AFM®
ACTIVATED FILTER MEDIA

DRYDEN AQUA
SUSTAINABLE WATER QUALITY

AFM® Application in Mammal & Bird Systems

Refer to the AFM® Information for Use document (IFU) for more details and performance data

- Intake/supply water applications
- Freshwater applications - Hippo/ Elephant/ponds
- Chlorinated/Ozonated Marine Mammal Systems
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- Examples of Standard system drawings
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GENERAL - AFM® for use in Aquarium/Zoo Filtration Systems

Preamble

Dryden Aqua's philosophy is prevention rather than cure. AFM has been developed as a bioresistant media with surface activation to ensure optimal adsorbtion of specific contaminants. Our philosophy is to remove as much organic material as possible from the water and to efficienctly evacuate it from the filters.

Source Water

Water is never the same from any source. Different sources will contain different contaminants and, irrespective of contaminants, may have very different water chemistry. Filtration of incoming water is key to the biosecurity of any aquarium or aquaculture facility. The bioresistance, mechanical filtration performance and long term stability of AFM® media offers a simple, one stop treatment solution for a large proportion of incoming water filtration challenges. AFM® is not however the answer to all problems and, a knowledge of the incoming water chemistry is necessary in order to specify any complementary treatment that might offer e.g. viral protection or, the ability to remove heavy metals.

Recirculation Systems

Many LSS schematics and filtration practices have evolved over decades to overcome inherent system's weaknesses. In different countries these have evolved in different directions and, in many cases have become part of a design culture. The fact that these have evolved in different ways in different continents demonstrates that there are a number of approaches to filtration of aquarium water that can work. The schematics that feature in this document should therefore be used for guidance only, in the knowledge that other approaches are possible.

AFM® can also offer significant advantages by reducing oxidation demand and noxious disinfection by-products in chlorinated systems.

AFM® is only one of a series of components that contribute towards the efficiency of any LSS. AFM® cannot substitute for biofiltration but, if correctly used, its efficiency in organics removal will substantially reduce the load on biofilters, allowing for smaller biofilters to be installed (i.e. land mammal systems that include fish and therefore need biological filtration as part of the overall system). It will also significantly reduce oxidation demand, with consequent reductions in ozone demand and reliance on protein skimmers. (See the YouTube video - AFM® Aquaria - E-learning video)

As a result of AFM®'s filtration finesse, it is also possible to substantially reduce the turnover rates that have traditionally been applied in LSS, in certain scenarios, and to benefit from substantial energy savings.

Backwash velocity is the key to performance of any media filter and AFM® will provide a significant performance advantage over sand or non-activated crushed glass media. Even in systems where backwash flows are compromised AFM will still perform substanitally better than all other medias, but it will not perform as to full potential.

N.B. Media layering can be tailored to your specific system. All recommendation in this document are generalised to the standard LSS systems we have encountered world wide. If you have a specific challenge, we are more than happy to help you determine the best layering for your systems requirements

Applications & Benefits of AFM® use in Aquaria/Zoos.

Application	Water source	Advantages
All Systems		• AFM® offers increased media lifespan (10 - 20 years)
Raw Water intake	• Open seawater. • Borehole or sub surface beach	• Up to 1µ filtration of incoming water. • Helps to reduce heavy metal content in incoming water. • Stable filtration quality without clogging. • Dramatically improves biosecurity • Return on capital from savings is always under 2 years and often under 1 year.
Animal systems i.e. elephants etc	LSS Recirculation system	• AFM® offers stable filtration quality without clogging. • AFM® reduces turbidity, which improves water clarity. • AFM® reduces oxidation demand and ozone dosing requirement in ozonated systems. • AFM® helps stabilise pH and reduces requirement for chemical pH correction. • AFM® will not support bacterial growth/unwanted pathology, therefore improves biosecurity. • AFM® offers reduced energy and backwash water consumption.
Chlorinated Mammal Systems	LSS Recirculation system	• AFM® offers stable filtration quality without clogging. • AFM® will not support bacterial growth. No bacteria => no biofilm => **reduced oxidation demand** => reduced chemical consumption => reduced requirement for pH correction. • No biofilm = **reduction in trichloramine & Trihalomethane production (THM's)**. These are the major causes of eye and respiratory issues in mammal systems. • AFM® reduces turbidity, therefore improves water clarity. • AFM® offers reduced energy and backwash water consumption.

AFM® will not support bacterial growth thereby improving pH stability

Sand filters are enclosed vessels and the available oxygen in the circulating water is insufficient to satisfy the needs of the autotrophic bacterial nitrification process. Available oxygen is consumed and, a reduction in pH is therefore inevitable. This initial reduction in pH then triggers a cascade effect that results in anaerobia in the filter bed and colonisation by unhealthy heterotrophs that exert even further downward pressure on pH. This process may take 3 to 6 months (depending on temperature and load) before it starts to impact on system performance but, it is inevitable in any sand filter. Sealion systems are particularly susceptible to this happening.

With AFM®, bacteria cannot settle and so there is no colonisation of the filter, no biofilm development, no increase in oxygen demand, and no pressure on pH.

Reduced water consumption during backwash

Due to sand's density and the biological fouling that takes place in a sand filter, backwash flows of 50 to 60m/hr ($m^3/m^2/hr$) are required to effectively fluidise the bed to evacuate material trapped during the run phase. However, even at these flows, research has shown that a maximum of only 77% waste evacuation from the surface layers is achieved (Assessment methodology of backwash in pressurised sand filters, Fábio P. de Deus et.al.). To achieve a 15% bed expansion, as required to effectively remove the 77% debris levels, a flow of 70m/hr is required (Study of the performance of Rapid sand filters after backwashing by Raw Water, Ahmed Fadel, et al.). Bacterial settlement is quickly followed by biofilm development which binds sand grains and prevents effective backwashing.

AFM® is less dense than sand and is bio-resistant. No bacteria => no biofilm => the media remains fluid => more efficient evacuation of >95% of particles during backwash. This is achieved with as little as 50% of the water required to backwash sand.

For many systems, especially in closed systems where salt is lost in backwash, Backwash water savings result in substantial water and salt cost savings.

Reduced energy consumption

As media bed filters start to capture particulates, the pressure differential between inlet and outlet increases, and this differential results in an increased energy consumption. AFM® captures particles not only by mechanical entrapment, but also by loose electrostatic and Hydrophobic adhesion of particles to the glass surface. As a result, filtered particles are retained throughout the bed and there is less pressure loss, while acheiving more filtration of fines. The absence of biofilm and resultant clogging ensures that the pressure differential range remains consistent throughout AFM®'s 15 to 20 year lifespan.

Typical sand filter pressure loss throughout the run phase will be 0.3 - 1 Bar. This compares with 0.2 - 0.5 Bar max for AFM®.This equates an extra 2 - 3m of head and a substantial annual running cost. Pressure loss will also increase dramatically once sand media starts to clog.

Doubling the pressure quadruples the energy consumption!

To show our dedication to sustainability and practice what we preach, AFM is wholy made by sustainability practices:

AFM® is manufactured from 100% recycled bottle glass from the region

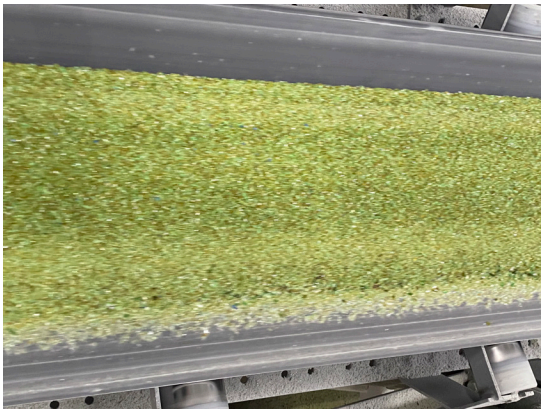
Waste (metal, paper, plastic) and non-target product (flint glass, CSP, fines) are separated and recycled or used in other industries. Sludge is responsibly disposed of (incinerator)

The production process is 100% energy and water self-sufficient, using rainwater in a closed-loop filtration system and up to 850,000 kWh self-generated solar power per year

Once AFM® has reached its end of life, it can be returned to the Dryden Aqua factory where it will undergo the same process of cleaning and decontamination and is re-manufactured into new AFM®

Raw material in

AFM out



AFM® application in LSS for Aquaria and Zoos

Application Type	Associated Processes	AFM® Type and Grades	Typical velocity m/hr		% reduction
Zoo systems			min	max	
Hippo systems	• Pre-screening of large particulates i.e. straw, grasses, floating faeces, by wedge-wire screens or drum/belt filters • Good water circulation in exhibit to re-suspend particulates and to reduce dead-spots • Good biological filtration loop • 1.5 hours minimum turnover through filtration and biological filters • Coagulation/Flocculation options • NoPhos dosing prior to filters for Phosphate removal	• AFM®ng Grade 1 - 60% - 50% of remaining media depth • AFM®ng Grade 2 - 40% - 50% of remaining media depth • AFM®s Grade 3 to top of laterals	10	15	95%
Land mammal systems e.g. Elephants	• Pre-screening of large particulates i.e. straw, grasses, floating faeces by wedgewire screens or drum filters • Aeration within the ponds to encourage water movement and pre-oxidation of particulates	• AFM®ng grade 1 - 60% - 50% of remaining media depth • AFM®ng grade 2 - 40% -50% of remaining media depth • AFM®s grade 3 to top of laterals	10	20	95%
Polar bear, Tigers, Otter systems	• Drum filter/wedgewire screen for removal of hair • NoPhos dosing prior to filters for Phosphate removal • Good water circulation in exhibit to re-suspend particulates and to reduce dead-spots	• AFM®ng grade 1 - 60% - 50% of remaining media depth • AFM®ng grade 2 - 40% - • 50% of remaining media depth • AFM®s grade 3 to top of laterals	15	30	95%
All Chlroinated systems	• Optional for enhanced performance •DA-GEN (chlorine generation by electrolysis) •APF coagulation & Flocculation ensures particle removal down to 0.1µ. •ACObio dosage after filters for all outdoor exhibits				

Note:

- For instruction on use of *ACO* see Dryden Aqua Downloads website - ACO for aquariums
- For air breathing mammals in any chlorinated system both standard and ACObio are suitable although standard ACO will be slightly more effective. In fish and invertebrate systems and/or systems with biological filters you should only use ACObio.
- DA Gen - Advanced Oxidation. The most effective reduction of orgnics without the harmful byproducts such as chloramines and THM's. Requires on 0.1mg/l of free chlorine for effective and safe water quality control. Free radicals do the work that is currently been done by high chlorine dosing.

Chlorinated Marine Mammal & Bird Systems

Points to consider

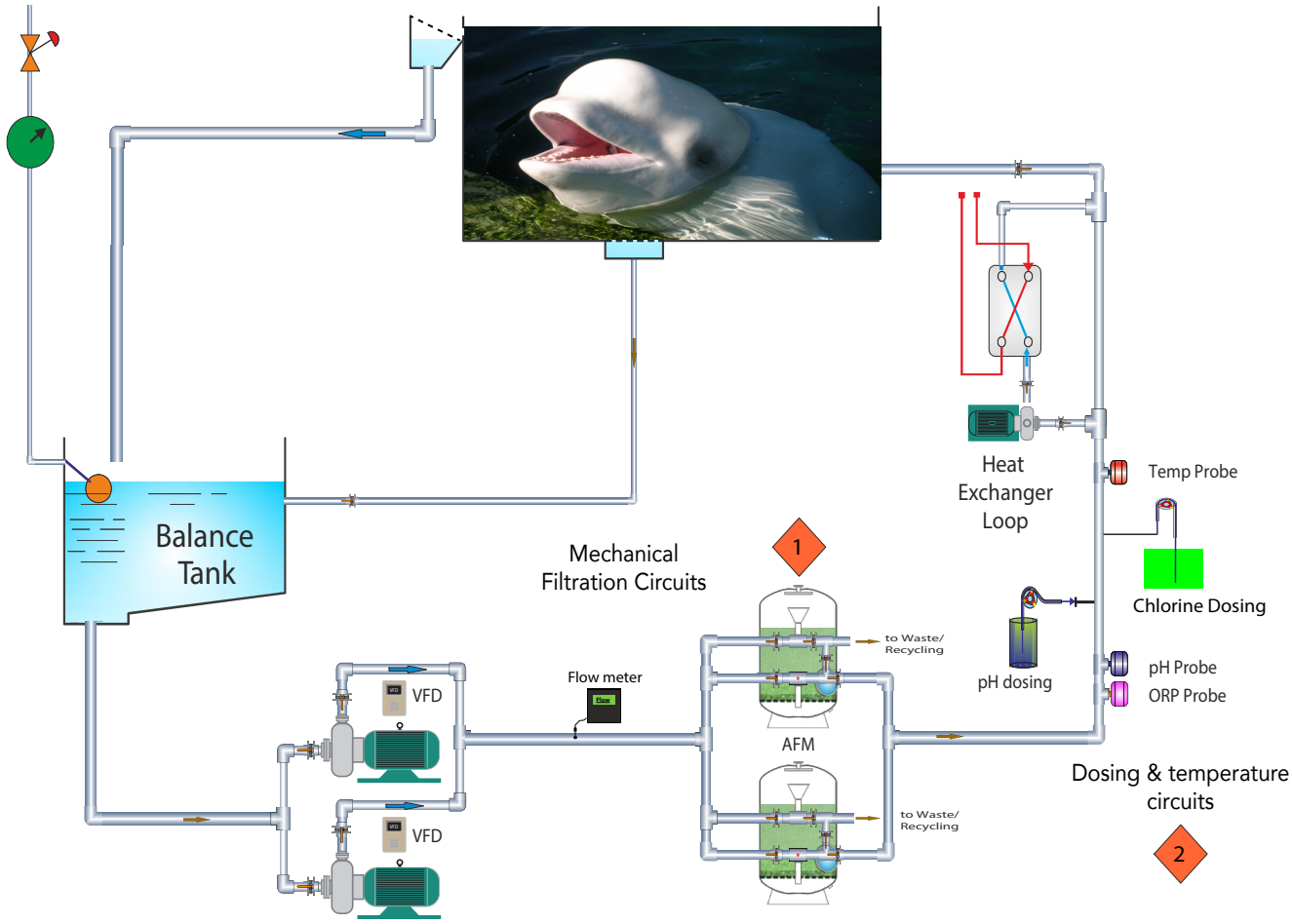
- The Dryden Aqua swimming pool video is for humans but, the same chemical principles apply to marine mammals and birds. As aquatic mammals and birds stay in the water for longer than swimmers, bioloads are much higher, with proportionally higher production of chlorine disinfection by-products such as chloramines and tri-halomethanes (THMs). Eye sensitivity is extremely high in pinnipeds and dolphins & penguins are highly susceptible to lung infections. Good practice is therefore even more important for animal facilities than humans. See video - Chlorinated systems
- Chlorine dosing - AFM®ng offers dramatic reductions in chlorine consumption and disinfection by-products that directly impact on animal health. Chlorine dosage and pH control must be fully automated to ensure adjustment to changing diurnal loads, different loads during feeding and changes in biomass.

Application Type	Associated Processes	AFM® Type and Grades	Typical velocity m/hr		% reduction

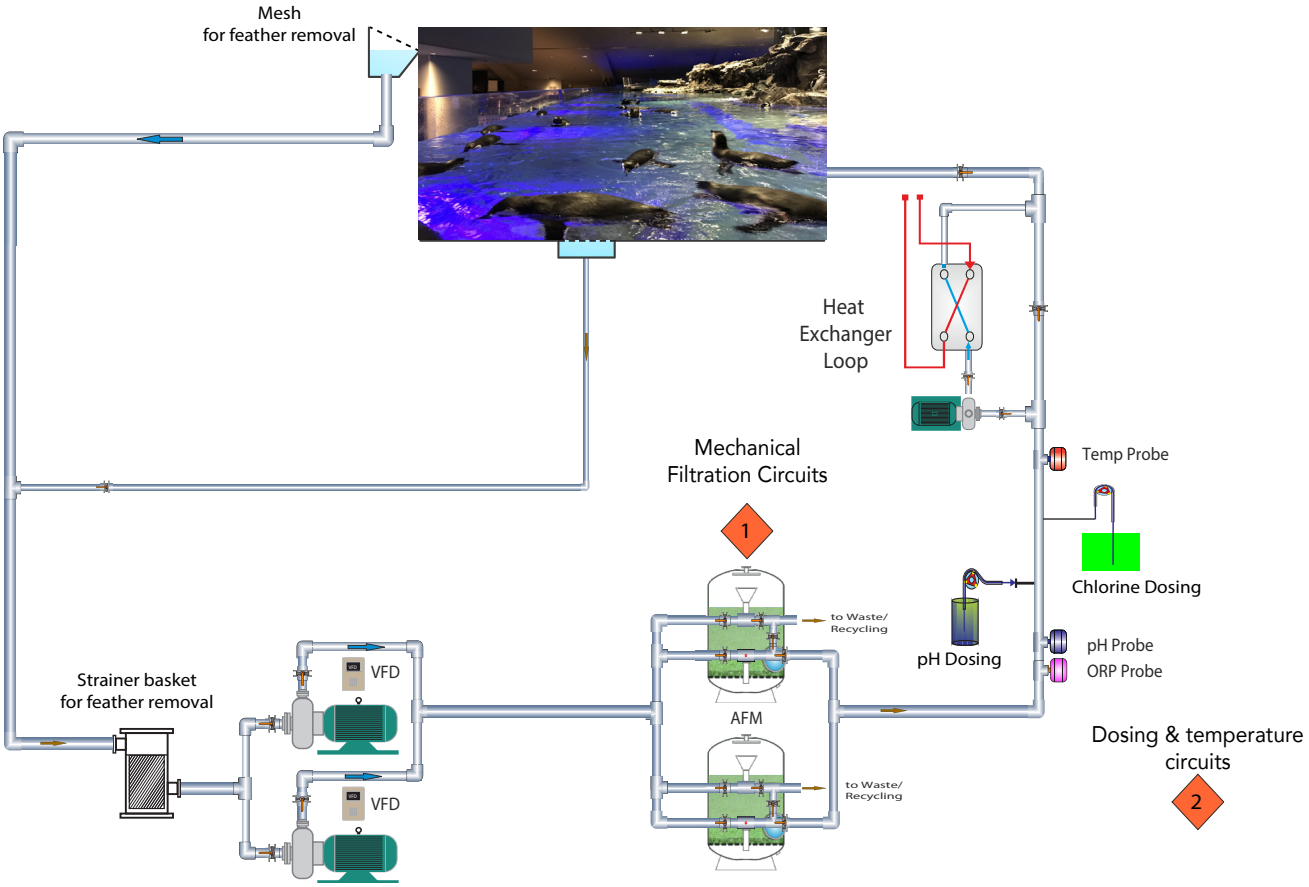
Penguin systems	• Pre-screening of large particulates i.e. feathers during the moulting season, by strainer baskets at the pool and strainer baskets before pumps
	• Good water circulation in exhibit to re-suspend particulates and to reduce dead-spots
	• Optional for adhanced performance
	  • NoPhos dosing prior to filters for Phosphate removal
	  • APF coagulation & Flocculation ensures removal down to 0.1µ
	  • ACO dosage after filters for all outdoor exhibits
		• AFM®ng grade 1 - 60% - 50% of remaining media depth
		• AFM®ng grade 2 - 40% - 50% of remaining media depth
		• AFM®s grade 3 to top of laterals
			10	20	95%

Chlorinated/Ozonated Marine Mammal Systems	• Good water circulation in exhibit to re-suspend particulates and to reduce dead-spots
	• Optional for adhanced performance
	  • NoPhos dosing prior to filters for Phosphate removal
	  • APF coagulation & Flocculation ensures removal down to 0.1µ.
	  • ACO dosage after filters for all outdoor exhibits
		Filters <800mm diameter
		• AFM®ng grade 1 - 50% of remaining media depth
		• AFM®ng grade 2 - 50% of remaining media depth
		Filters >800mm diameter
		• AFM®ng grade 1 - 60% - 50% of remaining media depth
		• AFM®ng grade 2 - 40% - 50% of remaining media depth
		• AFM®s grade 3 to top of laterals
			10	30	95%

Simple diagram of a Marine Mammal system



Simple diagram of a Penguin system - sample



AFM® for phosphate removal from water

Total phosphate analyses include phosphates in three forms;

1. Soluble reactive phosphate is referred to as free phosphates or orthophosphates.
2. Organic phosphates are found in plankton, algae and bacterial cell biomass.
3. Inorganic phosphates bound up in rocks and minerals or, compounds such as struvite.

Total phosphate can be analysed by wet chemistry in the lab but it is difficult to analyse in the field.

Orthophosphates are easily analysed in the field, but are literally only the tip of the iceberg. Organic phosphates are contained within the mitochondria of all cells and fuel the mechanism (ADP <=> ATP) for nutrient transport across cell membranes. All algae, bacteria and animal feed therefore contain phosphates. Oxidation or UV lysis of cell membranes will therefore simply release bound organic phosphates into the water as free orthophosphates.

In view of the above, any strategy for phosphates control must include both effective filtration and removal of organics, as well as control of free phosphates.

Points to consider:

- "Mature" sand filters will perpetuate rather than reduce phosphate levels, as biological activity in sand filters is uncontrolled.
- Aggressive use of ozone for sterilisation rather than flocculation will liberate organic phosphates into solution.
- UV irradiation will lyse algal and bacterial cells with the same effect.
- AFM®ng will provide stable filtration of 95% of particles >1µ and will remove a huge proportion of the organic phosphates that might otherwise be transformed into free phosphates.
- When coupled with pre-coagulation and flocculation, filtration efficiency can be further improved to 0.1µ.

In summary, prevention is better than cure and phosphates management starts by efficient cropping of organics by good AFM® filtration.

Water treatment to remove Orthophosphates

AFM® provides a sustainable and efficient primary means of removing phosphate from wastewater.

Animal systems can also have high phosphates input from the feed. AFM® filtration will efficiently remove bound phosphates from most sources but, will not, on its own, remove free phosphates from solution.

Chemical coagulation can, however, be used in conjunction with AFM® for removal of orthophosphates from the water. For animal systems, we recommend the use of our NOPhos product, which is lanthanum chloride based and can even be safely used with corals, so there is no safety concerns using it in mammals systems. The lanthanum chloride binds the phosphate into lanthanum phosphate extremely efficiently, making is removal by AFM a simple task, however if used in filters systems with sand media, the lanthanum phosphate will quickly bind up the sand into a concrete like block, making filtration impossible.

At Dryden Aqua we have been using Lanthanum chloride (NoPhos) to remove phosphate in the aquarium and aquaculture industries for over 20 years. NoPhos is dosed into the water at a 1:1 stoichiometric ratio to bind free phosphates as lanthanum phosphate. 10ml of NoPhos will remove 1 g of phosphates. NoPhos should be dosed by dosing pump into the water prior to the AFM® filters using an aggressive cavitating static mixer such as a Dryden Aqua ZPM or dosing just before the pump, this ensures maximum efficiency in coagulation and the most economic use of NoPhos. The process is simple, reliable and sustainable when Lanthanum chloride (NoPhos) is used.

Ferric chloride is sometimes used. It is cheaper but, less efficient than lanthanum in non-chlorinated systems and is not compatible with chlorination.

Both Lanthanum and Ferric phosphates will rapidly clog any sand filter. As long as backwash protocols are respected with a slightly higher 45 - 50m/hr backwash velocity for iron/phosphates removal, then AFM® will never clog.

Dryden Aqua fine bubble air diffusers

AFM® dual-media beds - Activated Carbon

In the following context for dual-media layers, AFM® is used as synonym for AFM® ng and AFM® s. Activated Carbon is used ot help reduce chlorine residuals.

At 20% bed expansion, for AFM®, a 50% bed expansion must be used for Anthracite or GAC during backwash. A 17.5% free-board from expanded bed is to be considered to avoid loss of media during backwash.

Dual media bed with Activated Carbon and use of Disinfection/ Oxidation

AFM® can be combined with activated carbon when chlorine or other oxidising agents are used for disinfection purpose. The activated carbon bed will usually be AFM® Grade 1 with a 50 mm (to a maximum of 100 mm) layer of activated carbon. It is very important not to use more to prevent biofouling of the activated carbon.

AFM® is often used in combination with activated carbon for covered marine mammal and bird water treatment systems, to reduce the combined chlorine concentration.

The new AFM® factory in Switzerland

Dryden Aqua System recommendations

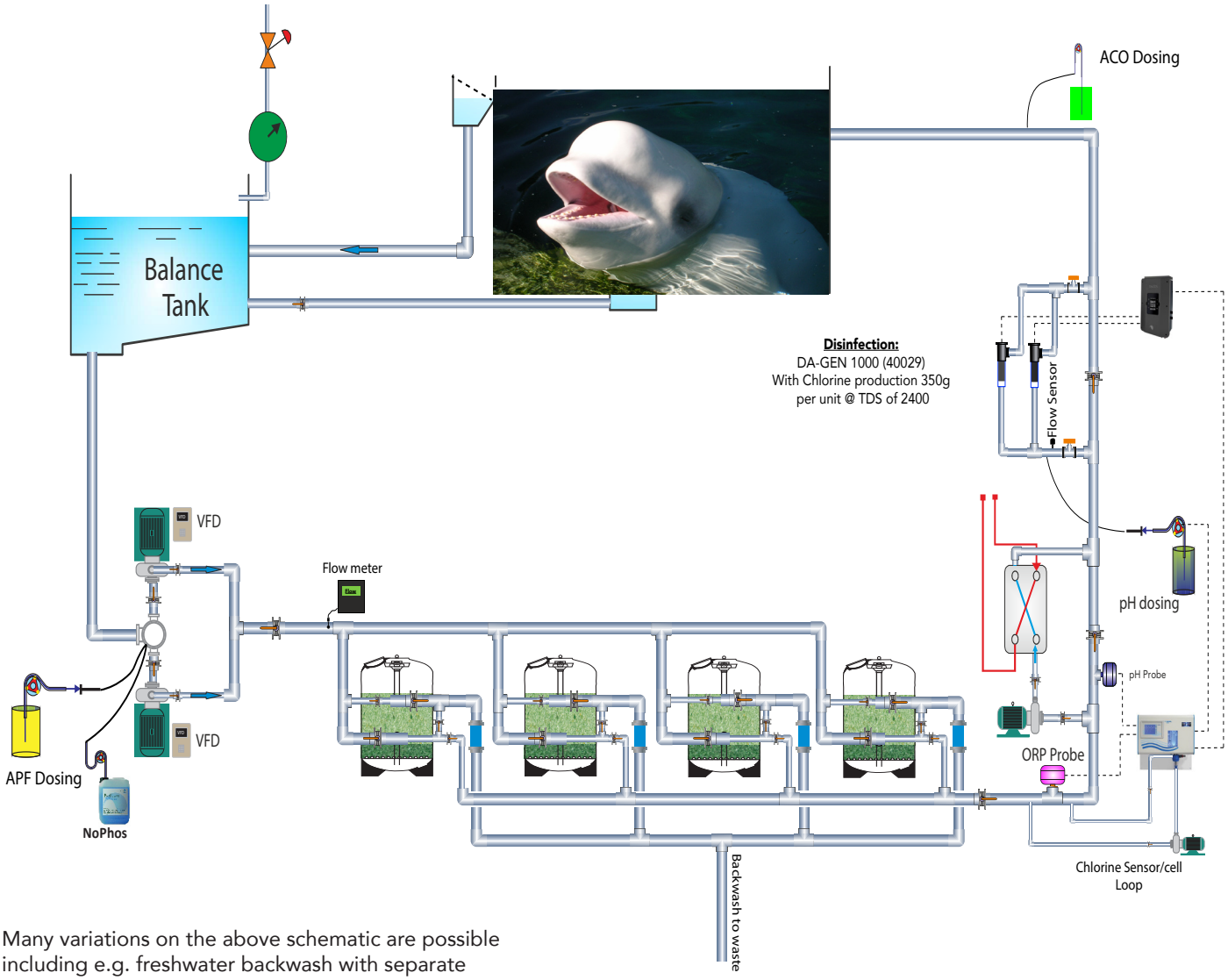
Dryden Aqua has more than 40 years of experience in the aquarium field. During these many years of operation and design of aquarium systems we have developed our own thoughts on the design of systems and the below two drawings respresent the systems we would (and do) recommend to our clients if starting from scratch.

Our objective is to develop sustainable designs to optimise all processes:

- to reduce the requirements for high levels of chemical dosing i.e. chlorine, ozone, peroxide
- to reduce water and electricity consumption.
- to provide stable, premium water quality for the animals in the exhibits.

Please feel free to contact us if you would like to discuss these designs in more detail.

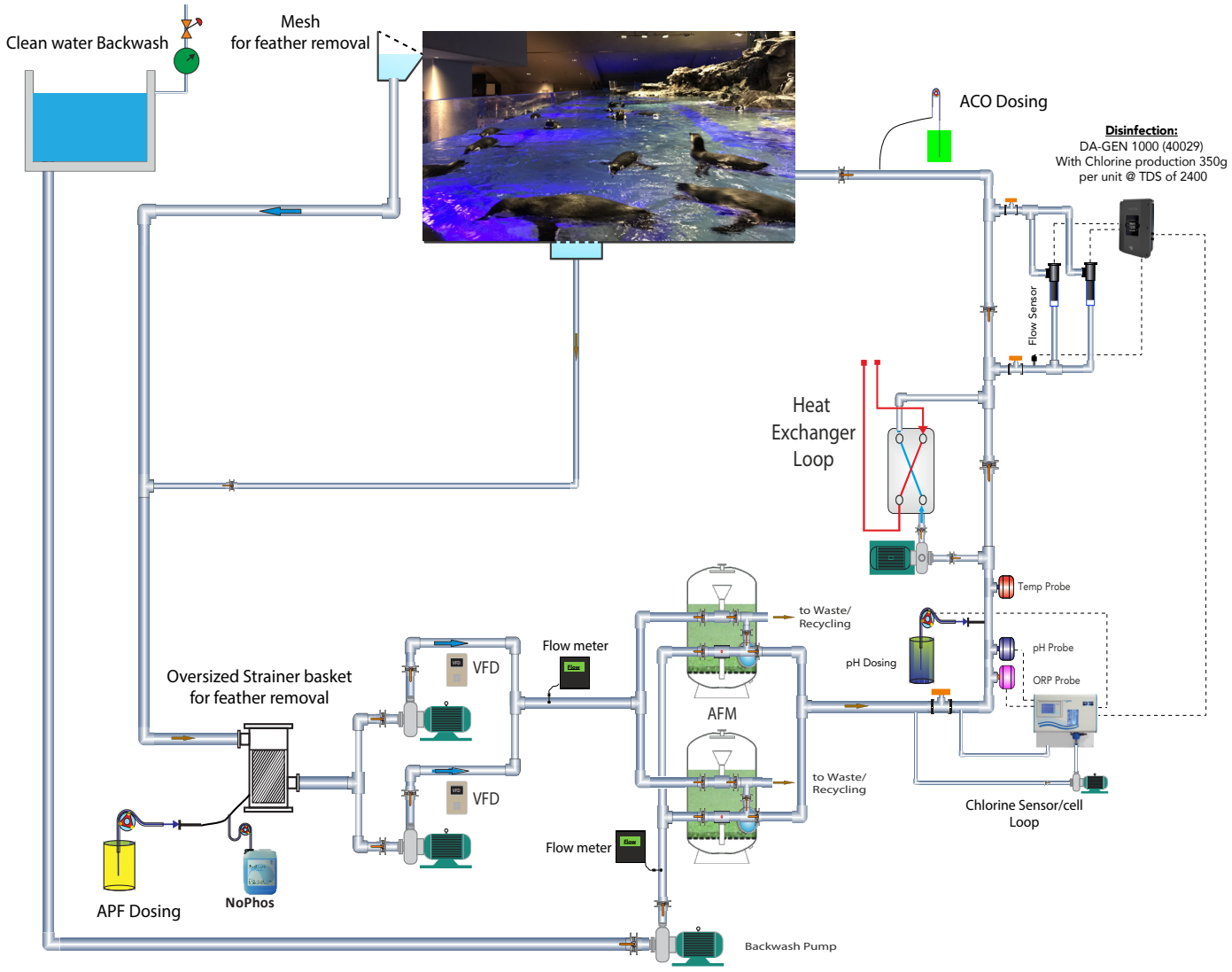
Recommended design for a Chlorinated Marine Mammal System



Many variations on the above schematic are possible including e.g. freshwater backwash with separate backwash pumps for inland aquaria

- **APF - Coagulation/Flocculation - acheive 0.1 micron filtration**
- **NoPhos - Phosphate removal**
- **AFM filtration - without biological contamination/fouling**
- **Temperature control circuit**
- **DA Gen - controlled disinfection, pH balancing and algae control**
- **ACO - enhanced, safe oxidation of organics in outdoor exhibits**

Recommended design for a Chlorinated Penguin System



Many variations on the above schematic are possible including e.g. freshwater backwash with separate backwash pumps for inland aquaria

- **Physical screens for feather removal**
- **APF - Coagulation/Flocculation - acheive 0.1 micron filtration**
- **NoPhos - Phosphate removal**
- **AFM filtration - fitlration without biological contamination/fouling**
- **Temperature control circuit**
- **DA-GEN - controlled disinfection, pH balancing and algae control**
- **ACO - enhanced, safe oxidation of organics in outdoor exhibits**

Mixed bird/fish systems would be based more on our biological LSS systems, with adjustment for load and feathers removal. See AFM Application in Aquarium Systems document.

In all chlorinated and biological systems some water exchange will be nescessary to control chlorides, nitrates and/or to ensure correct mineral balance.