Rocky Hill PFAS Remediation System.

Section 11. Martucci proposal critique.

This document explains why the Borough Engineer's design for Rocky Hill PFAS remediation is not acceptable and must be rejected. It is shown that the filtration parameters, resin volume, and also the anion exchange mechanism are not fully understood, and the mathematics of proposed filtration design is flawed. The engineering parameters for pressure drop across the filter medium are also unacceptable. We conclude by describing the essential design components and full working details for a Rocky Hill PFAS remediation system to operate effectively as a viable, forward-thinking, and cost-effective modular alternative – and as modeled after successful on-line Municipal systems that have been previously described.

The proposal: In an e-mail presented on August 3, 2022 to Mayor and Council, and some listed Rocky Hill citizens, the Borough Engineer Robert Martucci explained some of his design parameters for the PFOS remediation system intended for Rocky Hill. This cryptic e-mail was the closest to any form of an engineering description that had been presented about the Martucci proposal. It is analyzed here.

PLEASE READ!
As to the claim that the Borough is spending too much and we don't need that much media:
Per (N.J.A.C. 7:10-11.14(c)2)
Pressure filters shall be designed so that the loading rate does not exceed 3 gallons per minute per square foot with one filter out of service.

Therefore, Per Our Design:
Total 3' dia single unit with 3' of media filter area= 21.2sft x 5 = 106.0sf

Design - 6- 3' vessels
5 vessels – (take away 1 vessel per regulation).
106.0sft total square feet of five vessels.

250gpm flow rate – Allocated Capacity This will not change, or the Treatment Plant capacity will not match the allocated capacity.
250 / 106.0= 2.4 gpm/sf Therefore ok. (Consider this a Factor of Safety). We have a total of six vessels per design.

Any other Licensed Professional Engineer is welcomed to check my calculations. However, NJDEP approved the design and flow rate.

Explained numerous times – AdEdge was used as a basis for bid pricing per Local Public Contracts Law. Any company can bid the work if they follow the basis of the design as permitted or approved equal. This will be my call, the attorney's call, and USDA's call.

Robert Martucci, P.E Principal
Martucci Engineering LLC

Filtration parameters need to be understood.

The correspondence starts with reference to New Jersey Administrative Code 7:10
https://www.nj.gov/dep/rules/rules/njac7_10.pdf
This deals with **Filtration** under 7:10-11.14 (page 95/142) and with **Filter unit design requirements** under N.J.A.C. 7:10 -11.14 (c).

Filtration is a general term that covers a lot of processes and is often misunderstood. Neither granular activated carbon (GAC) adsorption nor electrostatic anion exchange relate to classical filtration (which is based on particle size exclusion). They are distinctly different physical processes, and anion exchange is a unique electrochemical process that is fast and involves transport of anion charge groups through ultra-thin resin membranes.
The application of anion exchange to Municipal water purification is very new. Filtration procedures have to be based on the actual processes that are involved. There are some specifications (rules) that are therefore questionable, especially in regard to their relevance to Municipal water systems dealing with specific types of filtration for contaminant remediation, and they require engineering judgment about applicability.

One such specification is **N.J.A.C. 7:10-11. 14 (c) 2** that states: ***"Pressure filters shall be designed so that the loading rate does not exceed 3 gallons per minute per square foot with one filter out of service".***
The direct applicability of this design specification (rule) to the Rocky Hill PFAS remediation system is problematic for three (3) reasons, outlined below.

1. In the filtration systems industry, there are practical parameters for what is considered to be acceptable and effective filtration operation, and they are generated to assist in filtration systems design.
The flow rate loading (or hydraulic loading) on the filter is a parameter with a stated acceptance range from 5 to 20 gallons per minute per square foot (gpm/sqft). This is considered in the industry to be the acceptable range of values of hydraulic loading for good filtration – regardless of filtration medium being used (provided it can sustain the flow-rate). For example, Waterco is one of the largest filter manufacturing companies in the world. In all of their filtration products the acceptable input flow rates appropriate to the 5 gpm to 20 gpm per square foot hydraulic loading range are tabulated in their product data sheets. This applies to the Waterco filter units SMD 1200 and SMD 1400, and these data quickly indicate that both filter units can satisfactorily operate at 200 gpm input flow rate, within this accepted range of hydraulic loading.

2. In the case of existing Municipal filtration systems for PFAS remediation in drinking water, the Horsham PA facilities wells #10 and #17 operate at **7.96 gpm/sqft**, with 4 ft diameter filters in lead-lag, with 40 cu ft of anion exchange resin in each filter and with a continuous pumping rate of 100 gpm – (52 million gallons per year).
Similarly, the large Horsham well #21 facility operates at a loading of **7.1 gpm /sqft**, with 6 ft diameter filters in lead-lag, with 85 cu ft of resin in each filter, and with a continuous pumping rate of 200 gpm – (around 105 million gallons per year).

Even the original Horsham well#10 (as used in the Horsham study) operated at a hydraulic loading of **10.2 gpm/sq ft**, – using a single 2.5 ft diameter filter, 20 cu ft of anion exchange resin, and with a continuous pumping rate of 50 gpm (26 Mgpy). All of these hydraulic loadings are obviously well above the stated 3 gallons per minute per square foot.

To get a better understanding of the significance of the hydraulic loading parameter, it can be considered in terms of the linear velocity through the filter by dealing in cubic feet of water rather than gallons of water (where 1 cu ft = 7.48 gallons). The range 5 gpm/sq ft to 20 gpm /sq ft then corresponds to the linear velocity ranging from 0.67 feet per minute to 2.67 feet per minute through the filter. These are very low linear velocities through the filter, characteristic of water diffusing slowly through the filter medium – the objective of filtration design.

3. On this basis, a specified loading requirement of less than 3 gallons per minute per sq ft corresponds to a linear velocity of less than 0.4 feet per minute, which is a flow rate of less than 4.8 inches per minute through the filter**.** This is an extremely slow rate. This might possibly be a requirement for some research laboratory filtration process or a pharmaceutical purification procedure, or other specific application, but it is totally inappropriate for a working municipal water system. The stated hydraulic loading specification of ***"less than 3 gallons per minute per square foot"*** for Rocky Hill has no merit in our situation, and cannot be an applicable parameter.

It should be noted that the filtration procedure integrates and transforms the step function response of a duty cycle water system into a flat low-velocity diffusion through the filter medium. When combined with the fast electrochemical process of anion exchange, this is the reason why the anion exchange process with anion exchange polymer resin is so efficient and effective, even for duty cycle water systems. There is no contact time requirement as is needed for adsorption media (such as GAC).

What does this N.J.A.C. 7:10-11. 14 (c) 2 relate to?

This rule, stating that the hydraulic loading of the filters is required to be less than 3 gallons per minute per square foot, is the specification that is solely addressed in the Martucci e-mail, as being critically important. It has been considered here to be problematic in application to Municipal water systems, but needs to be addressed further from the standpoint of generally accepted filtration.

As stated earlier, Filtration is a term used very generally and often without understanding that distinct physical process can be involved that are unrelated to classical filtration. The classical filtration process is often described as being simply based on particle size exclusion, and in the range of 500 microns to 20 microns is called sand filtration (1 micron is 1/1000 mm or 39 millionths of an inch). The low range of sand filtration can cover algae and some bacteria. It can be lowered to around 3 microns particle size by using zeolites or diatomaceous earth (di-atom). Below this range, classical filtration exists in the form of membrane filtration at various levels from **microfiltration** (from 1 micron to 1/20 micron) then **ultrafiltration** (from 0.5 microns down to the 10 nanometer region) – which can include viruses (the Covid 19 virus is at 125 nanometers) – then further down to **nanofiltration** (10 nanometers down to 0.5 nanometers) and finally to **reverse osmosis** (from 1 nanometer down to 0.1 nanometers).

To put all this into perspective, ultraviolet light is in the 200 nanometer wavelength range, so some of these membrane filters are operating at less than wavelength of light dimensions. The PFOS and PFOA contaminants are C8 carbon long chain molecules, and PFOA has been cited as having a length of 0.14 microns (140 nm).

For PFAS molecule removal, filtration is required to operate in the nanometer range. This requires filtration that involves specific physical processes – or the possible use of the membrane filtration (i.e. ultrafiltration) technology.
There are two specific physical processes that are important in relation to filtration at the molecular level, namely molecular adsorption and electrostatic ion exchange.

In the case of filtration using granular activated carbon (GAC) the specific process is molecular adsorption. This involves very weak forces of attraction between molecules (or between atoms) at very short distances. The adsorption process then depends on the very close contact of the molecule with the adsorption medium. It is a surface effect. Granular activated carbon has an enormous surface area and a molecule will get trapped and held by the Van der Waals forces in a pore or crevice, referred to as a trapping site. To locate these trapping sites the water (containing the contaminant molecules) has to be flowing very slowly through large volumes of GAC. That is the reason behind the quoted "contact time" parameter – which for GAC with bulk filters is quite long (10 to 20 minutes). Molecular adsorption is the process that is operating in aquifers. There are huge amounts of aquifer materials, shale, clays, sandstone, fractured rock, etc., that are hydrophobic and exhibit excellent molecular adsorption properties.

For electrostatic anion exchange, the process is totally different. It is based on the electrostatic attraction between fixed cation groups (positive charges) in the polymer resin beads and the (negative charge) anion groups attached to the PFAS contaminant molecules. This process involves longer range electrostatic attraction forces, and is based on the mobility of anion charge groups in solution and on the transport of anion groups through very thin resin membranes in an electro-chemical anion exchange process, leaving the contaminant (PFAS) anions trapped inside the resin beads.
This is a completely unique process that was first demonstrated effectively for use in Municipal water PFAS remediation very recently (in the last 4 years) in the Horsham study (**Section 2** on this website).
This process is anion selective, is working at the molecular level, and is working even at very low concentration levels of the contaminant, and provides at present the only viable process by which trace level PFAS contamination can be eliminated. At trace parts per trillion (ppt) levels of PFAS contamination, the molecular adsorption process is ineffective – since the possibility of achieving the needed close molecular contacts becomes increasingly remote at very low concentrations of contaminant molecules, whereas the anion exchange process is still operational.

Both of these specific filtration processes are required to be able to support significant flow rates for satisfactory use in Municipal water systems.
The only possible situation involving a classical filtration scenario for PFAS molecule removal would be if the filtration medium could itself be of molecular size. This involves the use of polymer membranes as the filters – as described above. The contaminated water then has to be forced under pressure through these membrane filters. This has been done quite successfully (desalination for example). However there are problems with this approach, mainly low throughput and high electrical energy costs. Clogging of the membranes is always a serious problem. Recent efforts to alleviate this have significantly increased the efficiency, but actual throughput is low and large banks of filtration tubes are therefore required.
However, membrane filtration can remove all PFAS molecular contaminants.
It may then signify (from consideration of the above descriptions) that the rule **N.J.A.C. 7: 10-11. 14 (c) 2** is indeed referring to this type of filtration.
In this case the NJ DEP should clearly state this fact, to avoid implying that it applies to filtration systems overall. "Pressure filters" is not a definitive term.
Membrane filtration is the only obvious situation that would require use of banks of filter units in parallel, and involve very low individual filter flow rates – and that could also relate to the occurring failure of some of the filter units.
It seems apparent that N.J.A.C. 7: 10-11. 14 (c) 2 relates to membrane filtration.
It is very unlikely that township water facilities would be employing this type of membrane filtration process for PFAS remediation. These filters are very different from the usual tub or cylindrical filters that are being considered here. Membrane filters are not at all applicable to Rocky Hill and the use of anion exchange resin.

This **N.J.A.C. 7: 10-11. 14 (c) 2** rule as presented also seems to be somewhat out of accordance with the established EPA (and NJ DEP) policy of participatory non-involvement. The EPA mandate is to protect the environment and the public health nationally. Therefore, basically, the Agency establishes what needs to be done, and requires compliance, and their final approval and acceptance, but does not instruct on how to specifically do it. That is not their responsibility and is not their job, and they cannot be responsible for the details of how such work is performed. This is essentially an unwritten golden rule that they do not "approve" project proposals. On the other hand they do not "disapprove" them (unless they pose a clear danger to the public or are not rational or sane proposals). How the work is performed is therefore deliberately left to the Municipality as the responsible party.

It therefore cannot be claimed (by a Borough Engineer for example) that a proposed project has NJ DEP "approval" which is then considered to be the "official" and authoritative endorsement for a particular specific implementation of that project. That is however being claimed by Martucci in this case.

Instead of Martucci just stating that the required specification of less than 3 gallons per minute per square foot was totally unrealistic for real world municipal water systems, and as such had no merit (perhaps not realized) he appears to manipulate mathematics in an attempt to suggest that his design meets the requirement of this specification **N.J.A.C. 7: 10-11. 14 (c) 2**, so that it becomes N.J. DEP "approved "– neither of these possibilities being true.

<u>The flawed mathematics.</u>

There is simply no way in which the 6 filter vessels of 3 feet diameter in the Martucci proposal could possibly produce a hydraulic loading of less than 3 gallons per minute per square foot with an input flow rate of 250 gpm – but it is claimed that they do. That is an unfortunate mistake.

<u>Firstly</u>:

Martucci describes 6 filter vessels, and taking away one of them to leave 5 to give a "factor of safety". What on earth is going on – what is the point of all this?

We are using anion exchange resin – **this is not a membrane filtration situation.**

This apparently then leaves 5 working filter vessels of 3 feet diameter and with a stated internal surface area of 21.2 square feet x 5 = 106.0 square feet total area.

It is well known however that the surface area of a 3 ft diameter cylindrical filter is actually 7.068 sq ft (not 21.2 sq ft) and the total surface area of 5 such filter vessels is then actually 7.068 x 5 = 35.34 sq ft – not 106.0 sq ft as stated.

<u>Secondly</u>:

Martucci states the flow rate of the well pump is 250 gpm, which he calls Allocated Capacity. He then divides the flow rate 250 gpm by the supposed 106.0 square feet total area of 5 filter vessels to give a hydraulic loading of **2.4** gpm per square foot, and states, <u>"Therefore ok."</u>

Actually, 250 gpm divided by the real 35.3 square feet total surface area of the 5 filter vessels is **7.08** gpm per square foot. <u>Therefore **NOT** ok.</u>

<u>Operation of the proposed system not understood</u>.

None of this "6 filters-take-away-one-to-leave 5" routine relates in any way to how the proposed Martucci system (AdEdge based) is supposed to operate.

There are 6 filter vessels in the system, but they are **NOT** (ever) all connected in parallel. The AdEdge–Martucci design is actually based on connecting 3 filter vessels in parallel to represent a "lead" filter which is then connected in series to another group of 3 filter vessels connected in parallel representing a "lag" filter – and thereby functioning as two filters in a "lead-lag" configuration.

It does not seem to be understood that the original AdEdge design was intended to simulate a two-filter "lead–lag" system with the two huge GAC filter units. This is all described in **Section 4. Addendum p8,** and in **Section 10. Q11** and **A11.**

The combined surface area of 3 stated filter vessels of 3 ft diameter is 7.06 x 3 = 21.2 sq ft, and the hydraulic loading is then 250 gpm/21.2 sq ft = 11.8 gpm per square foot – and this hydraulic loading is the same for all the filter vessels in the system design. None of this hydraulic loading conforms with the **<u>N.J.A.C. 7:10-11.14 (c) 2</u>** rule of less than 3 gpm per square foot (but which is being claimed).

It is indeed ironic that, after the efforts to somehow establish compliance, this specification rule **N.J.A.C. 7:10-11.14 (c) 2** is not appropriate for the Rocky Hill situation (as presented above in detail) and therefore is not applicable anyway.

<u>System design flaws.</u>

<u>1. The initial concept</u>. The biggest fundamental design flaw in the Martucci proposal relates directly to the initial concept. The proposal assumes (incorrectly) that the Rocky Hill Water Facility is a system pumping continuously at 250gpm as a pressurized system. It is therefore being viewed as a large water system producing 131 million gallons per year. In reality however, the Rocky Hill facility is a small system (serving only 700 residents) running at 25% duty cycle, and producing 26 million gallons per year with a time–averaged pumping rate equivalent to 50 gpm. There is therefore a lack of understanding regarding the basic Rocky Hill water system (even how it works) and what the needs really are. The proposed system (based on 131 million gallons per year) is sized for more than 5x **(five times)** the processed water volume of Rocky Hill (26 million gallons per year).

Furthermore, in the Martucci proposal there is no apparent understanding of the unique mechanism of the anion exchange process with polymer anion exchange resin, and the polymer resin medium is treated exactly as if it were some form of activated carbon (GAC) medium with an associated contact time (EBCT) parameter. The AdEdge–Martucci proposal assumes a contact time of 3.4 minutes for the resin and assigns a resin volume of 850 gallons (250 gpm x 3.4 minutes) for each filter of the hypothetical (two-filter) "lead-lag" filtration system, namely 114 cubic feet of resin for each such filter. **That is a major error and design flaw that then impacts everything else.** This proposed resin volume is completely inappropriate and incompatible with the Rocky Hill water facility operation and its requirements.

2. Unacceptable pressure drop across the filters.

In the Martucci proposal the "lead" filter unit is actually 3 filter vessels that are connected in parallel. The "lag" filter is also based on 3 filter vessels in parallel.
In practice, each 114 cu ft of resin should therefore be divided between 3 of the filter vessels, with 38 cu ft of anion exchange resin in each.
Each filter vessel is of 3 feet diameter – with an internal surface area of 7.06 sq ft.
The bed depth of the resin medium in each filter vessel is then 5.38 feet – (which is 38 cu ft /7.06 sq ft). None of this information is presented, although very important.

The second significant engineering design flaw in the Martucci proposal then relates to a listed rule that was not even mentioned, namely: **N.J.A.C. 7:10 -11. 14 (c) 5 v**
"The maximum head loss through filter medium shall be eight feet of water."
In filtration systems it is always desirable to design for a low pressure drop across the filtration medium. In the case of water systems, a pressure drop across the filter medium that is above an 8 feet height of water column (3.5 psi) can often be a factor of concern, and so this specification does have relevance.

Purolite Corporation has provided data for their PFA 694E anion exchange resin showing the pressure drop per foot of resin depth measured against hydraulic loadings. From their data, the pressure drop through the resin at the 11.8 gpm/square foot loading of the filter units in the Martucci proposal is around 1.5 psi per foot. Consequently, in the Martucci proposal (with a 5.38 ft bed depth) the pressure drop across the resin medium is then 8.1 psi, which is equivalent to **18.6** feet of water. This is far too high, and clearly violates **N.J.A.C. 7:10-11. 14 (c) 5 v,** that requires a maximum head loss of 8 feet of water across the filter medium. Moreover, there is need to account for the system being intended to operate in a "lead-lag" configuration, where the pressure drops across the lead and lag filters become additive. Therefore, the actual total pressure loss for the Martucci system is 16.2 psi, which is **37 feet of water height** and which could make the whole system unworkable – especially in the desired Rocky Hill aeration stage location.

Summary: There are indisputable calculation errors and omissions in Martucci's proposal (simulating a "lead-lag" system) and significant engineering design flaws. The entire proposal is ill conceived, lacks scientific rigor, and the detailed system operation also, apparently, is not fully understood.

Essential design considerations for a Rocky Hill PFAS remediation system.

On the basis of the Horsham study, a very simple PFAS remediation system was proposed for Rocky Hill in November 2020 and presented in **Section 3.**
It is a relatively low-cost system, based on adding two filter units with anion exchange resin to the Rocky Hill water facility in the low-pressure aeration stage. Aeration is one of the main methods of reducing organic component (the volatile component mainly) from the water supply. Aeration reduces the background anion content in the water, and extends the useful life of the anion exchange resin.

Insertion of the filters in the low-pressure aeration section is also very important in protecting the fragile gel beads of the anion exchange resin, particularly with systems that are running under duty cycle operation. The small (3/4 mm) gel beads are porous and swell with water content, having very thin (10 microns) membranes – and they are fragile. There are therefore specific reasons for this location.
With duty cycle operation the pumping units are turned on and off as part of normal operation. In locations that use check valves the pumps turn on into a head pressure and there is a resulting pressure "hammering" effect on start-up. There are two locations where this occurs. One is at the main well pump, and the other is at the booster pump to the storage tower. It is particularly bad to install the polymer gel bead filter units directly at the output of these two mentioned pumps.

The AdEdge–Martucci proposal actually installs the filter units directly at the well pump output, not knowing about the Rocky Hill duty cycle operation, and not knowing anything about the gel bead resin. In normal operation the Rocky Hill facility does not have any problems with duty cycle operation and the aeration system is at atmospheric pressure. In the proposed Rocky Hill system described in **Section 3** and **Section 8**, the anion exchange filters are intentionally placed in the aeration stage between the receiving tanks at atmospheric pressure and, via the low pressure mid-stage circulating pump, they supply water to the open second aeration column – so there is no pressure hammering involved in this location.

The Filtration medium.
Anion exchange polymer resin is an ideal filtration material. It is comprised of small (3/4 mm) identical beads that are porous and built around a backbone structure with multiple very thin membranes. The resin beads swell with water content, and are fragile. The medium is equally transparent in all directions. There is no stratification. There is no clumping of filtration medium, and there are no wall shunts. Everything is of uniform small size. It is a perfect, ideal, filtration medium.

In this regard it is completely different from activated carbon (GAC). A standard requirement with GAC filtration is a periodic backwash routine (because of the GAC stratification) to break up the filtration medium and redistribute it and re-establish filtration efficiency. This procedure, from GAC based filtration systems, was also included in the AdEdge-Martucci proposal – although it is now using anion exchange polymer resin as replacement for GAC.
The polymer resin was being considered (incorrectly) to be just another type of adsorption material, similar to GAC.

The last thing that the anion exchange polymer resin requires is to be subjected to high pressure backwash routines to forcibly disperse and re-distribute the resin gel beads within the filter. With the backwash routine with GAC there is also the need for additional high pressure pumping equipment and a large storage tank for holding the contaminated effluent, requiring disposal.
None of this applies with anion exchange resin, and it is certainly not required – but it is still an included part of the AdEdge–Martucci proposal.
It does not seem they fully understand what is involved in this regard.
Although these engineering issues of pressure hammering and pressurized backwash are quite significant design lapses, they have not been introduced here earlier because they were not items related to the Martucci e-mail.

The Filter units
For the Rocky Hill PFAS remediation system now being described, the Waterco SMD 1400 filter is selected as the preferred filter unit. The Rocky Hill water facility operates at a 200 gpm pumping rate (through the filters) under duty cycle operation. The surface area of the SMD 1400 filter is 16.49 square feet, and at a 200 gpm flow rate the hydraulic loading is then 12.1 gpm per square foot.

From the Purolite data for PFA694E resin, the pressure drop through the resin medium is around 1.6 psi per foot at a 12.1 gpm per sq ft hydraulic loading.

With 35.3 cubic feet (1000 liters) of resin in the SMD 1400 filter, the bed depth is 2.14 feet. With a 2.14 feet bed depth in the SMD 1400 filter, the pressure drop across the filter medium is then 3.4 psi (equivalent to 7.8 feet height of water).
This meets the N.J.A.C. 7:10 – 11. 14 (c) 5 v specification.

For two SMD 1400 filters in lead–lag operation, the total pressure drop is around 6.8 psi (15.6 feet water height) and the two filters can be installed in series in the low-pressure aeration stage of the Rocky Hill Water Facility without changing the low-pressure mid-stage pump of the system (200gpm at 40ft TDH). The filtration parameters are therefore satisfactory. This was previously described in **Section 8.**

Alternatively, with the smaller SMD 1200 filter unit the internal surface area is 12.56 square feet and at 200 gpm flow rate the hydraulic loading is 15.9 gpm per square foot. Although this is still within acceptable range, the related pressure drop through the resin medium is around 2.1 psi per foot, and with a 2.8 ft depth of resin bed, the pressure drop across the filter medium becomes 5.9 psi (13.5 ft of water) which is considered to be possibly too high for use in a dual filter “lead-lag” system.

The SMD 1200 however would be quite acceptable as a single filter unit and, as such, could be operated in the Rocky Hill low-pressure aeration stage without any required change to the existing mid–stage pump. With 35.3 cu ft of resin the operating time of this filter should be 4+ years.

We are proposing a simple basic system using two SMD 1400 filter units in lead–lag, and with 35.3 cu ft (1000 liters) of PFA 694E anion exchange resin in each filter.

System Modularity.

It is now increasingly apparent that there is no single selective anion exchange resin to solve all PFAS problems, and that there is need for selective anion exchange resins to be developed for the many short chain carboxylic PFAS contaminants. This topic was outlined in the **Q10** and **A10** on page 7 of the previous **Section 10** on this website.

The future need will inevitably be for multiplexed anion exchange filtration systems – which will emphasize a modular system design approach.

Modularity is a concept that can apply to dual filters when arranged in a lead-lag configuration and, obviously, to single unit filters. Modular filter units are required to be "manageable" which in practical terms is being size-limited to around 4 feet diameter – certainly less than 5 feet diameter. At larger sizes the filter units generally tend to become fixed in position. At the manageable sizes mentioned, the filters (drained of water) can be handled and moved using hydraulic pallet jacks.

Modularity has already been adopted by some major European companies (such as ECT2) dealing with PFAS and other combined contaminant remediation – for which they propose "mix–and–match" modular solutions. By contrast, the proposed Martucci system uses filters that are fixed in a trailer, immobile and not modular.

System possibilities

In the case of Rocky Hill there are several system approaches. The initial one as proposed here uses the typical system approach referred to as "lead–lag".

The "lead-lag" arrangement uses two filters in series. The required filtration is done in the first filter, which is monitored for contaminant breakthrough.

When the breakthrough is detected, that filter is isolated and closed down with valve control and is by-passed, while still allowing the filtration to continue through the "lag" filter (unused up to that point for any contaminant removal). The "lead" filter can then be drained and new resin loaded at leisure, and it is then later returned to operation. The control valve arrangement (which can involve many valves) sets up this filter to now operate as the system "lag" filter while the original lag filter continues working as the "lead" unit. This switched lead–to–lag approach is extensively used in the water industry. It permits filters to be recharged without interrupting operations of the water facility. It is a generally accepted and popular filtration approach, and it can even be employed with large (fixed position) filters that are not modular. The required resin change–out procedure is then often made as infrequent as every four (4) years or longer, based on the design and the specific system operation.

Another approach is simply to use a (single) suitable filter equipped with an extra sampling port located above the filter output level so that the contaminant breakthrough can be anticipated. At the point of breakthrough, the filter is then closed off and replaced by another one that has been prepared and has been connected to the system. The filters themselves (fiberglass) are fairly inexpensive and are treated as modular units that are fitted with union couplings for rapid and easy attachment. The valve components and pipework sections would also be equipped with such couplings, all being relatively inexpensive commercial PVC items, and readily available.

Additionally, the two filters of a basic "lead–lag" filter system, can be operated in the manner described above (as individual modules with an added sampling port) and so can use different ion exchange resins. The filters then become separate modules that are performing two different filtration processes – in series, on-line.
This provides a valuable flexibility for solving future mixed contaminant problems that could be encountered in Rocky Hill water, and that would be remedied with appropriate filtration technology and with a multiplexed system. With a suitable low pressure drop across the filter medium, a third such filter might even be added in series to extend this capability further.
All such filtration units need installation in a Filtration Building of adequate working room and height as a requirement.
The Martucci proposed system does not have any such capabilities, and does not even relate to them. A train of filters welded together in a large trailer package (40 ft long x 10 ft high x 8 ft wide) does not permit any such modular possibilities.

Conclusion:

The Martucci proposed system is not adequately designed around the present and the possible future needs of Rocky Hill – and is an elaborate system that is extremely (million dollar) costly, and is grossly over-scale and is inappropriate for the Rocky Hill requirements. In addition, there are obvious indications that the Martucci proposal is flawed in many important practical engineering and design aspects.
These problems, and others, have been documented extensively, particularly in several **Sections** on this website rockyhillwater2020.com and have been presented and have been routinely ignored.
This attitude is particularly evident in the closing comments of the e–mail correspondence (on the first page) where it is implied that, regardless of facts and anything else that might be presented, it is still going to be Martucci's "call" on the final system design approval.
That is an unacceptable situation for Rocky Hill to be forced into.
The Martucci proposal is clearly inappropriate, unsatisfactory, and without any full engineering description, without any presented cost analysis, without any form of independent review, and without the needed Community support and approval.
It must be rejected.

Alternative proposal

An alternative system has been described above that uses two filters in lead-lag configuration installed in the aeration stage of the Rocky Hill Water Facility. This PFAS remediation system is based on the experimental results obtained from the

published Horsham PA study on the measured capacity of the Purolite PFA694E anion exchange resin in terms of the measured number of bed volumes processed to the point of resin saturation and PFAS contaminant breakthrough. This system for Rocky Hill has been described in **Section 3** and **Section 8** and in other Sections on this website. There are existing Municipal water systems for PFAS remediation that are based on the use of filtration units designed around these Horsham study parameters, and which can be considered as being applicable to Rocky Hill.
These are systems built at Horsham PA, and also the well number 26 system at Warminster PA – which was a GAC system converted to the use of anion exchange resin, and which also had an aeration system which they incorporated in identical fashion to that proposed for Rocky Hill. This Warminster well#26 system was visited and fully described in a provided trip report. It was functionally identical to the proposed Rocky Hill system that has been described. There are therefore established working two–filter anion exchange PFAS remediation systems already in existence. We have gone a step further by introducing system modularity to look ahead at future PFAS remediation requirements, and to provide Rocky Hill with system capabilities to be able to deal with them.

Ivor Taylor. Dec 2nd 2022.