biofouling-resistant
- Filters **95%** of all particles **>1µm**
- Best for **organics removal**
- Adsorbs oil & **hydrocarbons, microplastics**
- Efficient filtration in hard and soft water
- Not suitable for use with backwash air scouring



AFM®s: NEGATIVE SURFACE CHARGE

- Hydrophilic & polar
- Biofouling-resistant
- Filters **95%** of all particles **>4µm**
- Best for **heavy metals removal**
- Adsorps **cationic flocs and di-polar molecules**
- Efficient removal of oil in O&G applications
- Suitable for use with backwash air scouring



Note: These are general guidelines only. Every system and water source is unique. For a tailored recommendation, please contact Dryden Aqua at info@drydenaqua.com.

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AFM® Grades & Specification

Grade	Type	Particle size	Function
0	AFM®s	0.25 - 0.5mm	Extra fine filtration
1	AFM®s/ng	0.4 - 0.8mm	High filtration performance
DIN	AFM®s/ng	0.7 - 1.2mm	High suspended solid load / high flow filtration
2	AFM®s/ng	0.7 - 2.0mm	Support and filtration layer
3	AFM®s	2.0 - 4.0mm	Support layer

Specification	Grade 0	Grade 1	Grade DIN	Grade 2	Grade 3	Standard
Particle size	0.25 - 0.5mm	0.4 - 0.8mm	0.7-1.2mm	0.7 - 2.0mm	2.0 - 4.0mm	ISO 13322-2 EN 12902:2004
Undersized	≤ 5 %	≤ 5%	≤ 5%	≤ 10%	≤ 10%	ISO 13322-2 EN 12902:2004
Oversized	≤ 5 %	≤ 5%	≤ 5%	≤ 10%	≤ 10%	ISO 13322-2 EN 12902:2004
Effective size (expressed as d10)	0.25 - 0.29mm	0.40 - 0.43mm	0.72 - 0.82mm	0.80 - 1.0mm	2.0 - 2.4mm	ISO 13322-2 EN 12902:2004
Hardness	5.5 - 6.5mohs					ASTM C-730
Sphericity (average range)	-	0.79 ± 0.03	0.81 ± 0.03	0.80 ± 0.03	0.81 ± 0.03	ISO 13322-2 EN 12902:2004
Uniformity coefficient (d60/d10)	1.3 - 1.8					ISO 13322-2 EN 12902:2004
Roundness	-	0.65 ± 0.05				ISO 13322-2 EN 12902:2004
Specific gravity (grain) (2)	2.4 - 2.52kg/l					GTS QP9
Bulk bed density uncompacted	1.24kg/l ±0.03	1.33kg/l ± 0.03	1.36kg/l ±0.03	1.40kg/l ± 0.03	1.43kg/l ±0.03	EN 12902:2004
Acid Solubility	<0.2%					EN 12902:2004
Loss on ignition (LOI)	<0.03%					EN 17978:2024

Notes
(1) Specifications are measured and certified at point and time of manufacture
(2) Glass Technology Services, Sheffield, UK procedure QP9 - 'X-ray fluorescence analysis - predictive density measurement'
(3) Porosity - calculated using average bulk density and average particle density

Dryden Aqua Quality & Certification

- AFM® complies with **EN17978**, glass granulates, for **treatment of water for human consumption**
- AFM® complies with the **Directive (EU) 2020/2184** on the quality of **water intended for human consumption**
- AFM® is **approved in UK** under regulation 31 of the **Water Supply (Water Quality)** regulations 2016 (as amended)
- AFM® is **certified** by WQA to **NSF/ANSI/CAN 50** Equipment and Chemicals for Swimming Pools, Spas, Hot Tubs and Other Recreational Water Facilities.
- AFM® is **certified** by WQA to **NSF/ANSI/CAN 61 & 372 Drinking Water Systems Components**
- AFM® is **approved in Switzerland** according to **drinking water** ordinace (TBDV) Annex 4, paragraph 4
- AFM® is produced under **certified HACCP** principles for **use in food and beverage production**
- AFM® is approved by the **polish national institute of public health (NIH)** for the use in drinking water & public pools treatment
- AFM® (as GreenFil™) is approved by the **Public Health Institute of the Czech republic** for the use in drinking water applications
- Dryden Aqua is certified to integrated management control systems **ISO-9001, ISO-14001, ISO-45001**

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AFM® Chemical composition

Chemical composition of all AFM® types and grades

Composition (oxides)	Percentage +/- 10%	Composition (oxides)	Percentage +/- 10%
Silica	72	Calcium	11
Magnesium	2	Lanthanum	1
Sodium	13	Cobalt	0.016
Aluminium	1.5	Lead	<0.005
Antinomy	<0.001	Mercury	<0.0005
Arsenic	<0.0001	Titanium	<0.1
Barium	0.02	Rubidium	<0.05
Cadmium	<0.0001	Iridium	<0.05
Chromium	0.15	Platinum	<0.0001
Ferric	0.15	Manganese	0.1

Chemical tolerance

Oxidizing agents

AFM® may be exposed to high concentration of oxidizing agents:

Free Chlorine	10 g/l
Chlorine dioxide	10 g/l
Ozone	10 mg/l
Hydrogen peroxide	10 g/l

pH Resistance

AFM® is stable over a wide range of pH conditions, but strong acids and caustic conditions should be avoided:

pH range	pH4 to pH10

Salinity & TDS

Salinity and high TDS concentrations have no phyiscal or chemical effect on AFM®.

Temperature

AFM® is not affected by temperature, as long as the water is liquid then AFM® may be used.

Temperature range	0 to 100°C

Chemical resistance

AFM® is chemically resistant to solvents and hydrocarbons.

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3. AFM® packaging, delivery, storage and disposal

AFM® is packaged in fully automated Dryden Aqua manufacturing facilities, in sealed 25kg bag's or big-bag's (Flexible Intermediate Bulk Container - FIBC) labeled with product identification and tracking information.

Packaging & Delivery

AFM® is supplied in bags of the following size:

- 1000kg & 1250kg big-bag with bottom discharge on one 1200 x 1000mm pallet
- 25kg bag with 40 bags (1000kg) on one pallet 1200 x 1000mm
- AFM® in 25kg bags is delivered in full truck loads of 24 pallets and in 20ft container loads of 20 pallets
- AFM® in 1000kg or 1250kg big bags is delivered in full truck loads of 24 pallets and in 40ft container loads of 20 pallets

Bags & Labelling

Each AFM® bag and big bag is printed during packaging with the following information:

1. Batch number
2. Size grade
3. Production date
4. Product code
5. Barcode

AFM® Product codes

Package quantity **Pallet quantity**		**25kg bag** **40 on CP-1**	**1’000kg bulk bag** **CP-1**	**1’250kg bulk bag** **CP-1**
AFM®ng Grade 1	0.4 – 0.8mm	10005	10015	10115
AFM®ng DIN Grade	0.7 – 1.2mm	10007	10017	10117
AFM®ng Grade 2	0.7 – 2.0mm	10006	10016	10116
AFM®s Grade 0	0.25 – 0.5mm	10000	10010	10110
AFM®s Grade 1	0.4 – 0.8mm	10001	10011	10111
AFM®s DIN Grade	0.7 – 1.2mm	10004	10014	10114
AFM®s Grade 2	0.7 – 2.0mm	10002	10012	10112
AFM®s Grade 3	2.0 – 4.0mm	10003	10013	10113

Precautions for safe handling

The appropriate precautions, as detailed in the SDS data sheet for AFM®, must be observed.

Conditions for safe storage

Store in a dry place. AFM® may be stored outside. If stored outside it should be protected from the elements by covering with a tarp. Sunlight will not affect AFM®, however the polythene bags may suffer UV damage and the plastic will degrade. Avoid storage outside for long periods of time unless protected from UV radiation.

End of life disposal

AFM® typically lasts for the lifetime of the filtration system and has a guaranteed minimum lifespan of 10 years. At the end of its life, AFM® may be sent to an approved solid waste treatment facility for reuse in purpose fit applications or disposal (landfill). However, as a circular economy product, AFM® should ideally not be sent to landfill.

4. AFM® Filter loading, commissioning and decommissioning

AFM® filter bed depth and type of filter

The depth of the filter bed is a function of the filter design and typically ranges from approx. 500mm to 1500mm. See next page chapter 5 for "AFM® Filter media layering".

We recommend the use of filters from reputable manufacturers providing dedicated media loading instructions for achieving the best AFM® filtration and backwash performance. AFM® may be used in pressure, gravity or continuous backwash filters.

Transferring AFM® to the filter

AFM® contains no “free silica” dust, however when loaded into a filter some dust may be generated. From a Health & Safety standpoint, handling of AFM® is considered safe. Consult the AFM® safety data sheet for detailed product and handling information.

AFM® may be transferred into the filter by either using a dedicated filter media loading device, manually emptying the 25kg bags directly into the filter or using a crane for the 1000kg or 1250kg big bags in accordance with the filter manufacturer’s filling instructions, and by considering below AFM® filling and commissioning procedure.

When loading AFM® through a hose connection (e.g. using a liquid solids ejector), preferably only pressurized water is used to transfer AFM® from a silo truck, big bag, bag or other holding tank into the filter. Alternatively, water combined with compressed air may be used to transfer the AFM®. Do not use compressed air alone as it will cause attrition of the AFM®.

AFM® Filling and Commissioning

1. Half-fill the filter with water to prevent damage from falling media to the laterals, nozzles, distribution plate or otherwise underdrain system. This also helps for a uniform distribution of the AFM® in the filter and less manual intervention for levelling of the media. Ensure that a sufficient water layer is maintained above the media throughout the loading process.

2. The coarser support grades (AFM® Grade 3 and/or Grade 2) are added first, followed by the filtration grade (AFM® Grade 1, DIN and/or Grade 0). For filters with laterals, we recommend covering the laterals with AFM® Grade 3 to allow for a uniform water distribution and collection during filtration, but especially important for a uniform backwash across the full media surface. After the loading of each AFM® layer, make sure the AFM® is evenly distributed and the bed is flat before loading the next media layer.

3. Once all AFM® layers are loaded (*), perform a water only backwash at the recommended backwash flow rate for 5-10min (see chapter 7. Backwash Procedue and Table 5, Page 19). **For AFM®ng follow below notes(*)** before proceeding with the first backwash!

4. We recommend skimming off approximately 5cm of the top layer to remove fines or any residual debris/dust created during transport and that may be present and could affect filtration performance.

5. After skimming, backwash until the water is clear in the outlet of the filter.

6. Start filtration and rinse to drain until the filtrate meets the required quality standard. Confirm water quality compliance before passing it to downstream processes or distribution.

(*) Notes

AFM®ng, due to its hydrophobic surface must be fully submerged in water and soaked (wetted) overnight (>12h) prior continuing with initial backwash as described in step 3. If time does not allow for overnight soaking, turn the system into filtration mode and filter (rinse) to drain for approx. 60min, to remove air attached to the AFM®ng surface. After the wetting process, continue with above step 3.

For AFM®ng, avoid air to be introduced at any point in time during the commissioning process and future operation. This may lead to loss of media during backwash and possible reduced filtration performance. If AFM®ng surface is skimmed (step 4) or if air is introduced into the system repeat the above described wetting process before continue with step 5.

Decommissioning / Mothballing and recommissioning a filter

AFM® should preferably be operated continuously. If the filter must be turned off for >2 weeks or a longer period (mothballing), the filter must be backwashed for 15-30min, then disinfected by soaking in Chlorine Dioxide (1ppm free chlorine) or similar disinfection chemical for ca. 1-3 hours, followed by a normal backwash. After the backwash, drain the filter completely and leave the drain open. For questions to extended period of shut-down contact Dryden Aqua support at info@drydenaqua.com

For recommissioning the filter must be disinfected again, then backwashed for a period of 10-15 minutes followed by a rinse phase until the water achieves the required filtrate quality for starting of normal filtration operation.

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5. AFM® Filter media layering

The information in this section is intended as general guidance. Actual media ratios and layer depths should be determined using the filter manufacturer's drawings and specifications, based on filter type, total bed depth, and intended application.

It is not recommended to use gravel or other coarse support layers, as these promote bacterial growth and may compromise AFM® filtration and backwash performance.

For high suspended solids loads (>30 ppm TSS), anthracite may be applied as a top layer in pressure or gravity filters, to extend the filtration run time between backwashes. Granular Activated Carbon (GAC), applied in a 200mm layer, may be used on top of AFM® for applications such as dechlorination, color removal, and reduction of dissolved organics. GAC should not be used for removing suspended solids.

Vertical Pressure Filter

Vertical pressure filters fitted with nozzle plates typically offer the highest backwash and filtration efficiency when using AFM®. However, systems with a well-designed lateral layout, dense, evenly spaced, and extending close to the filter wall, can approach similar levels of performance. Vertical lateral pressure filters are not suitable for backwashing with air.

Horizontal Pressure Filter

Horizontal filters provide greater surface area per unit cost compared to vertical filters. However, they often have a lower and uneven bed depth, which can result in reduced filtration and backwash performance with any media. Nevertheless, they remain a cost-effective option for installations that require a large filtration surface. Horizontal lateral pressure filters are not suitable for backwashing with air.

Rapid Gravity Filters (RGF)

RGF's are commonly used in municipal drinking water treatment. Due to their typically lower filtration velocity (5–8 m/h), they can outperform both vertical and horizontal pressure filters in fine particle retention. However, they require significantly more surface area, resulting in a larger overall footprint and higher capital expenditure.

Continuous Backwash Upflow Filter

A continuous backwash upflow filter is a filtration system in which untreated water enters from the bottom and flows vertically upward through a single-media filter bed, while filtered water exits at the top. The filter media is continuously cleaned in a separate cycle without interrupting the filtration process. Filtration velocity is approx. 11m/h for standard industrial applications, and can reach up to 25m/h in large (concrete module) installations.

Table 1: AFM® media loading ratio

AFM® recommended grades and bed depths vary according to application, pressure or gravity filter design/type and even inlet water quality.

- The table below provides general recommendations for pressure and gravity filters, excluding continuous backwash upflow filters(5).
- AFM®s Grade 3 continuing with Grade 2 is the recommended support layer for pressure and gravity filter.
- Nozzle slot size must be <50% of the effective size (ES, d_{10}) of the AFM® support grade covering the nozzles, to avoid clogging or media loss through the nozzle slots.
- The filtration bed depth (layers above lateral or nozzle plate) typically ranges from 500mm to 1500mm. AFM® Grade 1 minimum recommended bed depth is 500mm, but preferably >800mm.

AFM® Media Ratio(5)	Support(1)	Filtration(4)				
	AFM® Grade 3 2 - 4mm	AFM® Grade 2 0.7 - 2.0mm	AFM® DIN 0.7 - 1.2mm	AFM® Grade 1 0.4 - 0.8mm	AFM® Grade 0 0.25 - 0.5mm	Anthracite(3)
AFM® Grade 1 or Grade DIN, with and without flocculation						
Pressure & gravity filters, with laterals	Required(1)	30-40%	60-70%		-	-
Pressure & gravity filters, with nozzle plate	See Note(2)	30-40%	60-70%		-	-
AFM® Grade 1 or Grade DIN + Anthracite, with & without flocculation						
Pressure & gravity filters, with laterals	Required(1)	30-40%	50-60%		-	100-250mm
Pressure & gravity filters, with nozzle plate	See Note(2)	30-40%	50-60%		-	100-250mm
AFM® Grade 1 + Grade 0 for fine particle removal, without flocculation						
Pressure & gravity filters, with laterals	Required(1)	20-30%	-	40-50%	20-30%	-
Pressure & gravity filters, with nozzle plate	See Note(2)	20-30%	-	40-50%	20-30%	-

Notes:

(1) In lateral filters, AFM® Grade 3 should fill the space below the laterals and extend 100mm above them, followed by a layer of AFM® Grade 2 or DIN. For lateral filters use the manufacturer's filter dimensions or existing filter gravel volume to calculate the required amount of AFM® Grade 3 or ask Dryden Aqua for advice at info@drydenaqua.com.

(2) For nozzle plate filters AFM® Grade 3 of >100mm is recommended as support layer if nozzle slots are >0.35mm and/or number of nozzles is <50nozzles/m^2, followed by a layer of AFM® Grade 2 or DIN.

(3) For high solid loads (>30mg/L or >15NTU), a layer of anthracite of approx. 250mm is recommended. Use an anthracite grain size of 0.6–1.6 mm on top of AFM® Grade 1, or 1.4–2.5 mm on top of AFM® DIN. To avoid fast clogging, do not use AFM® Grade 0 for feedwater with >5ppm TSS. Anthracite should not be used above AFM® Grade 0, as this results in mixing of the two media during backwash.

(4) For correct filter bed layering, consider the application specific filtration and backwash velocity (Table 2, page 14) and recommended bed expansion (Table 4, page 19), as well as filtration suspended solids loading capacity (Table 3 page 17 & 18).

- Filters from different manufacturers will have different dimensions and may require different proportions of each grade. Table 1 layering ratio relates to commercial filters that respect the Klopper standard for steel and, the Korboggen standard for (GRP) filter design, and applies as well for rapid gravity filters. Use the manufactuer filter dimensions to calculate the required AFM® support and filtration layers height and volume or ask Dryden Aqua for advice at info@drydenaqua.com.

(5) AFM® filtration and backwash performance may vary depending on the type, design, and build quality of the filter system.

- Typically vertical filters provide for a better filtration and backwash operation compared to horizontal filters, and where pressure filters with a nozzle plate are technically preferred over filters with laterals. In gravity filters, the use of Triton (Johnson Screens), Leopold (Xylem), Tetra (DeNora) or similar underdrain systems are superior in filtration and backwash operation over conventional nozzle plate and lateral gravity filters.
- For continuous backwash upflow filter e.g. DynaSand®, selecting the correct AFM® type and grade, ask Dryden Aqua for advice at info@drydenaqua.com .

Vertical Pressure Filters

Horizontal Pressure Filters

Continuouse Backwash Upflow Filter

DynaSand™, Nordic Water - nordicwater.com

Rapid Gravity Filters (RGF)

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Manual calculation of filter bed layering with AFM® Grade 1 and Grade 2

Depending on total filter media height the below AFM® layering is recommended and used as an example for the AFM® media layering calculation in vertical and horizontal pressure filters as well as most gravity filter types.

Filters >1000mm Height

* Recommended TC >800mm for optimal AFM® performance

** In laterals filter use AFM®s Grade 3 to fill +100mm above laterals.

AFM® calculation of filter bed depth allowing for expansion

Filters must provide sufficient vertical clearance above the AFM® bed to accommodate media expansion during backwash, along with an additional freeboard of approximately 200mm to prevent media loss. For mixed-media configurations, refer to the manufacturer's data to determine the bulk density and expansion coefficient of any material placed above the AFM® (e.g. anthracite or GAC). These upper media must be lighter than AFM® and compatible in terms of expansion behavior.

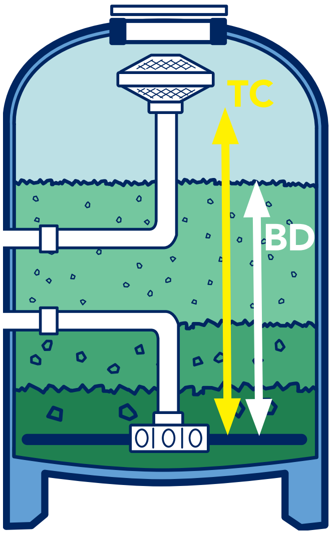
The following formula can be used to calculate the allowable AFM® bed depth in order to avoid media loss. Expansion ratios for each AFM® Type and Grade at different backwash velocities and temperatures can be determined by using the backwash bed expansion graphs as shown on pages 20

To calculate the allowable filter bed depth with consideration for media expansion during backwash, use distance from the top of the underdrain or support layer (gravel, coarse sand) to the outlet / top collector (TC). From this value, deduct 200mm to account for the required freeboard. This freeboard provides the necessary space above the expanded filter bed to prevent media loss during backwash. Bed depth does not include media in the bottom of the filter, below the underdrain (e.g. laterals).

Filter bed calculation example:

- TC of 1.6m from nozzle plate to top collector
  Recommended TC >800mm for optimal AFM® performance
- 20% backwash bed expansion for AFM®
- TC x 0.82 (ca. 200mm freeboard) / 1.2 (20% bed expansion) = Bed Depth (BD)

$$\text{Bed Depth (BD)} = \frac{1.6\text{m} \times 0.82}{1.2} = 1.1\text{m}$$



Simple rule to calculate TC using expanded media bed height and freeboard
Calculate bed depth (BD) + 20% bed expansion and add a 200mm freeboard to avoid loss of media during backwash.

When using multiple AFM® grade layers in your filter, bed expansion should be calculated for each layer using the AFM® backwash bed expansion graphs on page 20.

For multimedia bed using Anthracite or Granular Activated Carbon (GAC) read Annex 7, "AFM® dual-media beds - Anthracite & Activated Carbon" on page 31.

6. Filtration mode

The particle retention efficiency of any granular filter media is inversely proportional to the filtration velocity. Therefore, operating the filter at the lowest practical velocity generally yields the best removal performance. One of AFM®'s key advantages over sand or other filter media is its ability to deliver equal or superior filtration performance at higher velocities. This allows for reduced filter area, fewer filter units, and a smaller overall system footprint, resulting in a lower capital expenditure.

Filtration performance varies not only by media type but also by media quality. Sand sourced from different geological deposits can differ significantly in filtration efficiency due to variations in particle size distribution, sphericity, chemical composition, and uniformity coefficient. AFM® consistently outperforms sand under identical conditions, and in many cases can operate effectively at filtration velocities of up to 20m^3/m^2/h (m/h) or higher, depending on system design, raw water quality, and application.

The recommended flow rate or filtration velocity for an AFM® filter depends on the application (see Table 2, page 14), type (gravity or pressure filtration) and design (filter area, height) of the filter. For example in drinking water applications, for most pressure filters, the filtration velocity is around 12-15m/h. This equates to a water flow rate of typical 12-15m^3/h of water for every 1m^2 of filter bed surface area. RGF filters in drinking water treatment typically operate at a slower flow velocity of 5-8m/h.

The following graph illustrates particle removal performance at a filtration velocity of 20m/h, comparing AFM® Grade 1 with 0.5–1.0mm sand. AFM® achieves a removal efficiency of approximately 95% for particles down to 5µm, whereas most commercially high quality sand removes only around 70% under the same conditions.

Filtration performance in removal of 5µm particles at different filtration velocities

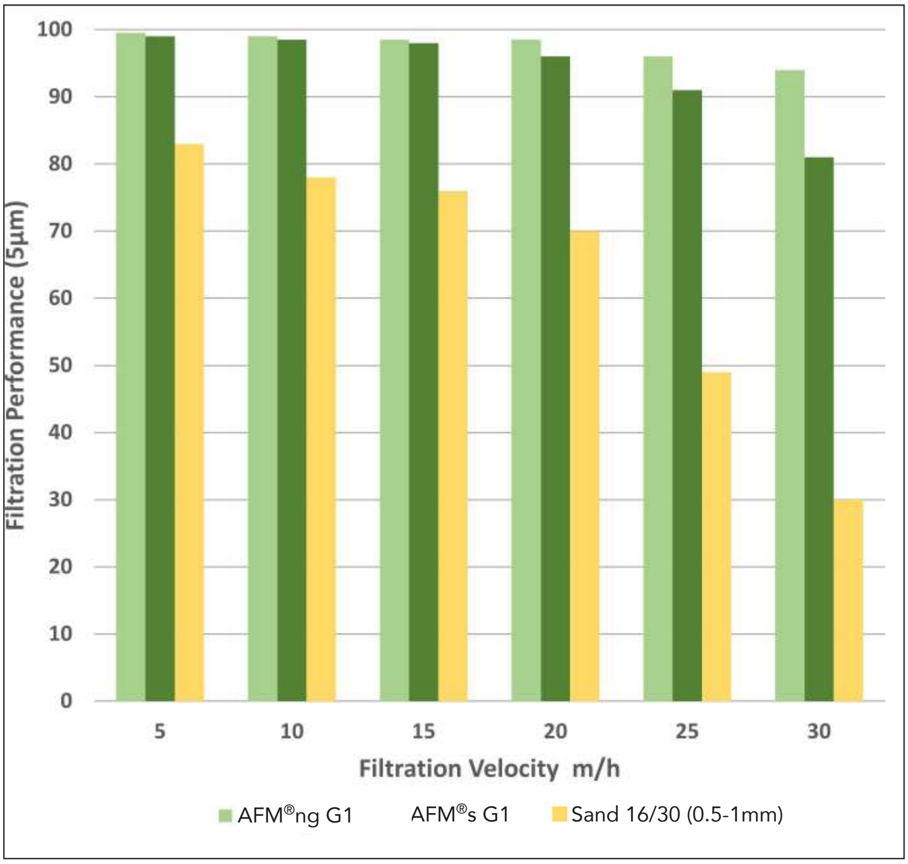


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Table 2: Application-specific filtration and backwash velocities

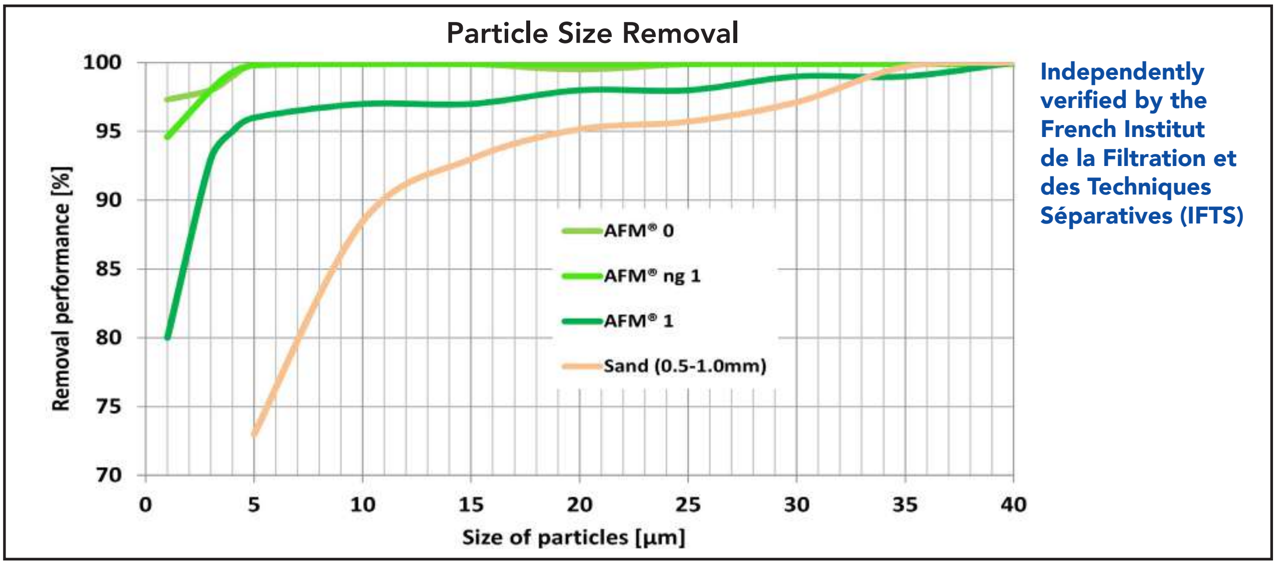
Application typical filtration and backwash velocity	Filtration velocity [1] m/h		Backwash velocity [2] m/h		
	Pressure Filter	RGF	AFM® DIN	AFM® G1	AFM® G0
Ground and surface (drinking) water	10-15	5-10	>40	>30	>20
Municipal waste water – secondary / tertiary effluent	5-15	5-10	>40	>30	>20
Ferric, manganese and arsenic removal	10-15	5-10	>40	>45	-
Pre-treatment to UF and RO membranes	10-15	5-10	>40	>30	>20
Cooling tower (side stream filtration)	15-20	5-10	>40	>30	>20
Aquaria	10-25	5-10	>40	>30	>20
Public swimming pools	20-30	-	>40	>30	-
Aquaculture	15-20	-	>40	>30	>20

Notes:
(1) For above listed applications Table 3a and 3b on page 16 for suspended solids loading capacity are to be considered
(2) Consider "Backwash procedure" (page 18-21) for correct backwash procedure and applicable filter bed expansion.

AFM® Filtration Performance

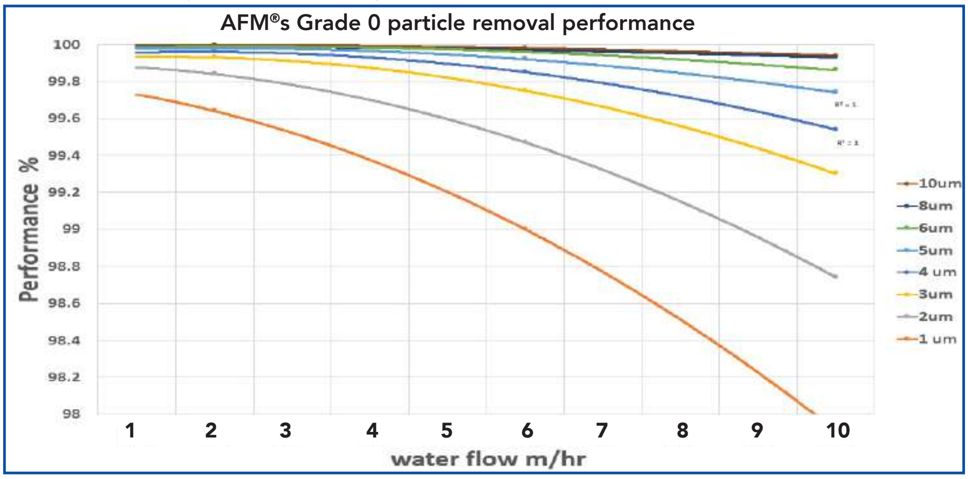
- AFM® Grade 0 (0.25–0.50mm) removes over 98% of particles down to 1µm, as verified by Institut de la Filtration et des Techniques Séparatives (IFTS). Suitable for applications with backwash velocities below 30m/h. Flocculants are not recommended as they can blind the media and reduce performance.
- AFM®s Grade 1 (0.4–0.8mm) removes up to 95% of particles down to 4µm. Its negatively charged surface enhances the removal of iron, manganese, and arsenic. Performance decreases in soft water, especially when hardness is <50ppm as $CaCO_3$.
- AFM®ng Grade 1 (0.4–0.8 mm) removes 95% of particles down to 1µm. Its hydrophobic surface is ideal for higher loads of fine particles and non-polar contaminants like organics, oils, pharmaceuticals, and microplastics. Coagulation and flocculation can boost performance.
- AFM®ng DIN and AFM®s DIN remove 96% of particles down to 4 µm. They can be used alone or in combination with anthracite in gravity or pressure filters for high TSS, high organic loads, or when higher filtration flow rates are required. AFM®s DIN is a direct replacement for sand in upflow filters (e.g., DynaSand™), enhancing water quality.
- AFM®ng outperforms AFM®s and sand in soft water conditions (TDS <50mg/l, calcium <40mg/l and alkalinity <40mg/l as $CaCO_3$), offering superior filtration where conventional media struggle.

AFM® vs Sand particle size removal performance at 20m/h

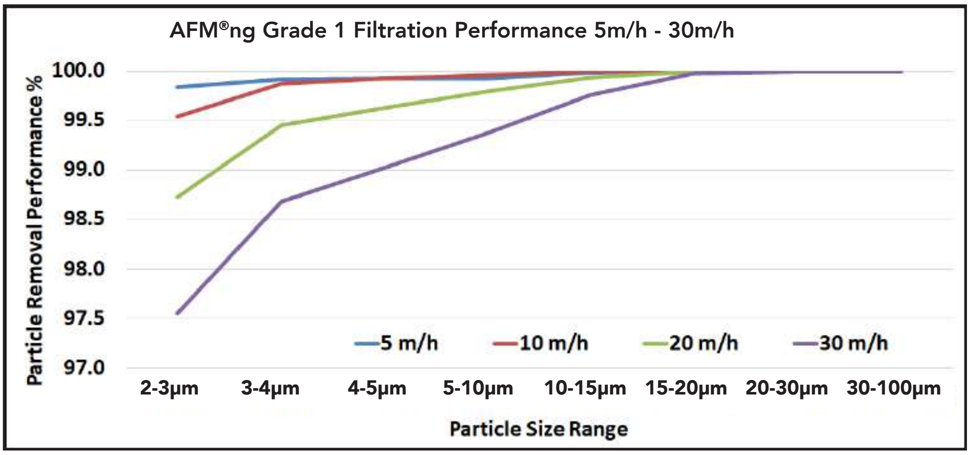


Independently verified by the French Institut de la Filtration et des Techniques Séparatives (IFTS)

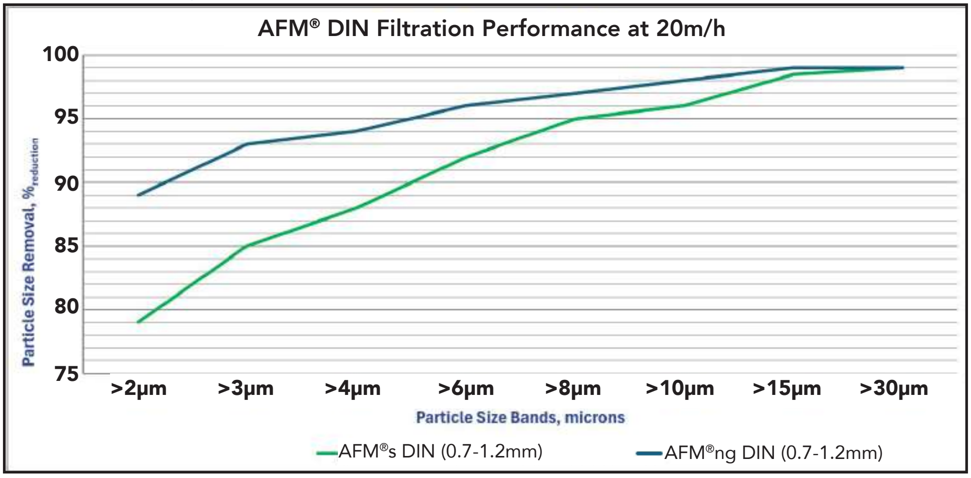
AFM®s Grade 0 particle removal performance at different velocities



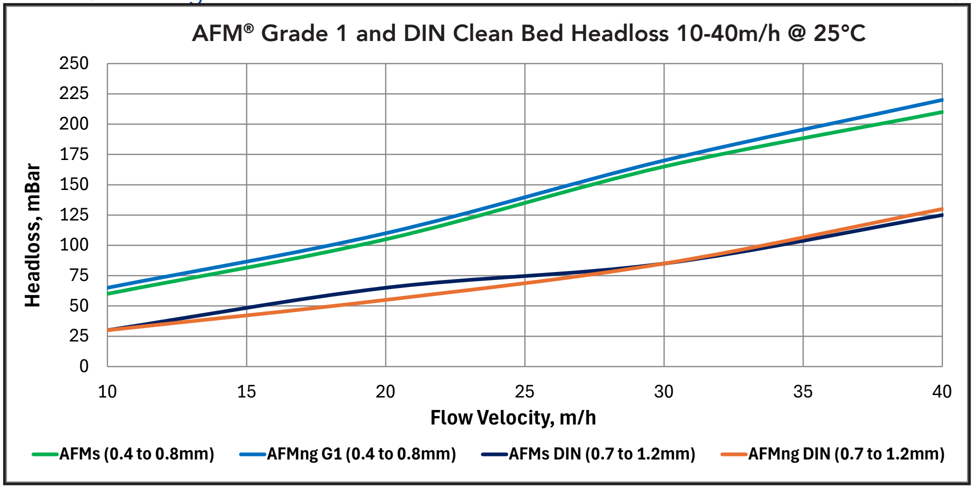
AFM®ng Grade 1 particle size removal performance at different filtration velocities



AFM®s / AFM®ng DIN particle size removal performance at 20m/h



AFM®s / AFM®ng Grade 1 and DIN clean bed headloss @ 200mm G2 + 800mm G1 / DIN



Filtration suspended solids loading capacity

AFM® functions as a mechanical filtration media, primarily designed to remove suspended solids from water. Its performance under high solids loading is determined by the rate of differential pressure increase and the allowable frequency of backwash cycles.

For long-term stability and optimal operation, a backwash is recommended if a pressure differential of 500mbar is reached. The maximum suspended solids (SS) loading capacity — expressed in mg/l — depends on the filtration velocity and the nature of the particulate matter.

Taking 8 hours as the shortest backwash frequency the maximum solids load capacity in mg/l suspended solids (SS) is given in table 3a and 3b. These values have been established through controlled laboratory tests using SO Arizona A4 test dust (Table 3a), and TOP Para 4.5.4B test dust (Table 3b).

Table 3a: Filtration suspended solids loading capacity, ISO Arizona A4 Test Dust

	AFM®s Grade 0			AFM®s / AFM®ng G1			AFM®ng/s DIN	
Filtration Velocity m/h	**mbar (1)**	**mg/l ss (2)**	**mg/l ss (2) Anthracite 0.6-1.6mm 250mm**	**mbar (1)**	**mg/l ss (2)**	**mg/l ss (2) Anthracite 0.6-1.6mm 250mm**	**mbar (1)**	**mg/l ss (2)**
5	70	33	131	30	68	272	20	158
10	130	16	65	65	34	136	30	79
15	210	11	44	75	23	90	40	53
20	310	8	33	110	17	66	55	40
25	370	7	26	130	14	54	70	32
30	430	5	22	170	11	45	90	26

Table 3b: Filtration suspended solids loading capacity, TOP Para 4.5.4B Test Dust

	AFM®s Grade 0			AFM®s / AFM®ng G1			AFM®ng/s DIN	
Filtration Velocity m/h	**mbar (1)**	**mg/l ss (2)**	**mg/l ss (2) Anthracite 0.6-1.6mm 250mm**	**mbar (1)**	**mg/l ss (2)**	**mg/l ss (2) Anthracite 0.6-1.6mm 250mm**	**mbar (1)**	**mg/l ss (2)**
5	70	66	262	30	113	260	20	368
10	130	33	131	65	56	128	30	184
15	210	22	87	75	38	84	40	123
20	310	16	66	110	28	64	55	92
25	370	13	52	130	23	52	70	74
30	430	11	44	170	19	40	90	61

Notes:

(1) Differential pressure against flow velocity for a clean AFM® bed with 1000mm total bed depth (800mm filtration media).

(2) The above suspended solids removal figures have been established on wet laboratory testing using ISO Arizona A4 (Table 3a) and TOP Para 4.5.4B (Table 3b) test dust particles (see "Test Dust for AFM performance testing", page 35). In practice, depending on the nature of the feed water, these SS load rate figures can be up to 50% higher at same or even reduced filtration velocities.

Use of Coagulants and Flocculants to improve filtration performance

Coagulants and flocculants are used to enhance the removal of fine suspended solids, and facilitate the precipitation and removal of humic and fulvic acids in water filtration processes. When used with AFM®ng / AFM®s Grade 1 or Grade DIN, they significantly improve the removal of fine organic and inorganic particles and can also provide an effective barrier against Cryptosporidium oocysts. at filtration velocity of 20m/h and higher.

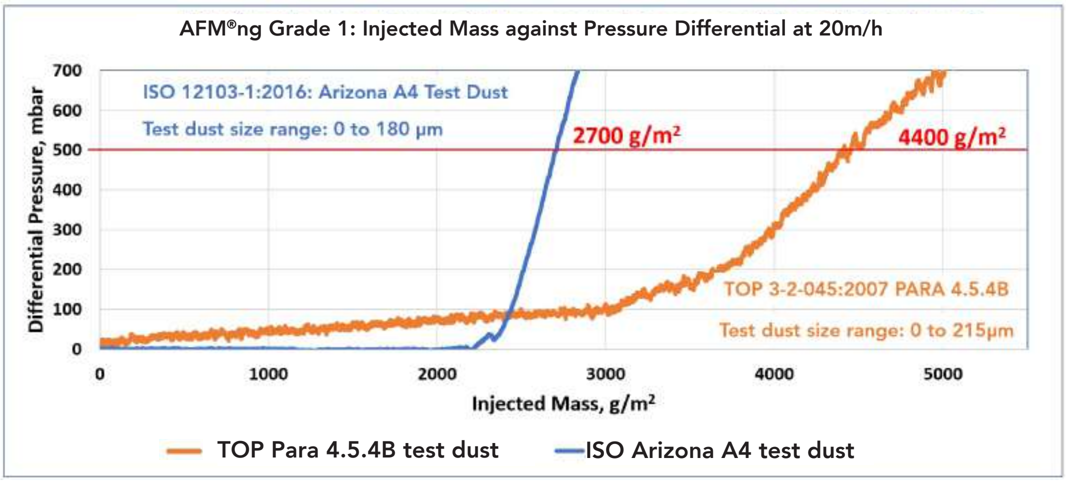
AFM® is compatible with both cationic and anionic coagulants and flocculants, provided that chemical dosing follows the manufacturer's recommendations. Overdosing must be avoided, as this may lead to media clogging and reduced filtration efficiency. AFM® may be used with the following generic coagulant and flocculant products;

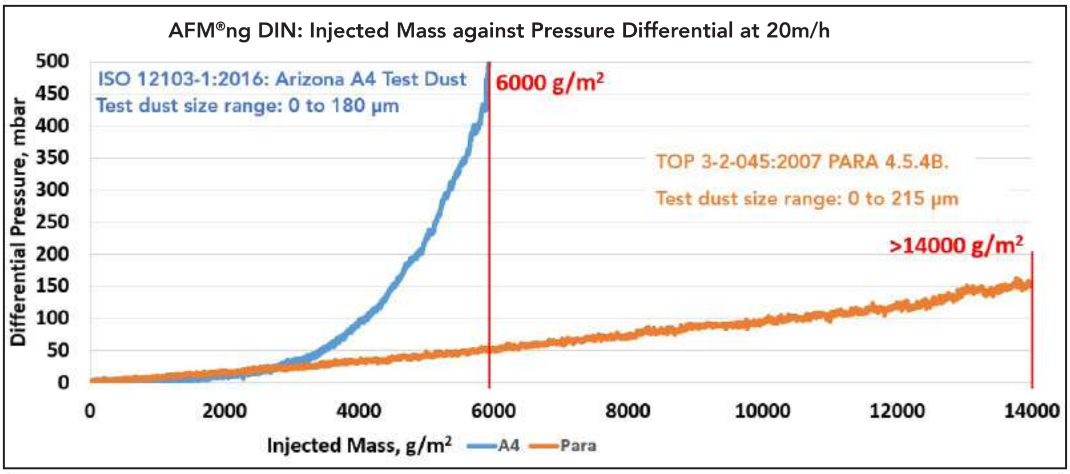
- Ferric coagulants and flocculants.
- Aluminium coagulants and flocculants.
- Polyamide and other polyelectrolytes.

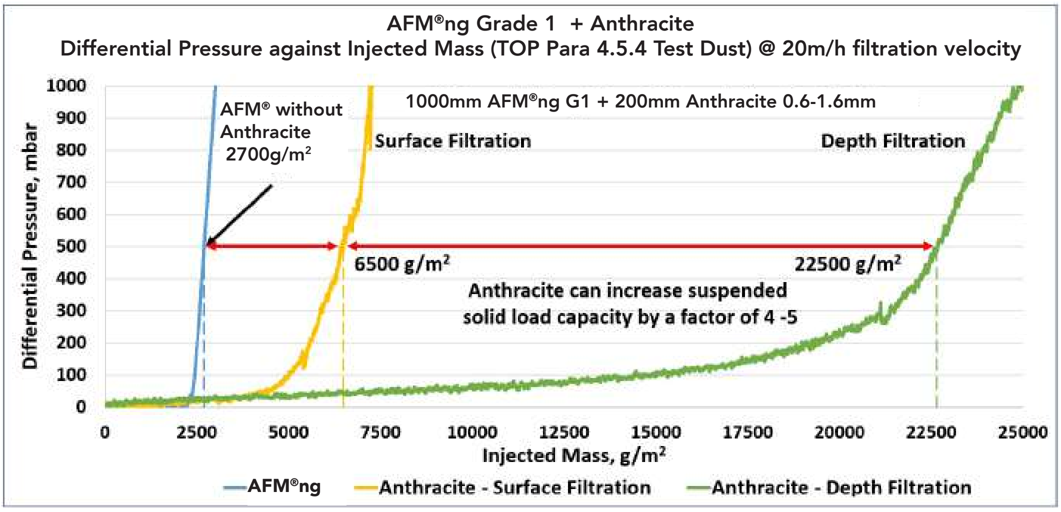
Differential pressure against injected mass

The following graphs present the run phase differential pressure across the bed at 20m/h, and the mass of solids removed by AFM®. The loadings were generated using engineered ISO Arizona A4 and TOP Para 4.5.4B test dust (particles).

Loading capacity depends on particle size, type (organic and/or inorganic) and its mechanical properties. In practical applications, the loading rate at 500mbar pressure increase after last backwash ranges from 2.7-4.4kg/m² for AFM® s and AFM® ng Grade 1 and for AFM® ng and AFM® s DIN ranges from 6 - 14kg/m².

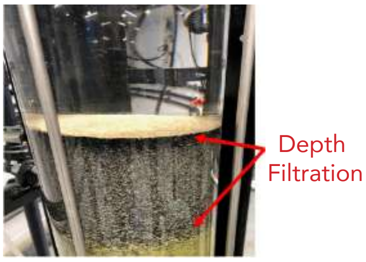

AFM®ng Grade 1: Injected Mass against Pressure Differential at 20m/h


AFM®ng DIN: Injected Mass against Pressure Differential at 20m/h


AFM®ng Grade 1 + Anthracite
Differential Pressure against Injected Mass (TOP Para 4.5.4 Test Dust) @ 20m/h filtration velocity

AFM® + Anthracite Surface Filtration

AFM® + Anthracite Depth & Surface Filtration



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7. Backwash procedure

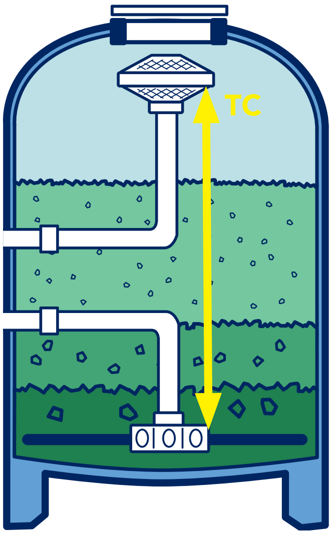
Importance of backwash velocity

The primary purpose of backwashing is to dislodge accumulated impurities/debris from the filter media. The backwash velocity should expand the bed at least 15% but preferably 20% to reach the required fluidization of the top AFM® layer and to achieve efficient removal of accumulated contaminants.

The selected filter height and total bed depth must accommodate the filter bed expansion. The backwash velocity depends on several factors, specifically the grain size and bulk bed density of the media and the water temperature (see backwash bed expansion curves on page 20).

As a general rule, a higher backwash velocity reduces the required backwash time and improves overall backwash efficiency. Filter bed expansion and fluidization lift the solids to the top of the bed, but it is the water flow velocity that transports them to the top collector and out of the filter. This is especially important for heavy particles such as (heavy) metals.

The backwash velocity is inherently linked to backwash time and is best explained with the following example.



Backwash time example

Pressure filter with 2m height from lateral arms or nozzle plate to top diffusor (TC). Apply a factor of 1.5 for the calculated time:

- 60m/h backwash: 2m/(60(m/h)/60(min)) = 2min * 1.5 = 3min backwash time
- 30m/h backwash: 2m/(30(m/h)/60(min)) = 4min * 1.5 = 6min backwash time

A high backwash water velocity (>45 m/h) results in significantly shorter backwash times and lower water and energy consumption, while also providing substantially better backwash performance compared to a slower velocity (<30 m/h), which requires longer backwash durations.This is especially important for heavy particles such as iron and manganese (heavy metals).

Backwash water wind-up & wind-down/reclassification of the filter bed

To avoid mixing of the AFM® layers and prevent damage to piping and internal filter components due to water hammer caused by fast start of backwash, it is recommend that backwash flows are started slowly and ramped up to 100%. The table below provides guidance on ramp-up times.

At the end of the backwash, the flow should be wound-down to allow the media layers to reclassify. In addition, this will lead to an even surface and dense filter media porosity, which promotes faster bed compaction and shorter rinse times, resulting in better filtrate quality before returning to filtration mode..

Table 4: Recommendation for AFM® backwash wind-up & wind-down time

Type of filter	Wind up time	Wind down time
Standard vertical filter with nozzle plate	15 sec	30 sec
Standard vertical filter with laterals	30 sec	30 sec
Horizontal filters with nozzle plates or laterals	45 sec	30 sec

AFM® water only backwash process:

1. Initiate backwash water flow to achieve >15% (preferably 20%) bed expansion as required to fluidize the top media layers and effectively remove dirt from the filter. To avoid mixing of the media layers, it is recommended to gradually accelerate the backwash flow to 100% over approx. 30 seconds.
2. Consider a backwash duration of 3–10 minutes (depending on backwash velocity) to ensure that all dirt is flushed out during the process. A backwash is considered complete when the turbidity of the outlet water is similar to that of the inlet water. Measuring this helps determine the optimal backwash duration.
3. At the end of the backwash, slow down the water flow over a period of approx. 30 seconds to allow the bed to properly re-classify.
4. Rinse the filter to drain for 3-10min or as long as required to reach required filtrate water quality and to reinstate particle removal performance.
5. Start filtration mode (run phase).

To achieve best AFM® backwash performance and long lasting filtration performance, refer to the following information:

- Application-specific filtration and backwash velocities, Table 2, Page 14
- Recommendation for AFM® backwash wind-up & wind-down tim, Table 4, Page 18
- Recommendation for AFM® backwash with water & air below Table 5
- AFM® bed expansion curves on Page 20

When **AFM® is retrofitted into an existing sand filter**, the backwash pump capacity must be assessed to achieve the recommended backwash velocity for AFM®. The media layering and total bed depth must be designed with consideration for bed expansion during backwash, to prevent media loss at the selected backwash velocity.

For existing filters with backwash velocities <25m/h and TSS levels <5 mg/L, AFM®s Grade 0 can be used due to its superior bed expansion at lower velocities. It may also be used at backwash velocities >15m/h in retrofits or new filters, provided TSS remains <5mg/L and no coagulants or flocculants are used.

AFM®s / AFM®ng backwash with air scouring

For AFM®s and AFM®ng with its biofouling resistant media surface, air scouring is not required. A water-only backwash achieving at least 15%, preferably 20%, bed expansion is sufficient to fluidize the media and allow contaminants to escape.

Air scouring may be used with AFM®s for ca. 2-5min, at an air flow rate of ca. 30-60m/h, if the filter is clogged by sticky and/or high impurities >30mg/l, such as from clay, heavy metals and/or organics (e.g. tertiary sewage effluent).

Air scouring followed by water backwash can be applied as well in dual media filters (DMF) using AFM®s G1 or AFM®s DIN and Anthracite as top layer.

Simultaneous air and water backwash may be used only with single-layer AFM®s beds. It must not be applied to filters containing multiple AFM®s layers or in dual media configurations (DMF), as this may cause media stratification, mixing, or loss. Rever to below Table 4, recommendation for AFM backwash with water & air.

Equal air scouring distribution is required to prevent mixing of media grades and to ensure efficient backwashing. As a consequence, mixed medias result in reduced filtration performance. Consult the filter manufacturer to confirm whether your underdrain system supports backwash air scouring. Although commonly used, air scouring is generally not recommended for filters with laterals.

AFM®ng is hydrophobic and must not be backwashed with air. This is to avoid loss of media during the backwash process and mixing with top layer of Anthracite in a dual media filtration (DMF) configuration. See below Table 5, recommendation for AFM® backwash with water & air.

Table 5: Recommendation for AFM® backwash (velocity) with water & air

Backwash options	Water Only(2)	Air then Water(3)	Air/Water combined (3)
Single layer	🟢	🟢	🟢
Multi layers	🟢	🟢	🔴
AFM®ng	🟢	🔴	🔴
AFM®s	🟢	🟢	🟢
Anthracite / GAC (1)	🟢	🟢	🔴
Min. BW velocity: 20m/h	AFM®s G0	–	AFM®s G1(4)
Min. BW velocity: 30m/h	AFM®s/ng G1	AFM®s G1	AFM®s G1 & AFM®s DIN
Min. BW velocity: 40m/h	AFM®s/ng DIN	AFM®s DIN	–

The min. backwash velocities indicated above are sufficient to achieve the minimum required bed expansion, but may not always be adequate to remove heavier particles or high solids loads from the filter, see filtration and backwash velocities in Table 2 on Page 14.

Notes:
(1) As dual media on top of AFM®
(2) Min. backwash water velocity to achieve a min.15% bed expansion
(3) Air scouring velocity 30-60m/h – not recommended with lateral underdrains.
Use water at 10-20m/h when combined with air scouring
(4) Not suitable for heavy metals/solids removal

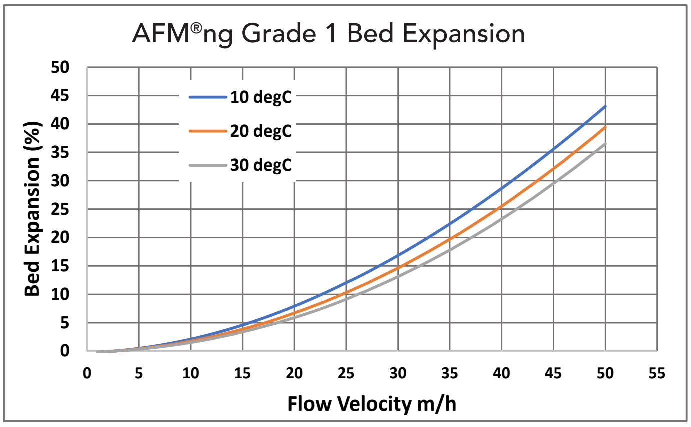
Why is air scouring required for silica sand and other filter media

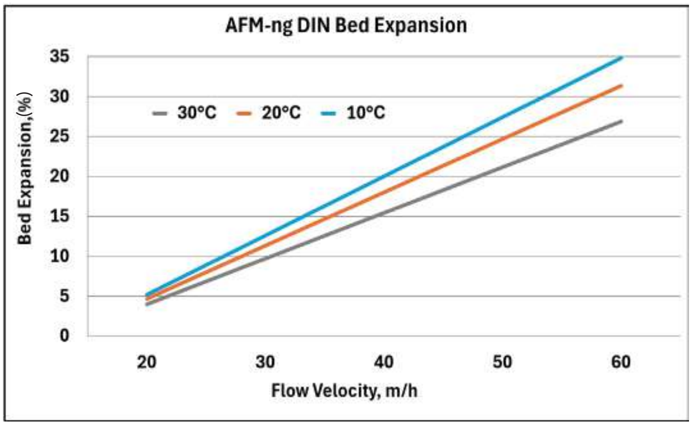
Silica sand and many other conventional filter media provide an ideal surface for bacterial colonisation and biofilm formation. As a result, the backwash process for these media typically requires air scouring (scrubbing) to dislodge and remove the biofilm from the media surface.

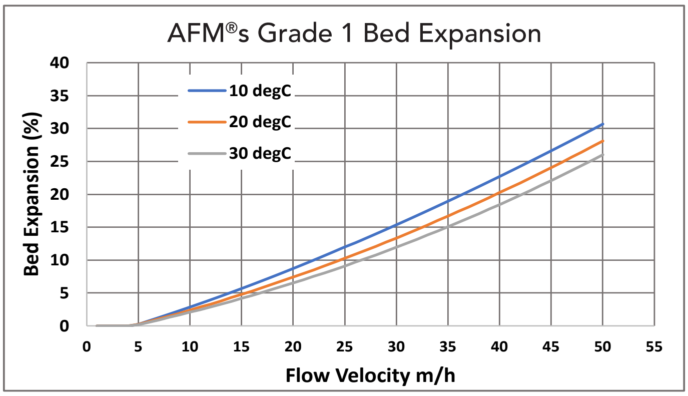
This biological vulnerability means that sand filters often require a more complex and extended backwash sequence, involving combinations of air, air–water, and water-only stages to restore filter performance. To effectively clean and reclassify a silica sand bed, air scouring of approx. 3min at 30-60m/h followed by at least 15% bed expansion must be achieved, which for silica sand typically requires a water backwash velocity exceeding 50m/h.

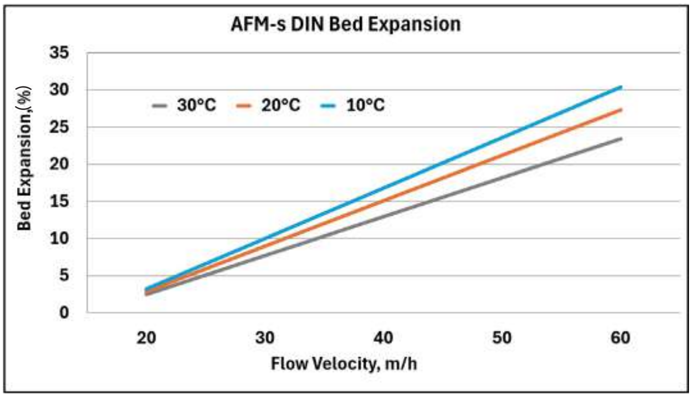
Air scouring is also commonly used in systems with inadequate backwash water velocity, where it serves to partially compensate for insufficient hydraulic energy. However, in such cases, the improvement in cleaning efficiency is often limited.

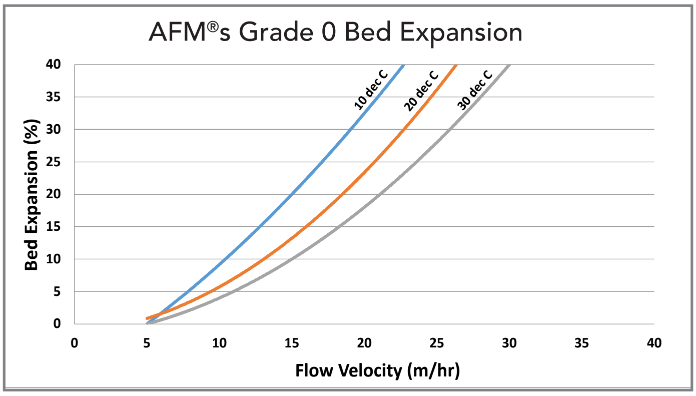
Backwash Bed Expansion AFM®ng & AFM®s

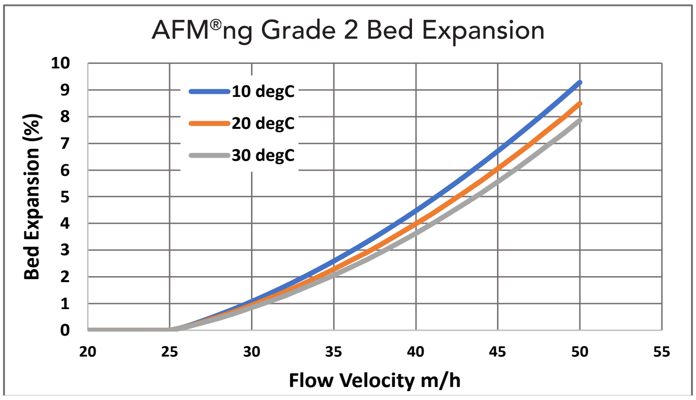

AFM®ng Grade 1 Bed Expansion


AFM-ng DIN Bed Expansion


AFM®s Grade 1 Bed Expansion


AFM-s DIN Bed Expansion

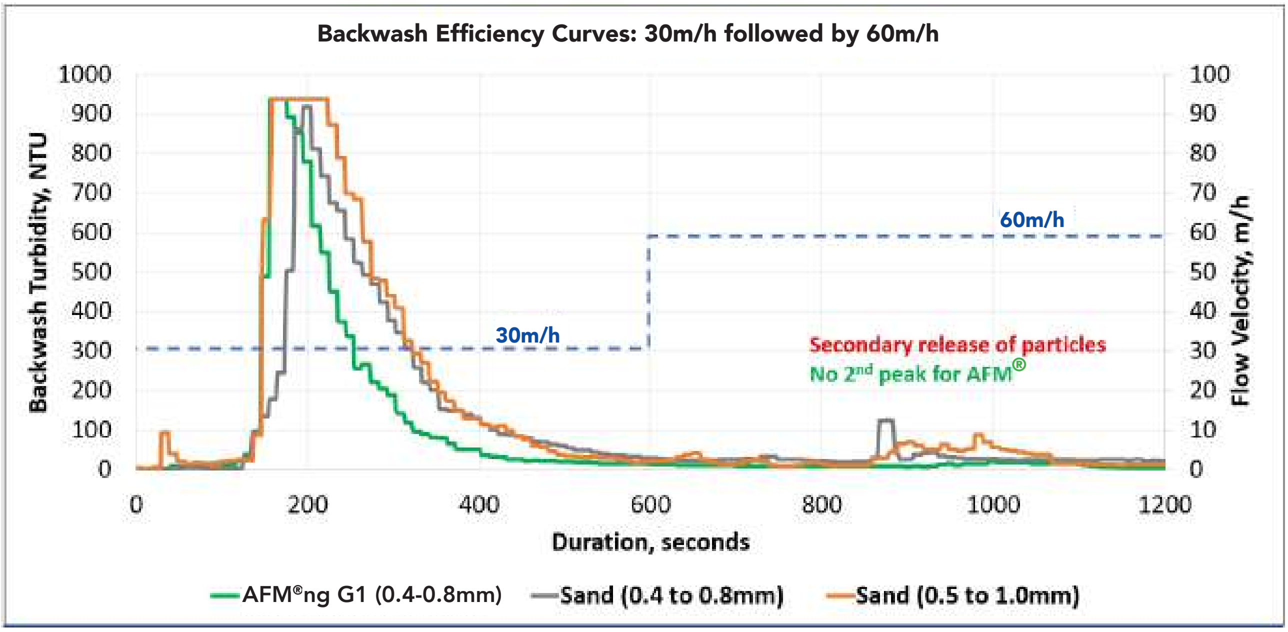

AFM®s Grade 0 Bed Expansion

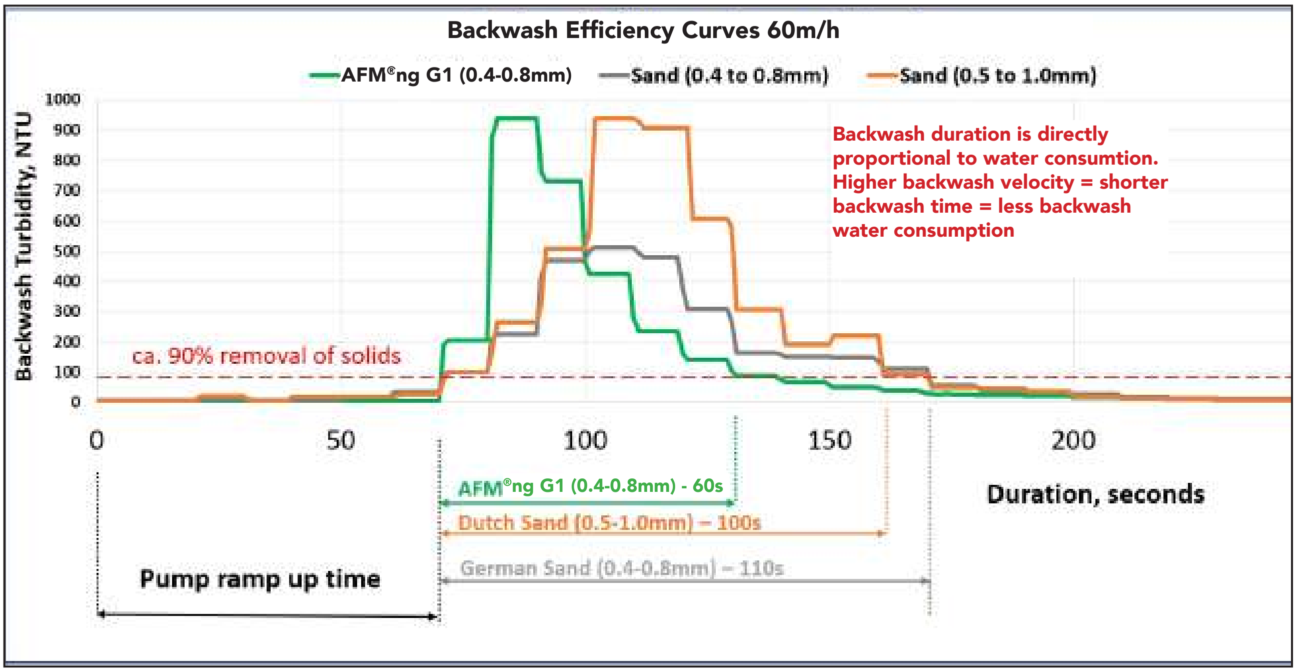

AFM®ng Grade 2 Bed Expansion

AFM®s Grade 2 and Grade 3 do not have relevant bed expansion at or up to 60m/h, therefore bed expansion is not shown for these AFM® types and grades. Bed Expansion is influenced by both temperature and by water density (TDS). In practice the influence of temperature is far greater than TDS. Expansion curves for seawater are therefore not significantly different from the above.

AFM® backwash duration & efficiency

- The backwash must continue until most accumulated solids are removed and discharged. This is only reliably achieved with a bed expansion of at least 15%, ideally over 20% (fluidization). Without sufficient expansion, effective cleaning is not possible—regardless of backwash duration (see Table 5, page 19),
- Backwash performance can be evaluated by measuring water turbidity at the start and every 15–30 seconds during the process (see graph above, AFM® vs. Sand). A smooth turbidity curve indicates stable media, free of compaction, bio-coagulation (e.g., mothballing), or chemical interference.
- AFM® typically completes backwash in under 300 seconds. Without proper fluidization at approx. 20% bed expansion, the curve flattens and lengthens. Deep solids penetration or large head-space above the media may also require extended backwash to clean the bed and flush the freeboard volume.
- Install a sight-glass on all filters to assess bed condition, expansion, and backwash efficiency.





Rinse phase

Depending on application, a rinse phase may be required after the backwash and before returning into filtration mode. Rinsing is required to settle and compact the filter bed leading to a better filtrate water quality. During the rinse phase any dislodged solids near the base of the filter bed are discharged to waste.

The recommended rinse duration for AFM® is 3-5 minutes (see below graph on instantaneous filtration performance). In drinking water systems this serves to reduce the risk of solids, such as *Cryptosporidium* parasites, passing into the product water after backwash. It also reduces discharge of solids that otherwise might foul or block a downstream filtration systems such as cartridge filters, ultrafiltration or reverse osmosis membranes.

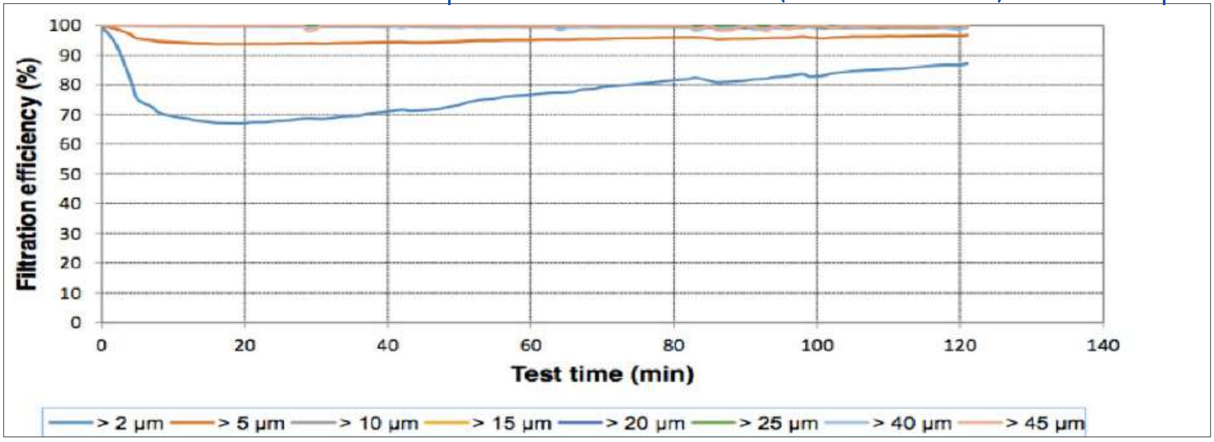
If the backwash profile indicates an unstable bed, recognizable by frequent changes in backwash cycle times, decrease in filtrate quality (also after backwash), then the rinse phase may need to be extended up to 30 minutes. If filtrate quality remains insufficient, or backwash profile continues to be unstable, review and adjust the backwash process and check the media for mothball formation and channeling.

AFM® vs Sand - Instantaneous filtration performance after backwash

The below data shows the instantaneous filtration performance of AFM®s Grade 1 at 20m/h in comparison to sand. After each backwash, the media must be compacted before it will deliver its design performance. The graphs below illustrate the time required for this compaction to take place *(referred to as "ripening" by drinking water technicians).*

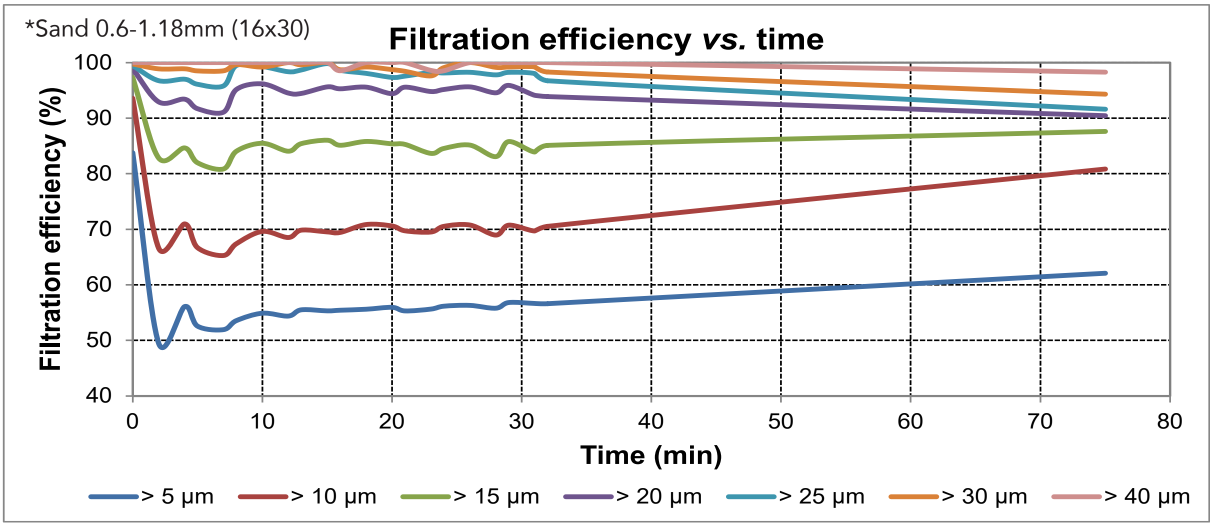
Note the much higher instantaneous filtration performance of AFM® (change from backwash to rinse or filtration mode) , achieving a removal rate of >90% for patricles up to 2 µm within a few minutes, whereas sand requires 2 hours to reach a removal rate of only >80% for particles >20µm.

AFM® s Grade 1 instantaneous filtration performance at 20m/h (no flocculation) down to 2µm



At particle sizes >5µm and a water flow of 20m/h, results from water treatment risk analysis confirm AFM® instantaneous high water quality and the consequently greater filtration security it provides compared to sand.

Sand* instantaneous filtration performance at 20m/h (no flocculation) down to 5µm


*Sand 0.6-1.18mm (16x30)

Taking >5µm particle size, there was a gradual decrease in performance of AFM® which stabilized at approx. 92% removal efficiency. Sand experienced a rapid drop in performance to 50% efficiency and then stabilized at approx 55%.

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Annex 1: Applications overview for AFM®

Application Type	Associated Processes		Typical Removal
Drinking water			
Surface & Ground Water	$FeCl_3$ or PACl (Iron or Aluminum Salts) coagulation prior to AFM®		>90% TSS
Iron, Mangenese and Arsenic removal	Oxidation by aeration, H_2O_2, or NaOCl prior to AFM®	$FeCl_3$ or $FeSO_4$ coagulation prior to AFM®	>95% TSS
Membrane pre-filtration (Sea or Brackish Water)	AFM® filtration to 1µ (AFM®ng G1 or AFM® G0)	1 micron cartridge filter post filtration	>95% TSS SDI <5
PFAS pretreatment for Ion Exchange, Activated Carbon	AFM® filtration to 1µ (AFM®ng G1 or AFM® G0)		>95% TSS
Municipal Waste Water			
Tertiary Treatment	Phosphorous & Bacteria, BOD, COD & TOC Pre-filtration to <100µm + $FeCl_3$ or PACl coagulation then AFM®	Oxidation 30mins with NaOCl after AFM® filters	>95% COD
Industrial Process Water			
Cooling tower sidestream filtration	Organic pollutants & oils, TSS, VSS & particles >1µm Filtration 15 - 20m/hr with AFM®		>95% TSS
Industrial Waste Water			
Low conc' mineral oil (<50mg/l) removal	Oxidation 30 mins by aeration	PACl coagulation prior to AFM®ng	>90% OIW
Chromium or Copper removal	pH correction 7.0-7.5 by $Ca(OH)_2$ (lime), or MgO, or 8.5 by NaOH (caustic). Reduction by dosage of Calcium polysulphide	Sedimentation 30 min. prior to AFM® at 5 - 10m/h max.	>95% TSS
Aquaculture / Aquaria			
Seawater Intake Filtration	Pre-screening of macro-algae by mesh or wedge-wire screens	AFM® filtration	>95% TSS
RAS Systems Hatchery & Ongrowing	Biological Filtration after AFM®	Aeration	>95% TSS
Mechanical Filtration in Biological LSS	Biological Filtration prior to AFM®	Side Stream Protein Skimming	>95% TSS
Mechanical Filtration in Chlorinated LSS	Coagulation & Flocculation prior to AFM®	Chlorine + ACO® in external facilities	95% TSS

AFM® can replace sand and most other filter media in any pressure or rapid gravity filter. AFM® is suitable for many applications beyond those listed above and can be used as substitute for processes such as ultra- or microfiltration before reverse osmosis membrane filtration. Consequently, AFM® improves particle retention, filtration stability, backwash water consumption and service life.

Annex 2: AFM® for pre-filtration to reverse osmosis membranes

Introduction to Reverse Osmosis (RO) pretreatment

The pretreatment of raw water prior to reverse osmosis (RO) membranes is a critical process step that significantly impacts economics, sustainability and ease of operation of an RO water treatment system. RO membranes for desalination / TDS reduction will always be subject to fouling from biological contamination, organic and inorganic precipitation. Pretreatment usually involves sand filters or ultra filtration (UF), followed by 5µm and 1µm cartridge filters. For selected small to medium-sized industrial applications (approximately 100–1000 m³/d), activated carbon or UV irradiation may also be used as part of the pretreatment. It is essential to allow the RO membranes to perform their intended function without excessive demand for maintenance and cleaning chemicals. AFM® will reduce the risks, reduce the costs, optimizes and therefore improves the pretreatment process.

Disadvantages of current pretreatment technologies

Ultra filtration down to 0.03µm

UF has better mechanical filtration performance than sand / cartridge filter combination, but UF will not remove dissolved organics or chemicals from solution. UF is purely a mechanical filtration process, dissolved components or particles smaller than 0.03µm will pass through the membranes. The dissolved organics lead to biofouling of the membranes. The inorganic components such as free silica or phosphate will form a precipitate and scale up the membranes.

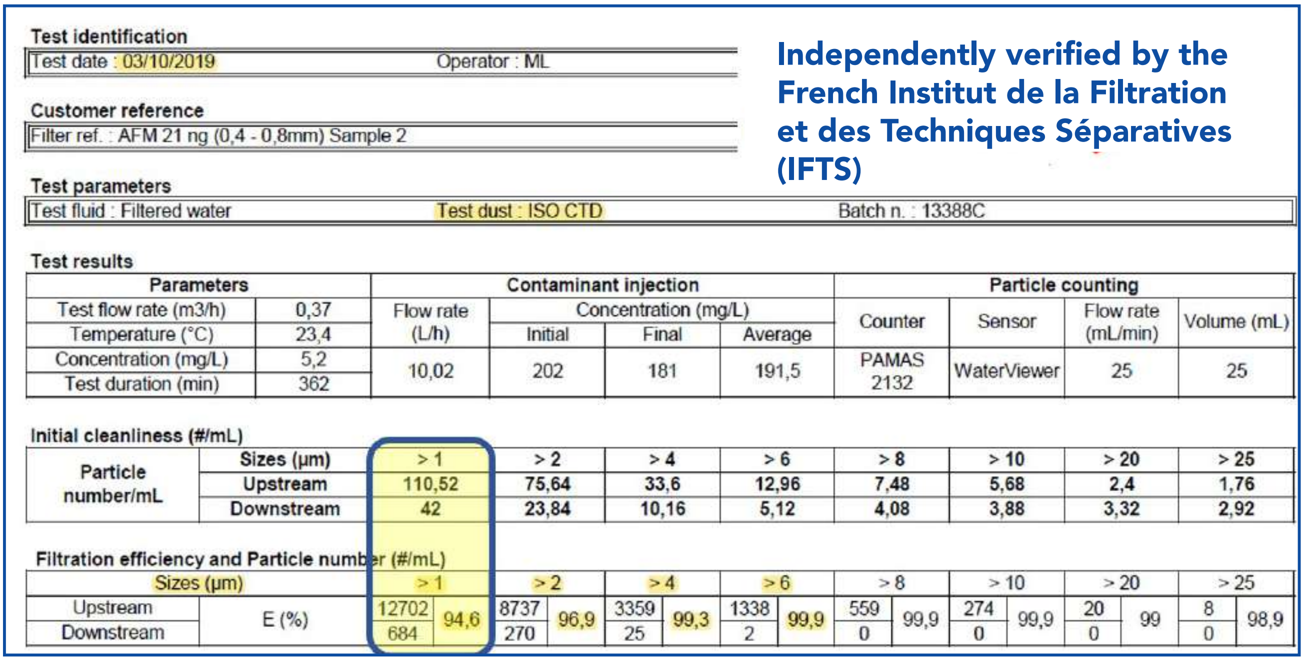
Sand filtration followed by cartridge filters

Sand is effective at removing particulates and dissolved biological nutrients, but the filter will generate bacterial cell biomass, which will foul the membranes. Sand filters also suffer from biodynamic instability, leading to transient channeling and consequent passage of unfiltered water, which blocks the cartridge filters. Coagulants and flocculants may be used prior to sand filters to remove fine particulates or phosphate from municipal effluents. However, sand contains free silica, which can eventually precipitate and block RO and UF membranes, reducing performance, especially if aluminium is present in the water or aluminium-based coagulants are used.

AFM® filtration as pretreatment prior to RO

AFM® is an activated soda-lime-silica glass and used as a direct replacement for sand with very similar operating conditions. AFM® has a surface area much greater than sand. The very large surface area of AFM®s with its negative surface charge or AFM®ng with its hydrophobic surface property will remove particles down to 4µm and 1µm, respectively, with up to 95% removal efficiency. AFM®ng additionally enhances the removal of organics and provides an excellent performance removing hydrocarbons up to 10ppm.

When AFM® is combined with pre-coagulation and/or flocculation, filtration performance can be improved several times. In addition to removing suspended solids, coagulation preferably $FeCl_3$ being compatible with RO membranes can precipitate dissolved organics allowing for the efficient removal of humic and fulvic acids, lipids, amino acids, phosphate and free silica, by AFM®. The performance of AFM®ng has been independently verified by IFTS (Institut de la filtration et des techniques séparatives) in France.



Independently verified by the French Institut de la Filtration et des Techniques Séparatives (IFTS)

Test identification

Test date : 03/10/2019 Operator : ML

Customer reference

Filter ref. : AFM 21 ng (0,4 - 0,8mm) Sample 2

Test parameters

Test fluid : Filtered water Test dust : ISO CTD Batch n. : 13388C

Test results

Parameters		**Contaminant injection**				**Particle counting**			
		Flow rate (L/h)	Concentration (mg/L)			Counter	Sensor	Flow rate (mL/min)	Volume (mL)
			Initial	Final	Average				
Test flow rate (m3/h)	0,37	10,02	202	181	191,5	PAMAS 2132	WaterViewer	25	25
Temperature (°C)	23,4								
Concentration (mg/L)	5,2								
Test duration (min)	362								

Initial cleanliness (#/mL)

Particle number/mL	**Sizes (µm)**	> 1	> 2	> 4	> 6	> 8	> 10	> 20	> 25
	Upstream	**110,52**	**75,64**	**33,6**	**12,96**	**7,48**	**5,68**	**2,4**	**1,76**
	Downstream	**42**	**23,84**	**10,16**	**5,12**	**4,08**	**3,88**	**3,32**	**2,92**

Filtration efficiency and Particle number (#/mL)

Sizes (µm)		> 1		> 2		> 4		> 6		> 8		> 10		> 20		> 25	
Upstream	E (%)	12702	94,6	8737	96,9	3359	99,3	1338	99,9	559	99,9	274	99,9	20	99	8	98,9
Downstream		684		270		25		2		0		0		0		0	

Annex 3: AFM® for tertiary treatment of waste water

Both AFM®ng and AFM®s are used for the tertiary treatment of municipal or industrial waste water in gravity flow or pressure filters. AFM® has many benefits over sand filtration, including:

- No biofouling and does not coagulate or experience transient channeling
- Predictable and repeatable performance
- Turbidity (particulate) and TSS reduction >90%
- Perfect for ferric removal as well as very good at removing precipitated phosphate and arsenic
- AFM®ng is specifically adapted to removal of hydrophobic particles and will remove 94.6% of particles down to 1µm.

Operational criteria	Range		Notes
Bed depth	500mm	2000mm	Typical bed depth is 1200mm with 200mm of 1 to 2mm anthracite on top of the bed
Run phase water flow	5m/hr	15m/hr	The slower the flow rate the better the performance
Running pressures (differential)	0.1	0.5	Do not exceed 0.5 bar differential pressure increase
Backwash water flow	>40m/hr	50m/hr	Backwash for 5 minutes, or until the water runs clear. Air purge not required
Rinse phase duration	2 minutes	Until water runs clear	It takes a few minutes for the bed to stabilize after a backwash
Backwash frequency / hours	4	days/weeks	Depends upon solids load in waste water
Water quality			Ideally the dissolved oxygen level should be above 2mg/l or RedOx potential above 200mV entering the AFM® filter bed

AFM® tertiary waste water treatment performance comparison*

Type of Filter	SS (mg/l)		Performance %	Turbidity (NTU)		Performance %	Bacteria		Performance %	Filtration Velocity $m^3/m^2/h$
	inlet	outlet		inlet	outlet		inlet	outlet		
AFM® Pressure filter	10.60	0.89	96	2.98	0.24	92	23000	10000	58	3.59
RGF sand filter with sand	7.14	2.2	69	3.5	2.23	36	23120	12300	46	1.2
Pressure filter with sand	8.18	3.82	53	5.87	4.76	18	22311	18023	19	4.96
Moving bed sand filter with sand	7.08	3.82	46	2.13	1.79	16	14067	10307	26	5.4
Drum filter 10µm	14.66	7.33	50	7.16	3.88	45	56712	38460	32	3.23
Disc Filter 10µm	5.6	3.1	44	2.22	2.06	7	30450	21138	30	2.12
Ring Filter 10µm	7.41	3.98	46	3.01	3.17		9447	7761	17	2.5

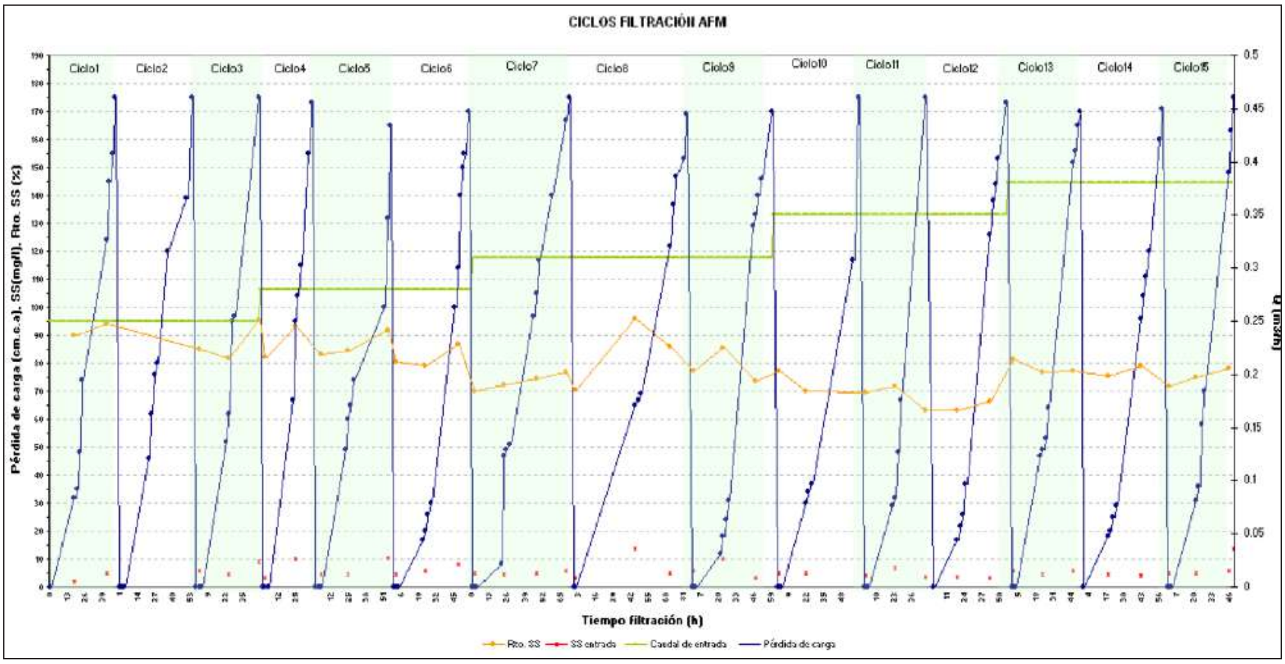
*Independent tests conducted by Spanish Water Company and reported in "Technology del Agua", December 2009, page 47

AFM® municipal waste water performance profile

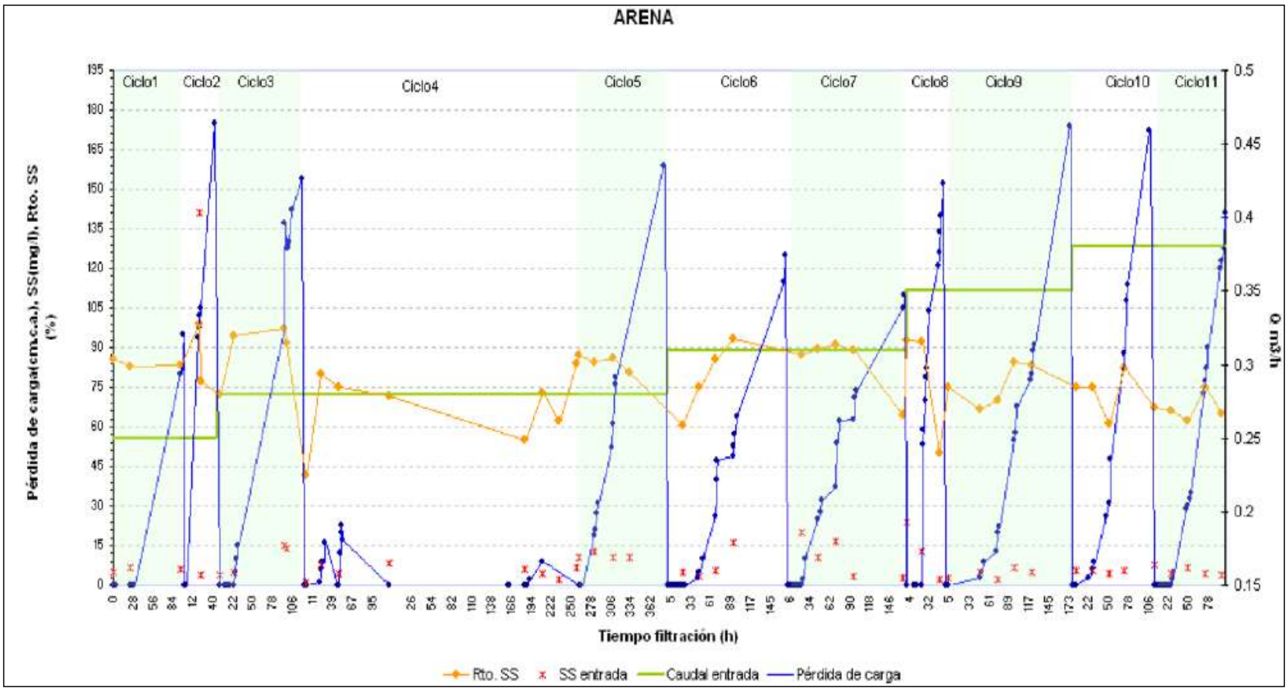
The following data, published by a Spanish water utility, demonstrates the reuse of wastewater. It shows a gravity filter backwash profile of sand compared to AFM® Grade 1. The results confirm the stability and superior performance of AFM® in comparison to the inadequate performance of sand.

The AFM® filter consistently delivers high filtration and backwash efficiency, with each filtration and backwash cylce performing identically. In contrast the sand filter was unstable and the large intervals between the backwash peaks confirm channeling of water through the sand bed.

AFM® Grade 1 filter tertiary treatment



Sand filter tertiary treatment, using 0.6 - 1.2mm sand



Data published: Technologia del Agua, No 334 November 2011, I.S.S.N. 211/8173
Independent tests conducted by Spanish Water Company and reported in Technology del Agua, December 2009, page 47.

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Annex 4: AFM® for removal of ferric, manganese and arsenic

Chemical parameter	Soluble fraction	Insoluble	Typical Drinking water standard	AFM® removal performance
Manganese	Mn^{2+}	Mn^{4+}	50µg/l	>80%
Ferric	Fe^{2+}	Fe^{3+}	200µg/l	>95%
Arsenic	As^{3+}	As^{5+}	10µg/l	>95%

Iron, manganese and arsenic are often found in borehole / tube wells and ground-water at varying concentrations, depending on local geology. The process used by Dryden Aqua to remove the oxidized (precipitated) metals is as follows;

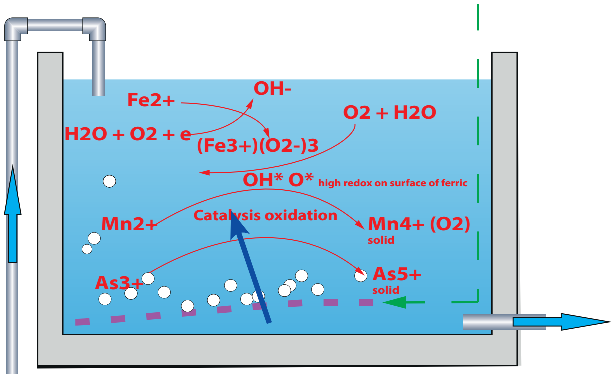
1. Oxidation reactions by aeration to convert metals from soluble ionic form to insoluble oxidized precipitates.
2. pH correction by aeration/oxidation
3. Decantation may be required if the concentrations exeed 5mg/l, if not proceed to AFM® filtration
4. Enhanced coagulation by ZPM cavitating mixer.
5. AFM® filtration to remove the suspended metal oxide solids, there will also be adsorption reactions and surface oxidation reactions further improving the (heavy metals) removal performance. AFM®ng and AFM®s remove oxidized (heavy) metals efficiently, but AFM®s, due to its negative surface charge, is the preferred media if (heavy) metal removal is the main filtration purpose.

Oxidation

Manganese and arsenic are removed by co-precipitation and catalytic oxidation by ferric. For the process to work the ferric concentration needs to be at least 5 times higher than the concentration of either arsenic or the manganese. If sufficient ferric is present, simple aeration of the water for up to 30 minutes will co-precipitate the arsenic and manganese, and the AFM® will remove them.

The process is simple and the arsenic concentration can be reduced to around 10ppb or below, in a sustainable system. If the water is deficient in ferric, this can be compensated by dosing ferric chloride ($FeCl_3$).

If ferric is not used for catalytic oxidation of manganese or arsenic, then an oxidizing agent such as chlorine dioxide needs to be added to the water to raise the RedOx potential to 500mV.



Fine Bubble Air Diffuser by Dryden Aqua

Aeration

The water should be aerated for at least 30 minutes. For a water flow of $50m^3/h$, the aeration rate should also be $50m^3/h$ of air, with a tank volume of $25m^3$ of water. Dryden Aqua manufactures fine-bubble, drop-in air diffuser for this application.

AFM® Operation for metals removal

	AFM® Operation	Notes
Bed depth AFM®	1000mm	Recommended bed depth / AFM® Bulk bed density 1.33kg/l
Run phase water flow	10-15m/h	Slower filtration velocity increases filtration performance
Typical operating pressures	0.1 - 0.5	Do not exceed 0.5bar pressure increase
Backwash water flow	>50m/hr	Backwash ca. 5 minutes, until the water runs clear. No Air purge required

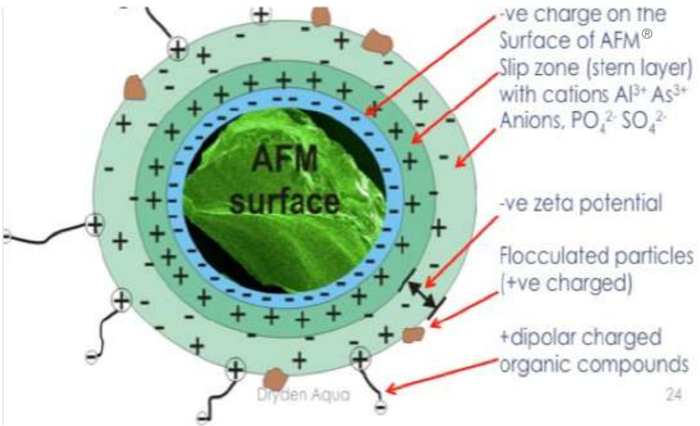
Annex 5: AFM® for removal of phosphate from water

Total phosphate includes consists of three forms:

1. Organic phosphate is found in plankton, algae and bacterial cell biomass,
2. Inorganic phosphate such as struvite, and
3. Soluble reactive phosphate also referred to as ortho-phosphate.

AFM®s will filter particles down to a particle size less than 1µm when combined with pre-coagulation and flocculation. The removal rate of organic and inorganic particulate phosphate will be >95%.

AFM®s will directly adsorb soluble reactive orthophosphate PO_4^{2-} in the AFM®s stern layer. The capacity for adsorption is low, but sufficient to make an impact on residual orthophosphate concentrations after coagulation with ferric, alum or PACl.



Water & waste water treatment to remove phosphate

AFM® provides a sustainable and efficient means of removing phosphate from waste water.

There are three main approaches, all of which involve the precipitation of phosphate to form an insoluble salt by the addition of:

a. ferric to form ferric phosphate
b. magnesium to form struvite
c. lanthanum to form lanthanum phosphate

At Dryden Aqua we have been using (a) lanthanum salts (NoPhos) to remove phosphate in the aquarium and aquaculture industry for over 20 years. Lanthanum is injected into the water at a 1:1 stoichiometric ratio to reduce organic phosphates down to concentrations below 0.05mg/l. NoPhos must be dosed upstream before AFM® using an aggressive, cavitating static mixer, such as our ZPM, to ensure efficient use of NoPhos, and effective ortho-phosphate removal.

The process is simple, reliable and sustainable when lanthanum chloride (NoPhos) is applied. The performance of ferric is less efficient as lanthanum, in order to compensate for the reduced performance, typically a 2:4 excess molar ratio is applied. Higher ferric doses may be required if the water contains elevated levels of suspended solids or dissolved organics.

Ferric chloride is injected into the water via a ZPM or another intensive (cavitating) static mixer. Ideally there should be a 10-minute aerated contact tank. The dissolved oxygen content must be kept above 2 mg/l or RedOx potential above 300mV. AFM®, when combined with pre-oxidation by air, is highly effective for removing ferric, arsenic and manganese and a good solution for the removal of ferric phosphate salt.

Lanthanum (NoPhos) or Ferric Dosing Considerations for Phosphate Removal

- The precipitating salts must be added via an aggressive static mixer, after the pump but before the filter.
- Lanthanum addition is stoichiometric at a molar ratio of 1:1.
- Ferric addition should be at a ratio of 2:4 to 1 molar Ferric to Phosphate. This will give a surplus of ferric for coagulation and other flocculation reactions. The optimum concentration should be determined on a case-by-case, as a high concentration of suspended solids or other chemicals can influence the required ferric concentration.
- Struvite, with a molar ratio NH^3:Mg:PO_4 equates to 1:8:3, this is not stoichiometric but it has been found to provide good results across different water types. Magnesium injection will require adjusting to determine the optimum ratio.
- The chemical reactions are rapid, and a period of 15 minutes is sufficient. Dryden Aqua air tube diffusers are designed to perform the mixing action. It is important to ensure that the dissolved oxygen concentration is above 2mg/l or the RedOx potential exceeds 300mV. Our air tube diffusers can be easily removed for cleaning and descaling.
- Decantation may be required if the phosphate concentration exceeds 5mg/l as PO_4-P. If not, it is a matter of just proceeding to AFM® filtration.
- The AFM® filtration process to remove the phosphate suspended solids will result in adsorption reactions of phosphate PO_4^{2-} directly onto the AFM®s.

Annex 6: AFM® for parasitic egg removal from waste water for reuse in irrigation


Picture: Public Domain

Water can often contain parasites, such as *Cryptosporidium* in drinking water, or nematodes, including the human parasite *Ascaris lumbricoides* in waste water.

Ascaris infects more than 2 billion people worldwide, and poses a particularly acute risk in the developing world, especially among people weakened by poor nutrition or chronic illness. One of the main vectors for the spread of the parasite is the use of waste water, which contains the parasitic eggs, for irrigation.

The parasite egg is large at 40µm, and can be effectively removed by AFM® during tertiary water treatment for reuse applications such as irrigation. Sand will also remove the eggs, but because sand suffers from biofouling and transient wormhole channeling, the infections eggs will break through the filter intermittently. This may explain why almost 1% of the population in Europe and North America, has the nematode infections.

The parasite larvae migrate through the bloodstream, internal organs, and lungs before returning to the intestine, where they can grow up to 35cm in length.

Case Study - Kaipara District Council Location: Mangawhai, New Zealand

We have been monitoring water quality in the Kaipara district in New Zealand since 2009. The municipal waste water is treated by AFM® pressure filters operating at 20m/hr. There are *Ascaris* eggs in the waste water, but none have been detected in the product water. The predictable high performance of AFM® has allowed the waste water to be used for irrigation.

In addition to human parasitic nematodes, there are also nematodes that will infect plants.

Waste water often contains heavy metals and metalloids such as hexavalent chromium and arsenic. AFM® is highly effective at removing these contaminants, significantly more efficient than sand. We have also shown that priority toxic chemicals tend to be hydrophobic and are adsorbed onto particles. Ensuring the highest water quality is essential to prevent the accumulation of toxins in plants and aquifers. AFM® provides a solution to these issues.


Picture: Public Domain


Picture: Public Domain

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Annex 7: AFM® dual-media beds - anthracite & activated carbon

In the following context for dual-media layers, AFM® is used as a synonym for AFM®ng and AFM®s.

Dual media bed with Anthracite

Anthracite, or other porous media may be combined with AFM®, in a dual or multi-media layered filter bed. The choice of media depends on the water treatment application, the required filtrate quality, and operational parameters (e.g. filtration and backwash velocities, backwash cycles, etc.).

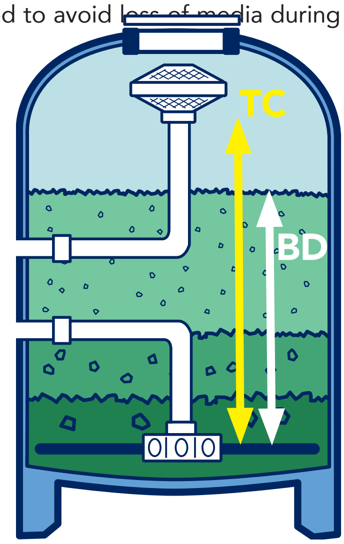
AFM® offers exceptional performance in particle filtration. Under heavy suspended solids (TSS) load >30mg/l (>15NTU), it is recommended to use a layer of anthracite on top of the AFM® to extend the filtration run phase between backwashes.Table 1 on page 10 provides recommendations for AFM® layering when combined with anthracite.

Anthracite is used on top of the filter bed to remove the bulk of (larger) particles, thereby increasing solids loading capacity and extending the run phase duration (Table 3a and 3b, Page 16. This allows AFM® to efficiently remove particles down to 1µm, with 95% removal efficiency. For heavy solids load >30mg/l, a 100mm to 250mm layer of f anthracite, with the following grain sizes, is recommended:

AFM® Grade 1 + 0.6 to 1.6mm Anthracite

AFM® Grade 0 Do NOT add Anthracite as this will mix with the Grade 0 during backwash

At 20% bed expansion for AFM® an approx. 30% bed expansion is to be considered for the above anthracite grain size, or 50% for GAC during backwash. A 200mm (approx. 18%) freeboard from expanded bed is to be considered to avoid loss of media during backwash.



Example AFM® + Anthracite dual media filter (DMF) calculation:

- TC of 1.7m from nozzle plate (or lateral) to top collector (TC)
- 1000mm AFM® Grade 1 filtration layer
- 100mm Anthracite layer
- 20% backwash bed expansion for AFM® and 30% backwash bed expansion for Anthracite

Expanded BD: TC x 0.8 (freeboard) = [(BD, AFM® x 1.2) + (BD, Antrhacite x 1.3)]

1.7m x 0.8 = 1.36 = [(1m x 1.2) + (0.1 x 1.3)] = 1.33

$$\text{BD AFM}^{®}\text{+Anthracite/GAC} = \frac{\text{TC x 0.8}}{\text{(BD AFM}^{®}\text{x1.2) + (BD, Anth.x1.3)}} = \frac{\text{1.7m x 0.8}}{\text{(1 x 1.2) + (0.1 x 1.3)}} = \text{1.022m}$$

$$\text{In reverse, TC} = \frac{\text{[(BD AFM}^{®}\text{ x 1.2) + (BD, Anth. x 1.3)]}}{0.80} = \text{1.67m}$$

Dual media bed with GAC and use of Disinfection / Oxidation

AFM® functions effectively as a support layer for activated carbon, particularly in applications where bacteria are released as floc. In these cases, AFM® captures the flocculated material and prevents its release into the treated water.

AFM® can also be combined with activated carbon when chlorine, ozone or other oxidizing agents are used for disinfection purpose. The typical layering consists of AFM® Grade 1 beneath a 100 to 200mm layer of GAC. While GAC layers up to 200mm serve well as catalysts for the removal of chlorine and similar oxidants, thicker layers are not recommended, as they may promote biofouling of the carbon media.

The following reactions will occur on the surface of activated carbon when exposed to free chlorine. In the first stage, the hypochlorus acid will oxidize the surface of the carbon to form very active CO· sites.

Stage 1. $HOCl + C\cdot \rightarrow CO\cdot + H^+Cl^-$

The chlorine will also react with chemicals in the water such as ammonia (NH_3) to form inorganic chloramines such as mono-chloramine, and organic matter to form organic chloramines.

Mono-chloramine $HOCl + NH_3 \leftrightarrow NH_2Cl + H_2O$

Depending on the pH and the concentration of organic compounds, additional inorganic chloramines, such as dichloramine and trichloramine, may also form. Organic chloramines are typically produced through reactions with proteins and amino acids.

Activated carbon can catalytically oxidize chloramines in the presence of chlorine through the following reactions:

Stage 2a $NH_2Cl + H_2O + C\cdot \leftrightarrow NH_3 + CO\cdot + H^+ + Cl^-$

Stage 2b $2NH_2Cl + CO\cdot \leftrightarrow N_2(g) + C\cdot + H_2O + 2H^+ + 2Cl^-$

These reactions result in the formation of nitrogen gas, hydrochloric acid, and water, and in the presence of organic matter, also carbon dioxide.

AFM® is frequently used in combination with activated carbon in indoor swimming pool treatment systems, where it supports the reduction of combined chlorine levels. It is also used in biological activated carbon (BAC) filters for drinking water treatment, where it helps to reduce the risk of bacterial contamination in the distribution network.

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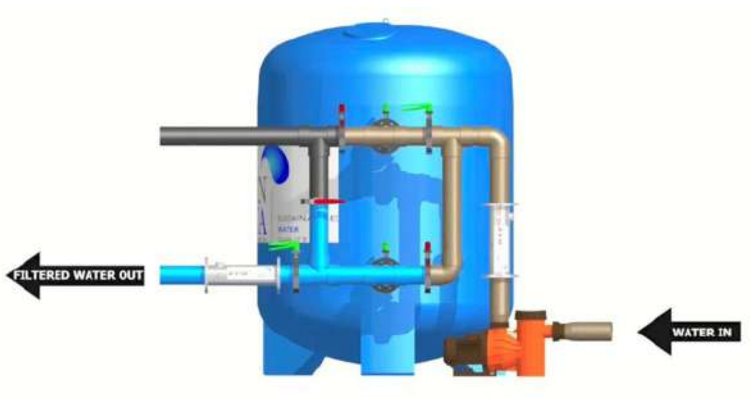
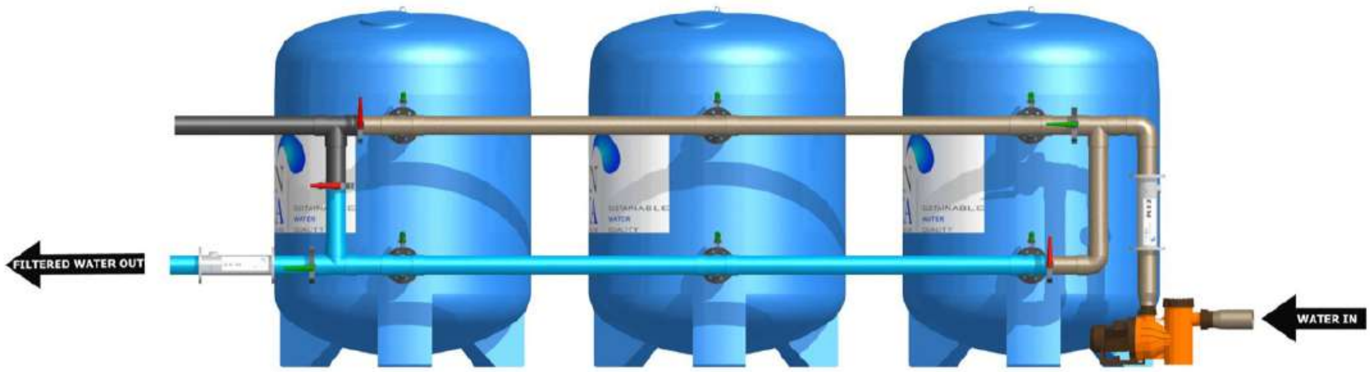
Annex 8: pressure filter system schematics

Single filter 5 valve configuration

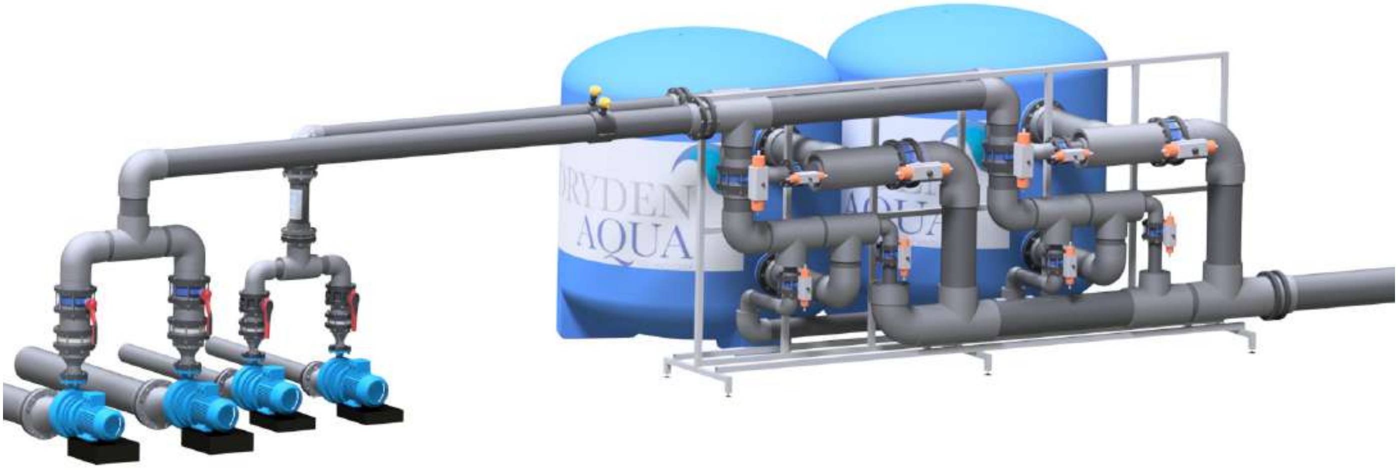


Single filter BESGO valve configuration

Multi filter configuration



Multi filter configuration with pneumatic actuated valves and separate backwash pumps



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Annex 9: filter media specification terms

Granular filter media

- A term used to describe particle shape and particle size distribution characteristics.

Particle shape

- There are 3 ratios that are used. These are expressions of the dimensional (3D) values of the particles – length, width and depth. Being ratios, the values given for these expressions are dimensionless numbers.

Sphericity

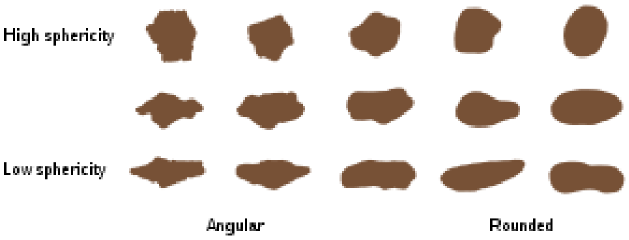
- A measure of the degree to which a particle approximates the shape of a sphere or a cube and is independent of its size. The sphericity of a sphere is 1.0. The adopted standard for the sphericity of glass grains is that the value should be ≥ 0.7.

Roundness

- A measure of the sharpness of a particle's edges and corners. This relates to angularity. Again, this ratio is a measure of the degree to which a particle approximates the shape of a sphere or a cube. The roundness of a sphere or cube is 1.0. The adopted standard for the roundness of glass grains is that the value should be ≥ 0.6.

Aspect ratio

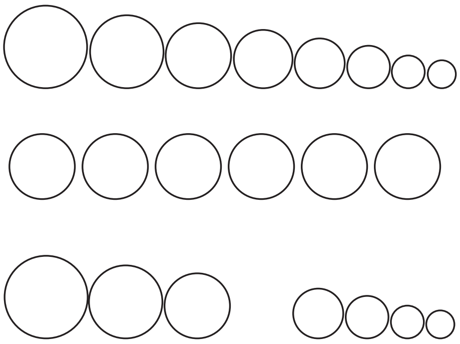
- A measure of the flatness and elongation of the particle. This ratio is an expression of the length and the depth of the particles. Again, this ratio is a measure of the degree to which a particle approximates the shape of a sphere or a cube. The flatness ratio of a sphere or cube is 1.0. The adopted standard for the flatness of glass grains is that the value should be ≤ 5:1. In other words, the average flatness value for the measured sample of particles should indicated that particle length is less than 5 times the particle depth.
- The most simplistic consideration of these ratios is:
    - Sphericity = width / length
    - Roundness = depth / width
    - Aspect = length / depth
- All 3 of these ratios provide an indication of how well the granular material will perform as a filter media. The aspect ratio is particularly important in that very flat and elongated particles can, over prolonged backwashing, build up in the filter bed and create a ‘mirror’ layer. This ‘mirror’ layer can detrimentally affect the hydraulic flow performance, and hence the overall filtration performance of the filter and may lead to hydraulic short-circuiting.



- The diagram right illustrates particle shape characteristics of sphericity in relation to roundness. The more the shape complies with the top right representation then the closer the 2 shape ratios are to 1.0. The more the particle shape complies with the bottom left then the more angular the particles become. This also illustrates the need to consider flatness.

Particle size distribution.

- An expression of how uniformly or non-uniformly a granular material is graded.
- The 3 main types are:
    - Well graded in terms of the spread of particle sizes.
    - Uniformly graded in terms of the same particle size.
    - Gap graded.



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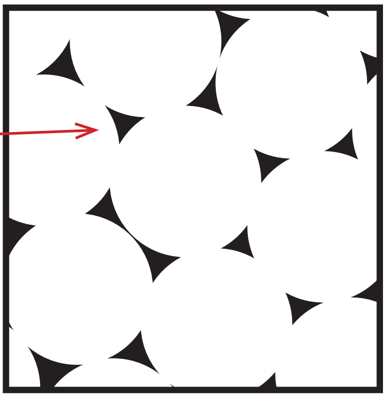
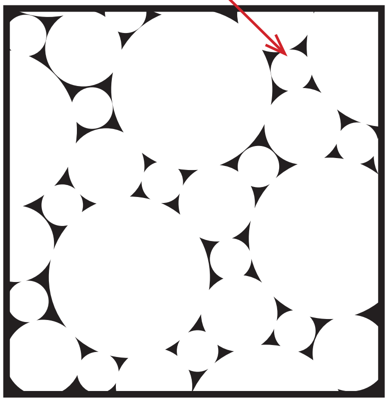
Uniformity Coefficient (UC):

- A value describing the range of grain sizes that are present in a sample. The lower the UC value then the more tightly graded the material is in terms of size. The more uniformly graded the media then the more uniform the interstitial porosity:



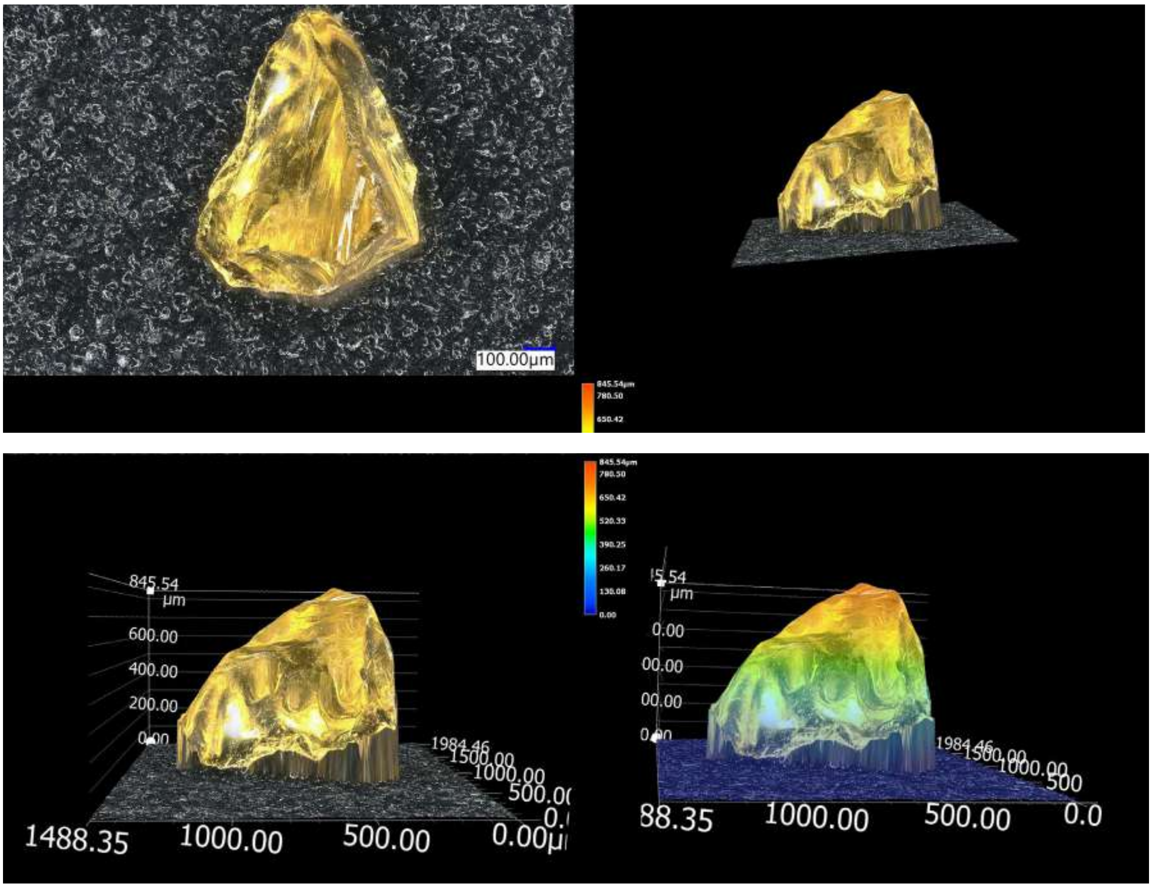


- This uniformity means, for example, that it is easier to predict the filtration and hydraulic performance of a filter. Engineers would tend to use tightly graded media to address specific filtration needs. They would specify Uniformity Coefficient and Effective size values.
- Where the media is well graded in terms of size, the interstitial porosity becomes much more variable. This results in improved filtration performance in terms of the size range of waste particles removed.
- UC calculated by using the following equation:
    - D60/D10 = UC
    - Where D60 = mesh size (mm) at which 60% of the media passes through
    - D10 = mesh size (mm) at which 10% of the media passes through

Effective Size (ES)

- Effective site (ES) = D10 = mesh size (mm) at which 10% of the media passes through
- Effective size is a value basically describing the average of grain sizes present in a sample. This is not to be confused with D50 which is often considered to be the average particle size in a sample.

Topography of an AFM® grain



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Annex 10: glossary of technical terms in water treatment

TSS - Total Suspended Solids(1)

Total Suspended Solids (TSS) refers to the portion of total solids retained on a no-ash glass fiber filter. A measured volume of waste water is filtered using a pre-weighed, wetted disc under suction. The filter with residue is dried at 103–105°C for one hour, cooled, and re-weighed. The weight difference gives the TSS in mg/l. This test indicates the potential for solids removal by settling, floating, or filtering.

(1) Norms applicable for the determination of total suspended solids: ISO 11923:1997, DIN EN 872:2005-04, ASTM D5907-18

TDS - Total Dissolved Solids(2)

Total Dissolved Solids (TDS) are the solids in the filtrate from the TSS test. The liquid is collected in a weighed dish, evaporated at 180 ± 2°C for an hour, then re-weighed. The weight difference gives the TDS in mg/l. This quick, low-cost test reveals chemical or biological solids that cannot be removed by settling, floating, or filtration.

(2) Norms applicable for the determination of total dissolved solids: DIN EN 15216:2008, ASTM D5907-18

NTU - Nephelometric Turbidity Unit

Nephelometric Turbidity Units (NTU) measure light scattered at 90° from an incident beam to assess turbidity—fluid cloudiness caused by tiny suspended particles. Turbidity is a key water quality indicator. While larger particles may settle quickly, smaller or colloidal ones remain suspended, making the liquid appear hazy.

SDI - Silt Density Index

The Silt Density Index (SDI) measures water's fouling potential before reverse osmosis by tracking how quickly a 0.45µm filter clogs under 206.8kPa (2.1bar). It reflects the average percentage drop in flow rate over a set time, typically 15 minutes.

Nominal Filtration

Ability to extract (filter out) more than 90% of particles on any given particle size.

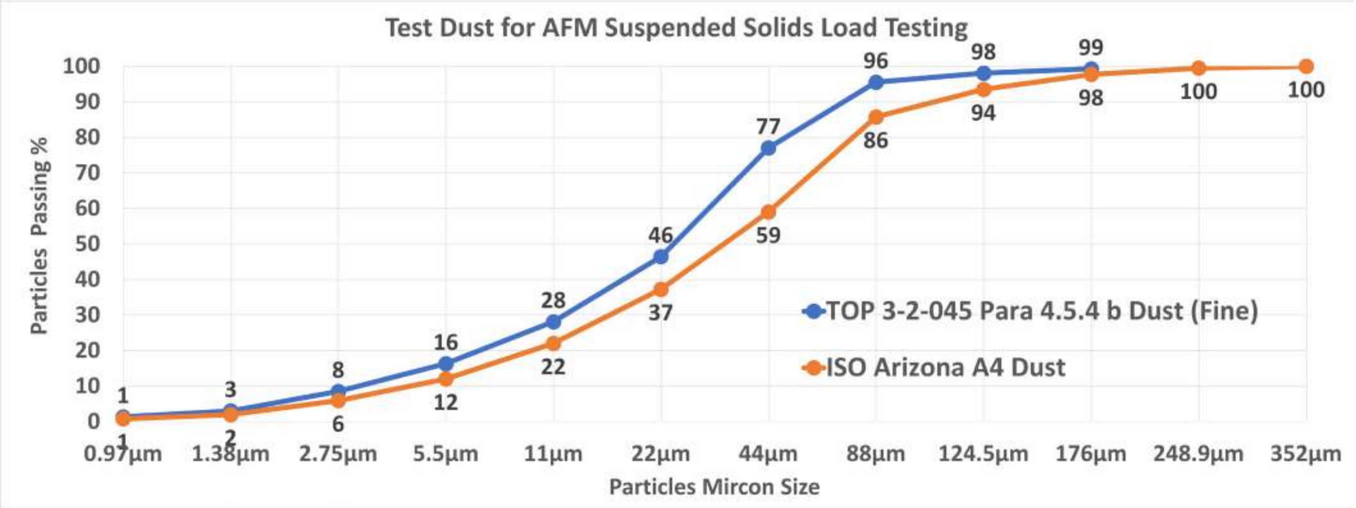
Absolute Filtration

Filtration where all particles larger than a specified pore size are completely removed. The filter has a precisely controlled pore size, ensuring no particles above that size can pass through.

Test Dust for AFM® & other Filter Media Performance Testing

Test dust is used in filtration testing to provide a consistent and repeatable way to measure a filter's efficiency, capacity, and pressure drop. It simulates real-world particles and ensures standardized performance comparisons across filters.

Dryden Aqua uses ISO 12103-1 Arizona A4 test dust (chapter 6, Filtration Mode, page 13–17) for its AFM® and other filter media performance testing. For its filtration suspended-solids loading-capacity testing, they use both ISO 12103-1 Arizona A4 and Top-3-2-045:2007 Paragraph 4.5.4 B test dust (see Filtration Suspended Solids Loading Capacity, page 16–17, Tables 3a & 3b).



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