

# The PERFECT Cassette— AAF's SAAF™ Cassette

ENHANCED PERFORMANCE, ENERGY EFFICIENT, AND ENVIRONMENTALLY-FRIENDLY

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## Abstract –

*Chemical or gas-phase air filters have been in use for over three decades now. These specialty air filtration products scrub malodorous, corrosive, harmful, and toxic gases from airstreams. At the onset, companies with access to information on gas scrubbing chemistry packaged different forms of gas removal chemical media and introduced them into ductwork or within HVAC configurations with the good intent to scrub problem gases from air streams. Applications of this invention spanned across scrubbing corrosive gases to protecting electronics and air compressors in industrial facilities, treating air in a museum or archive, removing odors within office buildings or commercial establishments, treating air quality at airports, laboratories, hospitals, healthcare, etc. But, due to little expertise in the physics of air, these inventions did not gain widespread use because of inherent product flaws such as high pressure drop, excessive dusting, uneven pressure drop and velocity gradients, ineffective chemical media utilization, excessive leakage, air bypass, and premature breakthroughs.*

*As air quality degrades globally, highly specialized air treatment companies such as AAF now address this market need with a highly innovative and advanced product offering. Problems from currently employed technologies were revealed using evaluations employing cutting-edge air analysis technologies at AAF's Global R&D centers. In the new realm, with AAF addressing gas-phase air filtration, it can now be safely expected that gas-phase air filters are not being designed to operate in isolation anymore. Gas-phase filters are an integral part of any HVAC system, are to be governed by the physics of air, of air, and need to be designed with a systems approach in mind. With the ultimate goal being to provide "better air."*

## Air Filtration

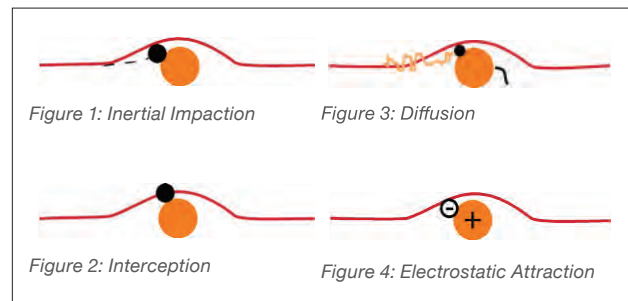
Gone are the days when the term "air filtration" used to immediately and exclusively imply particulate air filtration. In today's environment, premier health organizations such as the Centers for Disease Control's National Institute for Occupational Safety and Health (NIOSH) define air filtration as removing "unwanted material" from airstreams. The term "unwanted material" thereby further described as material removed via both:

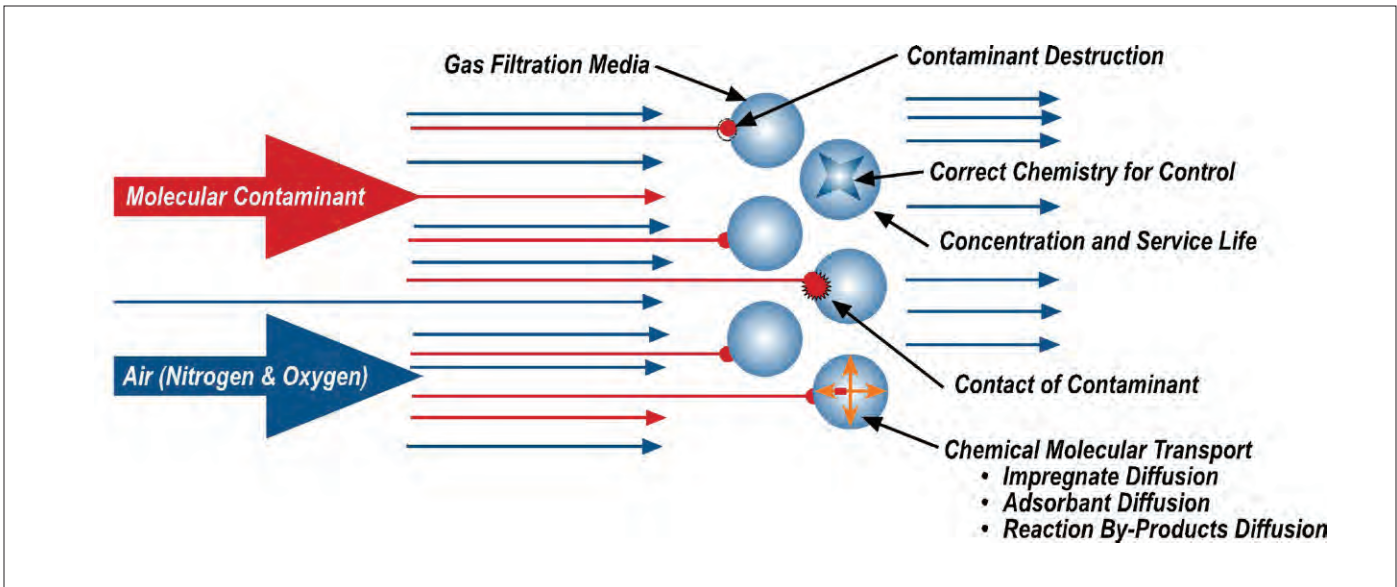
1. Particulate air filtration, and
2. Gas-phase air cleaning (for removing gases, vapors and odors)

The collection mechanisms for particulate filtration and gas-phase air cleaning are different. Description of the principles governing particulate filtration (See Figures 1 through 4) and gas-phase air cleaning provide an understanding of the most important factors one must

consider when selecting or enhancing an air filtration system. A more detailed discussion of air filtration principles can be found in the National Air Filtration Association's (NAFA) Guide to Air Filtration [NAFA 2001a] and the ASHRAE Handbook: HVAC Systems and Equipment [ASHRAE 2000].

## Four Primary Filter Collection Mechanisms





## Key Principles of Dry Gas-Phase Filtration

Other important parameters of gas-phase air cleaning include the following five principles:

- Breakthrough Concentration**  
 The downstream contaminant concentration, above which the chemical filtration device is considered to be performing inadequately. Breakthrough concentration indicates the agent (gas) has broken through the gas cleaning device, which is no longer giving the intended protection.
- Breakthrough Time**  
 The elapsed time between the initial contact of the gaseous agent at a reported challenge concentration on the upstream surface of the chemical filtration device bed, and the breakthrough concentration on the downstream side of the chemical filter bed.
- Challenge Concentration**  
 The airborne concentration of the gaseous agent entering the chemical media bed.
- Residence Time**  
 The length of time that the gaseous agent spends in contact with the gaseous filter.
- Mass Transfer Zone or Critical Bed Depth**  
 Interchangeably used terms, which refer to the chemical media bed depth required to reduce the chemical vapor challenge to the breakthrough concentration.



AAF Products



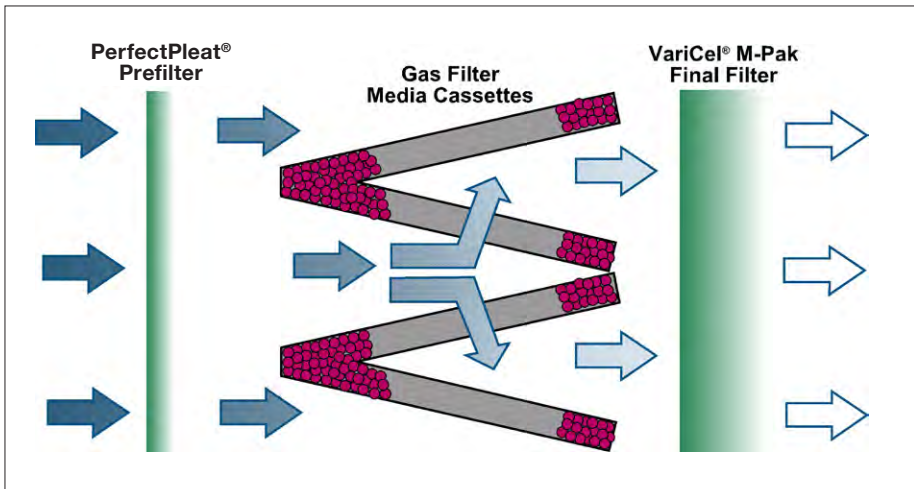
OptiFlo® Dust Collector

Just as there are various types of particulate filters to accommodate the wide range of particulate sizes and required levels of removal effectiveness, there are various types of gas-phase air filters. The most common technology in gas filtration is using gas-phase chemical media, which is either activated carbon or specially engineered chemical media.



*SAAFBlend GP is designed to remove from the airstream specific target contaminants, including sulfur dioxide, hydrogen sulfide, nitric oxide, formaldehyde, hydrocarbons and lower molecular weight aldehydes and organic acids.*

These specialty engineered chemical media are developed to target specific contaminant gases with the goal of achieving high removal efficiencies, along with high removal capacities. Additionally, being specially formulated, the engineered chemical media is normally relatively non-toxic, easier to dispose of, and safer to use than its predecessor—activated carbon.



Thin Bed System

### Current Technology Study—Cassettes

Chemical media to eliminate gases from air streams require an effective delivery mechanism by which the chemical media is to be introduced in the air stream. A satisfactory method of accomplishing this has been to position perforated trays containing chemical media in a V-bank arrangement in the air stream. See Figure 5. Trays are typically 1" or 2" deep (nominal) and are either arranged directly on tracks or are arranged within a housing frame. Trays are available in various standard sizes – 24 x 24 x 1, 24 x 24 x 2, 12 x 24 x 1, 12 x 24 x 2, etc.



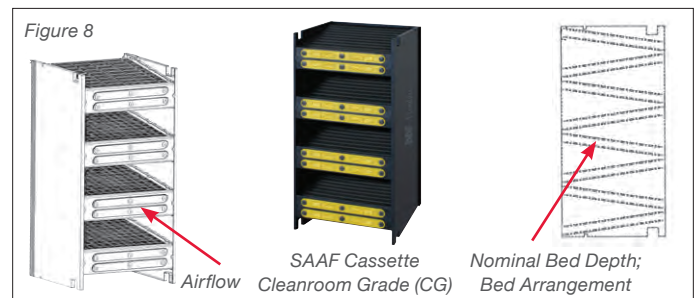
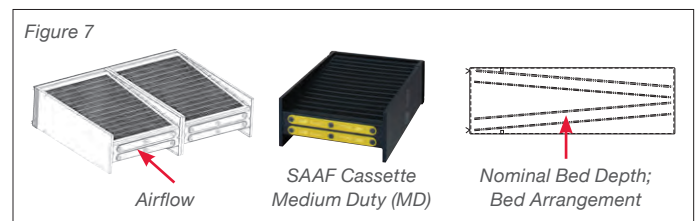
Figure 5: This tray system is a self-contained unit with removable carbon trays.

While trays are commonly used, they are also the most labor and maintenance intensive solution. A tray-type solution is commonly subject to air leakages and is generally a messy means of deploying chemical filtration media in the airflow. Early breakthrough due to high probability of chemical media settlement, ineffective construction integrity, and by-pass are some of the other problems commonly encountered with tray-type systems. Additionally, the frequent ongoing maintenance and cleanup work involved in replacing or refilling trays make them a very ineffective solution.

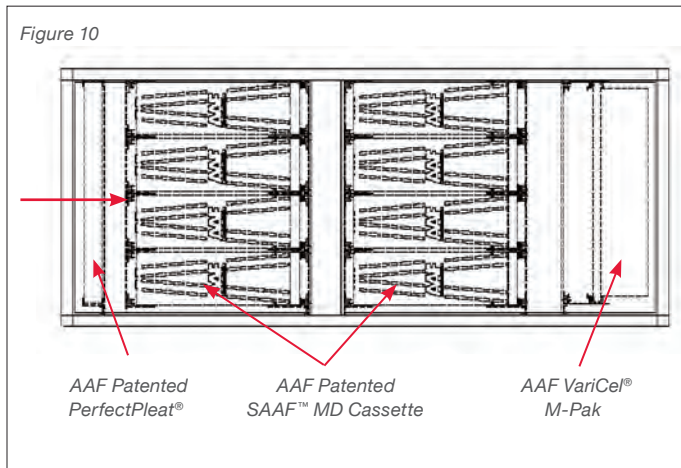
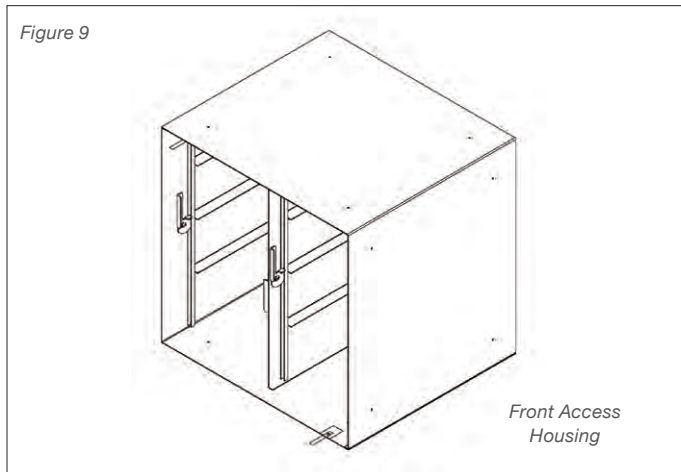
To address the shortcomings of trays and yet provide a system which offers a high chemical media quantity content, "cassettes" or "modules" were introduced back in the 1980s. Since the advent of cassettes, many prudent and conscientious end-users have adopted this option, as they offer an integral construction, enhanced resistance to breakthrough, ease of maintenance, and a more cost-effective solution than trays.

Gas phase air filtration cassettes are available in three models:

- 3"-deep V-bank in a 12"-deep cassette (Figure 6)
- 1"-deep V-bank in an 18"-deep cassette (Figure 7) and
- 1"-deep V-bank in an 12"-deep cassette (Figure 8)



Cassettes are typically deployed in a front access configuration or a side access configuration. Figure 9 indicates an example of a cassette in a front access arrangement. Figure 10 indicates a cassette in a side access type arrangement.



Schematic layout of SAAF™ Side Access Housing.

AAF R&D scientists and engineers studied cassettes from two main suppliers in the marketplace: a first-to-market company (henceforth denoted as Product P) and an aftermarket supplier (henceforth referred to as Product R).

This study was mainly undertaken because numerous market complaints were identified by users of Product P. The results of the study, presented in this paper, are very revealing and provide a rationale behind the product complaints.

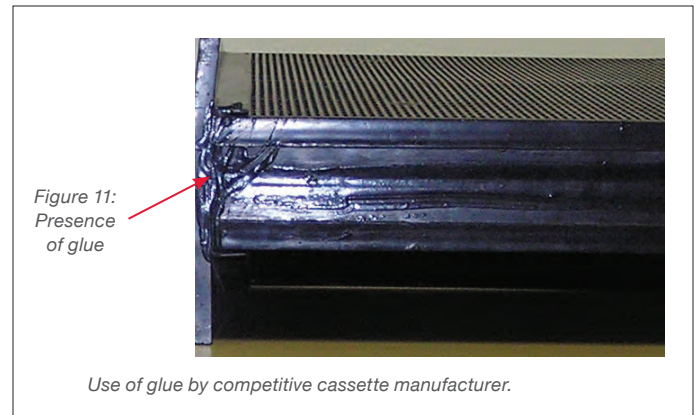
## Visual Evaluation

### Construction

Upon visual inspection, Product R (the aftermarket cassette) was more appealing than Product P (the first-to-market cassette). However, both presented little distinction and shared similar construction characteristics. The most noteworthy difference was that Product R had pressure-fit snap-on chemical media refill caps; vis-à-vis plastic stickers were used to contain chemical media in Product P.

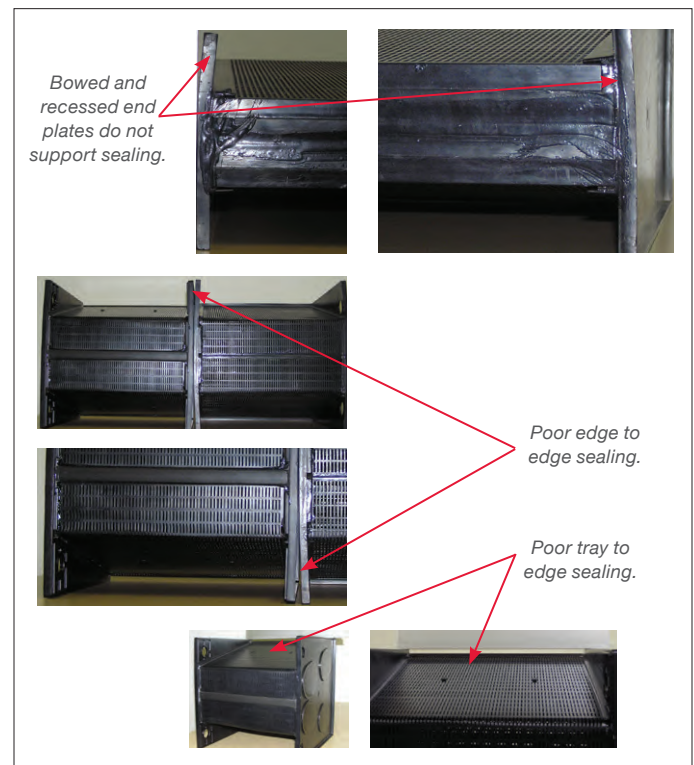
### Glue or Adhesives on Product

It was surprising to see that both Product P and Product R predominantly used adhesives (or glue) throughout product construction (Figure 11). The purpose of a chemical or gaseous filter is to react with gases, in air, streams. Having glue or adhesives, which heavily off gas used throughout in the product construction is surprising. It cannot be ruled out that offgassing from the glue itself leads to chemical media consumption and adds to the degradation of the chemical media, even while the cassette is in storage and not deployed in service.



### Surface-to-Surface Trueness

It was noted that cassettes were a two-piece construction without adequate sealing or bypass protection between mating surfaces. It was further noted that end plates on the cassettes were recessed, thereby creating easy cavities for air bypass. Additionally, the cassette surfaces were not true; i.e., 90° on critical angles. This would further contribute to air leakages and premature gas breakthrough on both Product P and Product R.



## Design Parameters of a Good Air Filtration Device

Going below the surface, beyond the branding and visual analysis, AAF's scientists put the two products through rigorous technical evaluations. These evaluations were centered around testing existing products on the standards of air filtration products. This is the expertise that AAF has honed.

In the current economic and hi-technology era, a good air filter should be designed to optimize the following key requirements:

1. Removal (or cleaning) effectiveness
2. Energy efficiency
3. Complete product utilization and environmentally friendly disposal post use.

Factors that directly contribute to the above objectives are sound construction (fit and finish), low pressure drop characteristics, unvarying pressure drops and velocity gradients throughout product, features to eliminate, and safe guard against bypass or early breakthrough. In general, this means a product that deploys well and is well sealed when put into service.

The above parameters are easier to work with, and innovation is easier, if the test medium being filtered is a visible fluid. Working with air is a challenge, due to the fact that majority of airflows are invisible and it is difficult to determine manual test readings. To address this problem, AAF scientists routinely employ state-of-the-art design and analysis tools. Designs from these tools are then validated in AAF's R&D test laboratories. These evaluation tools provide a reliable means for testing air filtration technologies and maintaining a product quality that has been the benchmark in air filtration for the past eight decades.

### Is Air a Fluid?

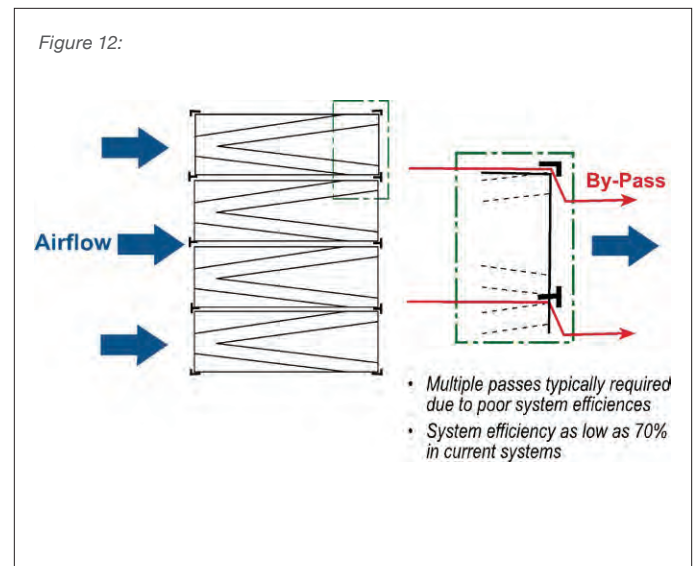
By definition, any substance that 'flows' is a fluid. Hence, things such as water, shampoo, and honey are all fluids. Although not necessarily obvious, even gases such as air are considered fluids.

Advanced fluid assessment tools are used in predicting events, quantitatively, when fluids flow. Such advanced analysis are used by engineers to maximize the yields from reactors and chemical processing equipment; land-, air-, and marine-vehicle designers to achieve maximum performance; risk-and-hazard analysts, and safety engineers, to predict how much damage to structures, equipment, human beings, animals, and vegetation will be caused by fires, explosions, and blast waves. Computational Fluid Dynamic-based flow simulations enable metropolitan authorities to determine where pollutant-emitting industrial plants may be safely located, and under what conditions motor vehicle access must be restricted so as to preserve air quality; meteorologists and oceanographers to foretell winds and water currents; hydrologists and others concerned with ground-water to forecast the effects of changes to ground-surface cover, of the creation of dams and aqua ducts on the quantity and quality of water supplies; petroleum engineers to design optimum oil-recovery strategies, and the equipment for putting them into practice...and so on. Within a few years, it is to be expected, surgeons will conduct operations which may affect the flow of fluids within the human body (blood, urine, air, the fluid within the brain) only after their probable effects have been predicted by computerized evaluation methods.

Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) tools are an expensive and very scarce resource, due to their widespread use within critical and high precision applications. AAF's R&D centers and laboratories employ scientists and design engineers who utilize these advanced tools and supercomputers to study the effects of different materials, designs, and construction on the effectiveness of air filters. Supercomputing power is critical because these tools are very resource intensive. These tools go through thousands of algorithm iterations and designs to arrive at an analysis result. Besides aerodynamic contours, CFD helps identify leak locations, dead cavities, and drag-intensive features. AAF's engineers use these CFD tools and other advanced tools to study the legacy cassettes available in the market.

## Deployment Studies

On studying the deployment of cassettes inside access housings, where cassettes slide over commonly available tracks, it was found that the current cassettes and track layout offered high instances of bypass and early breakthrough (Figure 12). To study why the incidence of bypass and premature breakthrough were so high on such expensive filters, the cassettes were reexamined, and it was found that ineffective design was the primary reason for the problems. Loose manufacturing tolerances and inadequate quality control amplified these problems further.



Poor surface-to-surface sealing causes greater than 25% air leakages.

Examples illustrating the poor surface-to-surface sealing encountered in the tested cassettes follow in Figures 13 and 14.

Figure 13

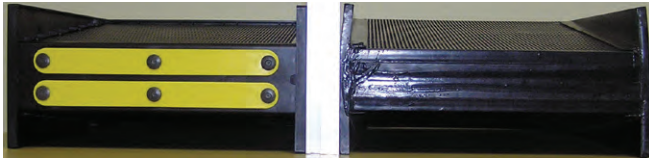
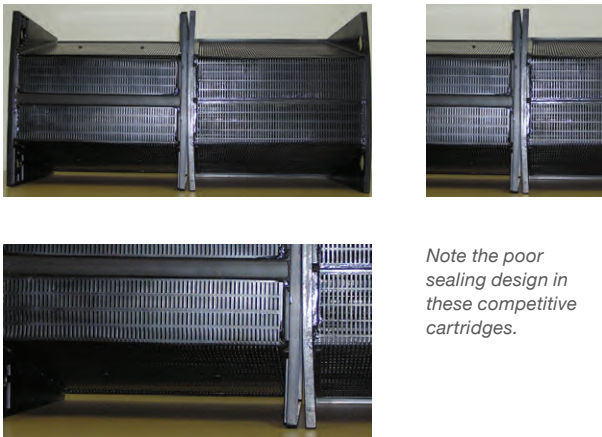


Figure 14



Note the poor sealing design in these competitive cartridges.

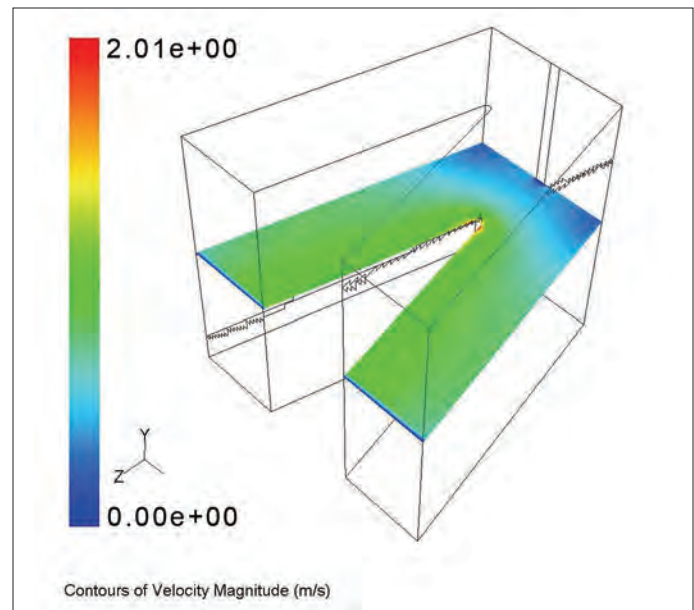
## Pressure Drop Studies

Product P and Product R cassettes were studied for pressure drops. It was noted that the pressure drops stated on the published literature for these products were much lower than what was experienced at that specific airflow during testing.

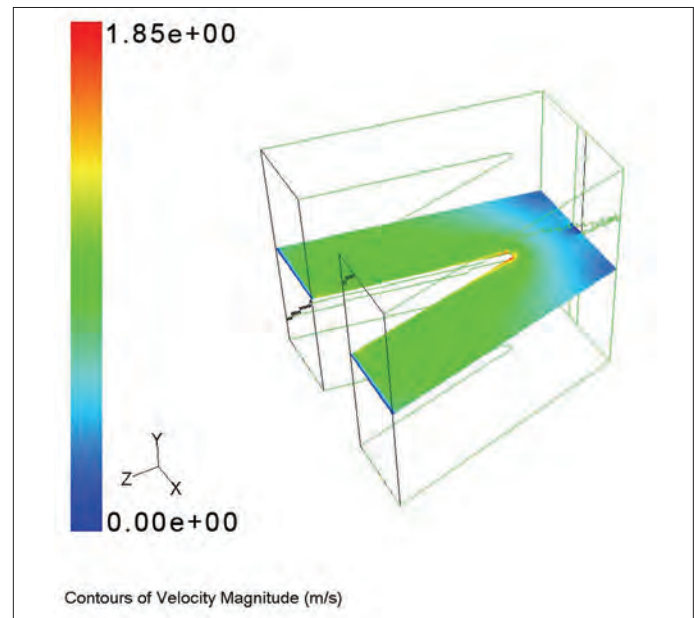
The main reason for the higher pressure drops was the design of the chemical media containment screens. While the products were essentially air filtration devices, the chemical media containment screens were just not designed with aerodynamics as a relevant criteria. It was evident that the only design consideration was to design the screens so that the chemical media would be retained inside.

It was observed that chemical media spillage occurred anyway. Obviously, this was not a very successful design, and definitely not aerodynamic. Since the cassettes offered a pressure drop difference, vis-à-vis what was documented on the published literature, CFD studies were employed to study the reason behind this. Pressure loss and velocity gradients were studied by “slicing” the cassette along various product axes and evaluating.

Following are some sample findings from the computational analysis showing how design shortcomings directly affect cassette performance.



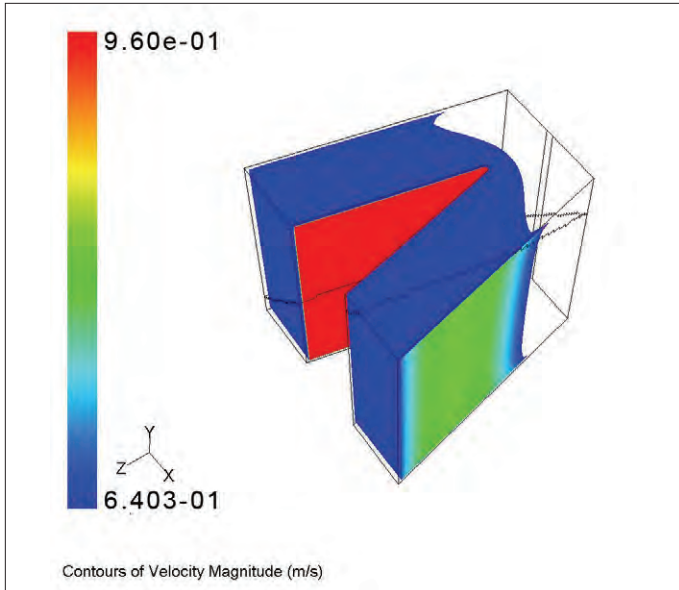
Product P, Velocity magnitude on horizontal planar section.



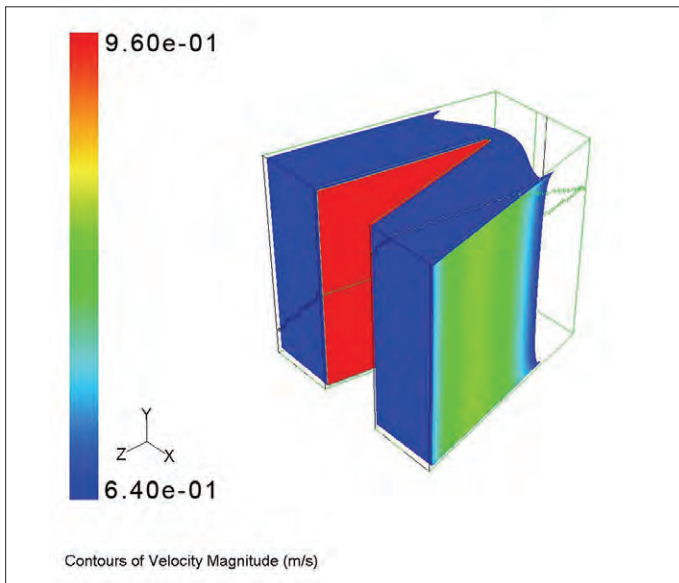
Product R, Velocity magnitude on horizontal planar section.

As shown by the figures of velocity magnitude on the horizontal planar section, it is clear that the airflow is different across the chemical media within the cassettes. CFD studies also exposed that there was a large portion of chemical media in the cassette that would not be utilized effectively over the useful life of the cassettes. This area, later identified as the “nose cavity” by design engineers, was actually very evident. Viewing the construction of the cassette, it was clear that the “V” was not a true “V” in the beginning.

Here are samples of spatial velocity isosurface evaluations, construction detail of the Product P and Product R cassette, and a schematic of what this represents.



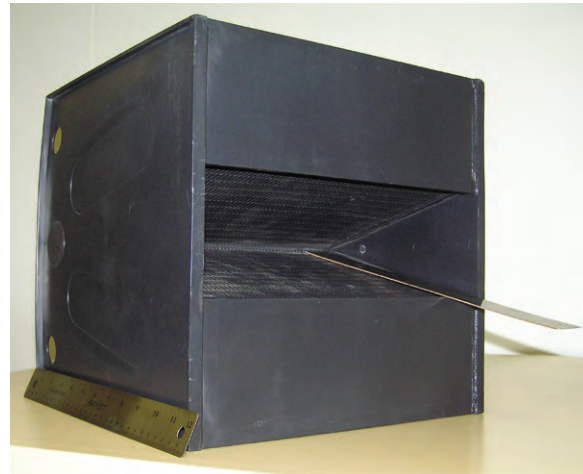
Product P, Velocity magnitude on horizontal planar section.



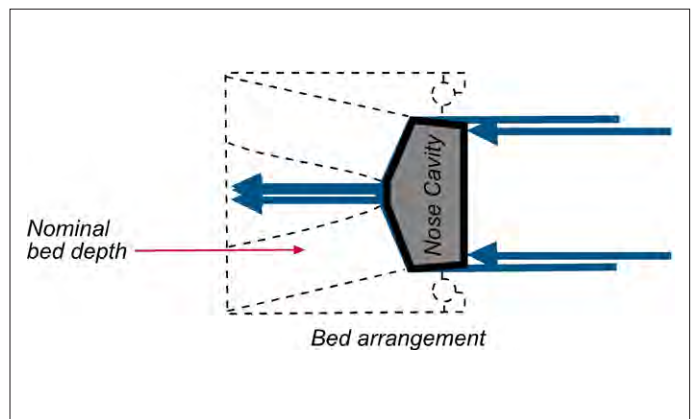
Product R, Velocity magnitude on horizontal planar section.



Construction of Product P cassette.

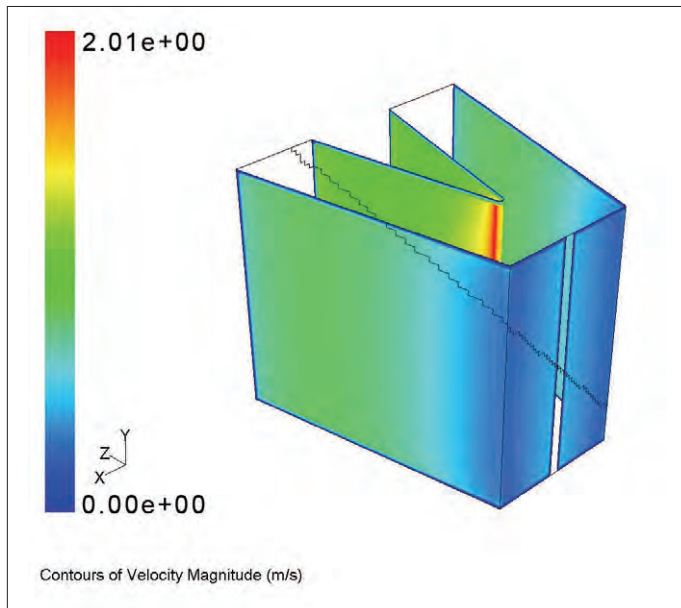


Construction of Product P cassette.

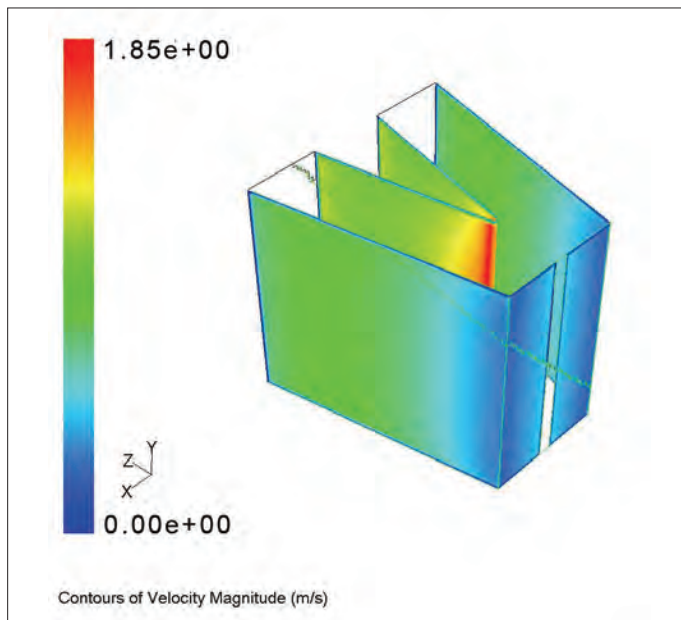


Schematic of poor "nose cavity" design which results in pressure drip variances.

Spatial velocities on the isosurface also indicate that the velocity magnitude of airflow leaving the chemical media's exterior surface has differing velocity gradients. This is a major flaw because now residence time of the air within the chemical media is not uniform. This has far reaching effects into the performance of the Product P and Product R cassettes. See the following figures.



Product P, Velocity magnitude on media exterior surfaces.



Product R, Velocity magnitude on media exterior surfaces.

## The PERFECT Cassette

Understanding the flaws that were exposed in the cassette designs of Product P and Product R helped AAF scientists with guidelines in their task to design "The PERFECT Cassette."

## Construction

The first design imperative was to eliminate offgassing products from the construction. This was accomplished by working closely with AAF's plastic and nano materials engineers. The design teams created a cassette that had no glue, much lower offgassing, and and was fully recyclable (or incinerable).



## Product Sealing

To enhance surface-to-surface sealing, all mating surfaces of the AAF cassette were made flat and not recessed. All axes (perpendicular surfaces) were designed to be true; i.e., exactly 90°. Specialty gaskets with proprietary Japanese technology were designed to ensure the best surface-to-surface sealing in the industry. All of this was done to provide abundant protection against air leakages and early breakthrough.

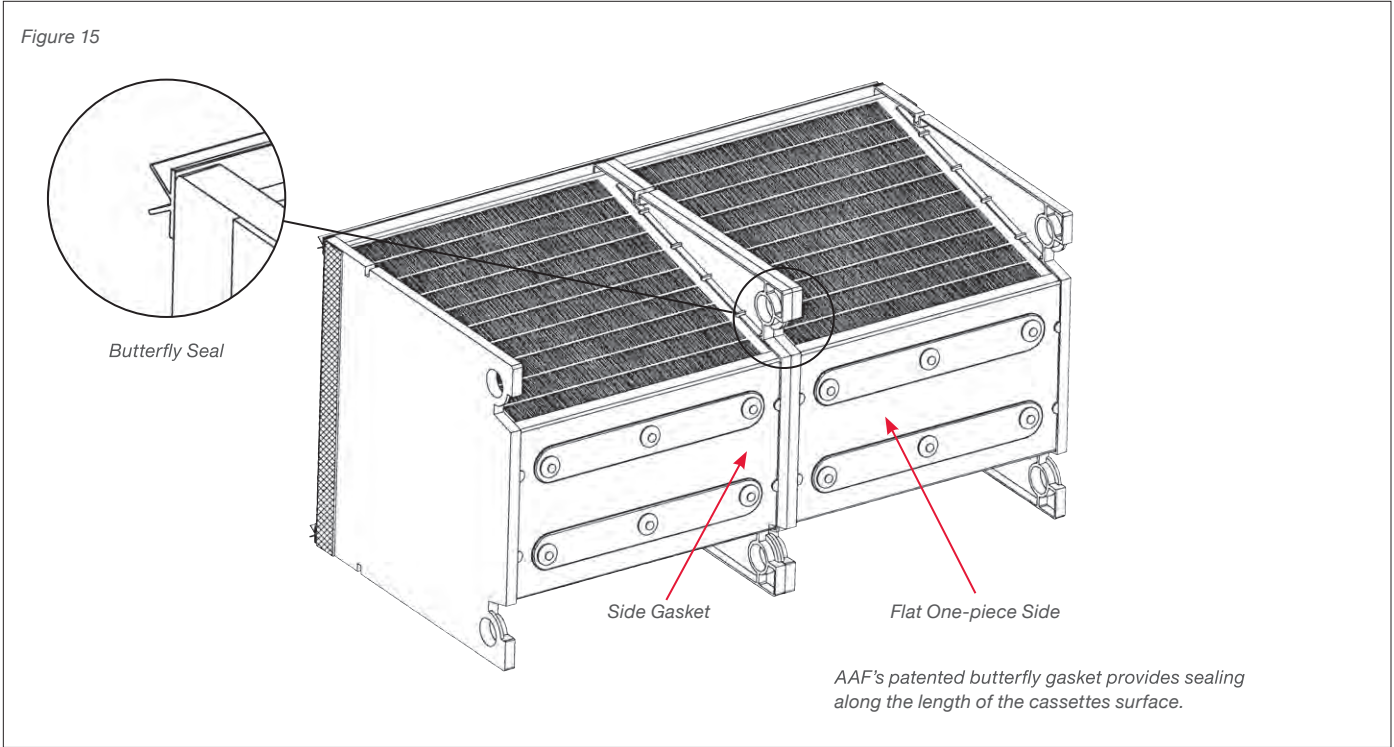
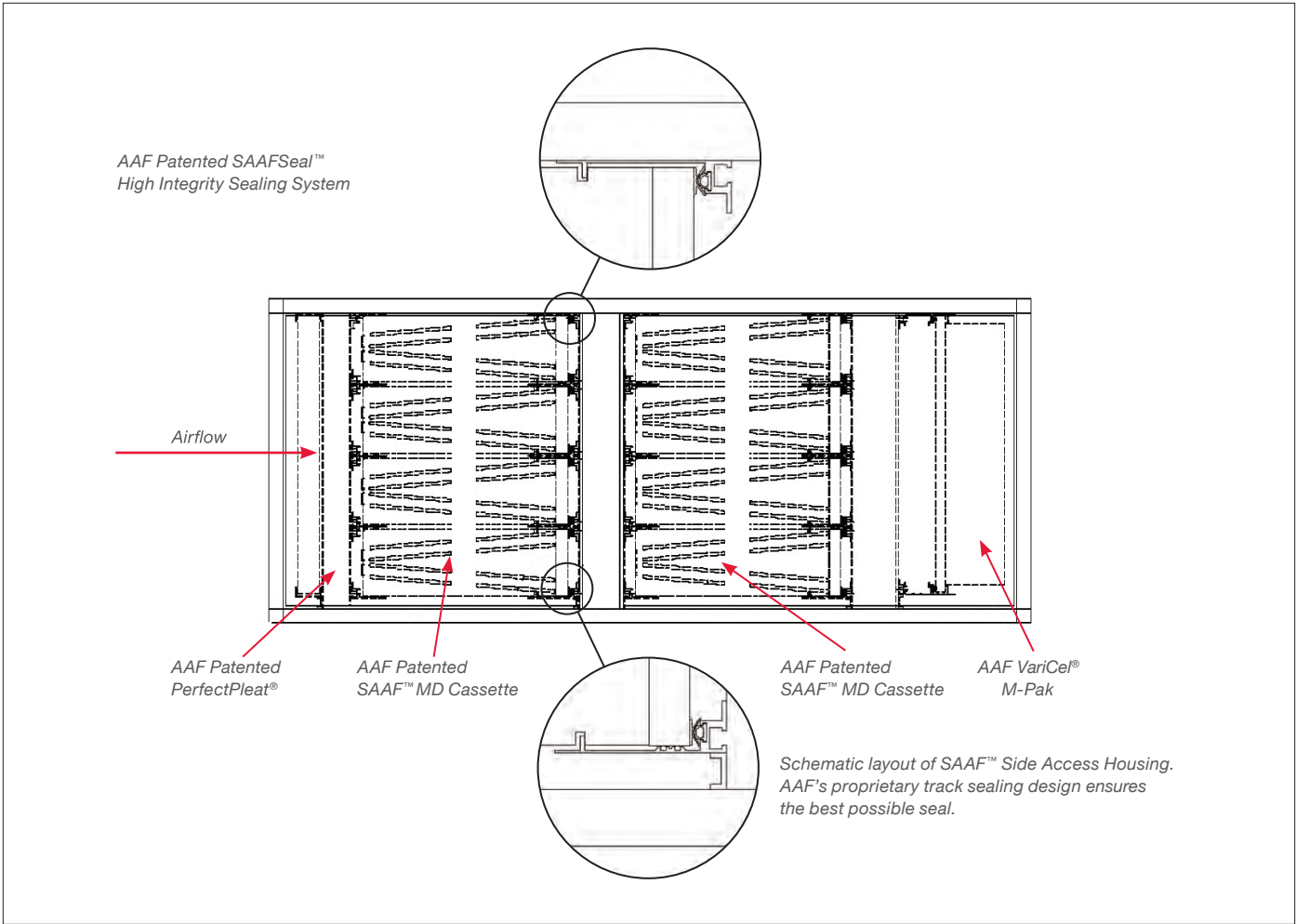
The figure indicates that a cassette is only as good as the track it "engages" on. Current market cassettes (Product R and Product P) were either designed to lay flat on the track or push against the track, utilizing the force of the cassettes over a very short force travel distance. In theory, the latter sounds like a viable concept. In practice, this did not quite work.

AAF's designers concluded that the AAF cassette had to have design features built into it to provide the best sealing possible. Design features were planned such that AAF cassettes seal better than cassettes and tracks currently available in the marketplace, when used in conjunction with an AAF proprietary track sealing design.

While designing the PERFECT Cassette, AAF designed the perfect track—one that offered an easy glide mechanism for effortless cassette travel and a built-in, effective, bubble-seal feature that provided complete surface-to-surface sealing between the track and the AAF cassette. The perfect did not include a pile seal (or) weather strip, as such a feature was not an adequate bypass reduction and sealing device.

To further enhance the sealing provided, a patent-pending butterfly gasket was designed using advanced airflow design tools. (See Figure 15) This mechanism provided yet another seal along the length of cassette's surface. The flaps of the butterfly gasket were designed so that air movement would force down the flaps and provide a full length seal along the track surface. The AAF design ensures that the butterfly gasket would work in ANY existing tracking system, making AAF cassettes better retrofits.



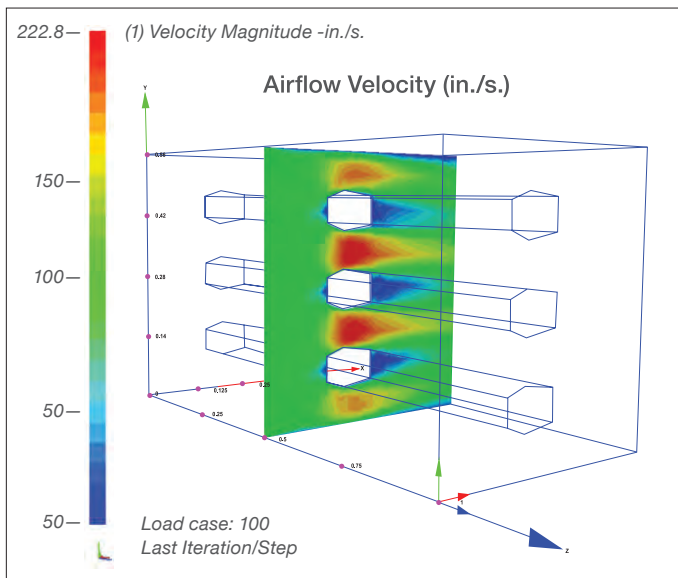


## Aerodynamics

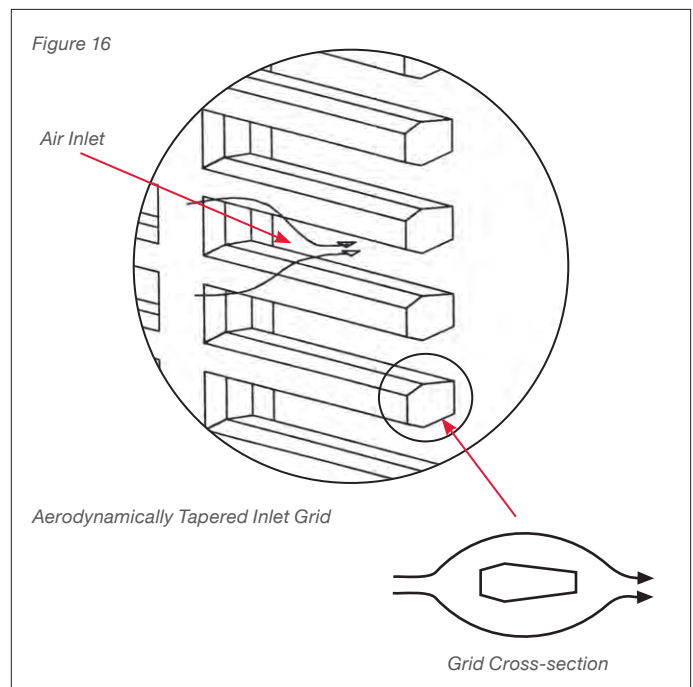
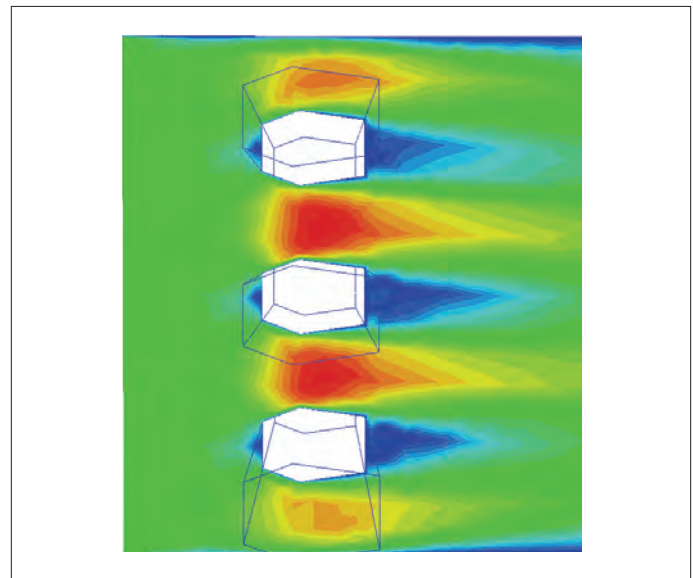
Individual cassette features were put under scrutiny, once the cassette's integrity and sealing ability achieved AAF's highly stringent standards. The first item under design scrutiny was the chemical media retaining screens.

The screens were designed with internal rib reinforcements and pressure retaining straps to prevent bulging or bowing. Bulging or bowing contribute to chemical media settling that may result in premature breakthrough. Controlling bulging of screens was critical.

The screens were designed such that they contained the chemical media better, and yet offered the greatest airflow exposure to the chemical media. This feature was added very creatively on the design lines of an aircraft wing. Individual ribs on the screens were designed and created such that each rib would resemble an aircraft wing, allowing air to "glide" past the screen into the chemical media bed and out (See Figure 16). This design is a huge advance when compared with competition cassettes, where the airflow strikes a punched-out, perforated screen-type structure with sharp corners. The AAF design creates individual contoured ribs and hundreds of micro-funnels, which allow for the best aerodynamics in cassette technology. The results of this exercise—the cassettes had a tremendously reduced drag, better chemical media retention, and offered the greatest open area available in cassette technology.

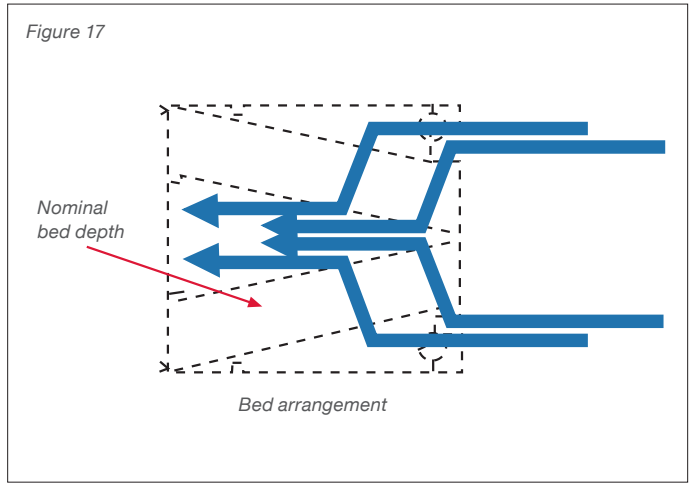
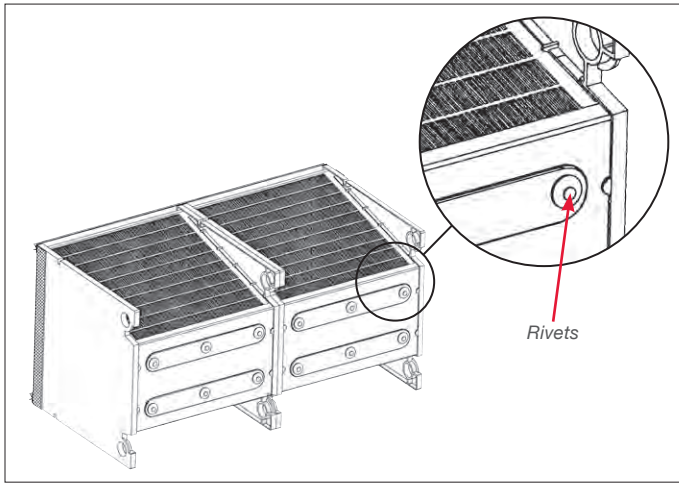


AAF's patented cassette design offers improved airflow characteristics to ensure full media utilization.



The next area to be addressed was the chemical media containment arrangement, since there were market reports of instances where chemical media had spilled out of the cassettes as a result of the plastic labels coming off, or the friction fit end caps releasing due to the pressure build up with the cassette.

To correct this, the media fill ports on AAF cassettes were designed with multiple layers of protection. First, the chemical media retaining mechanism are solid plates fabricated from a material identical to that of the cassette itself (not a plastic sticker). These plates are reinforced to prevent bowing. Second, these plates are pressure-fitted into the cassette frame. Third, these plates are secured with riveted fasteners (same MOC as the cassette frame) and anchored in the frame of the cassette, making them integral with the cassette frame. The result—the best burst resistance possible.



### The PERFECT Cassette—Cross-Checking Using Computational Tools

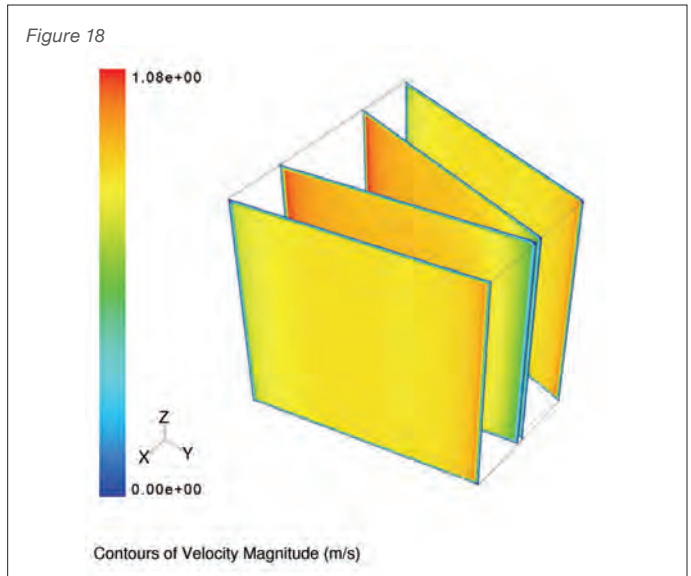
The advanced features on the new AAF cassettes were repeatedly tested and cross checked for optimization using AAF's advanced design review tools. Results of AAF cassette velocity magnitudes on the planar section, velocity magnitude on media exterior surface, and spatial velocity isograph are shown in the figures that follow (See Figures 18, 19, and 20).

Note the uniform velocity magnitudes on the horizontal planar section and exterior media surfaces. This ensures that the airflow through the entire cassette is uniform and even. Uneven pressure and velocity gradients are reduced.

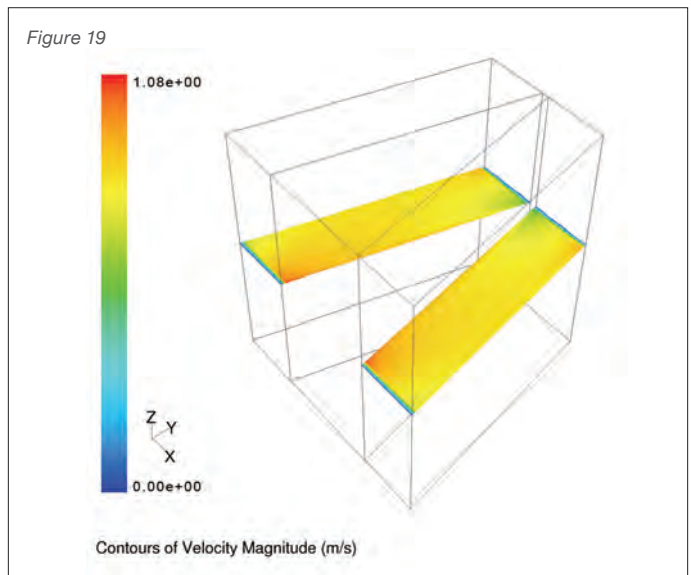
No exciting rainbows on AAF cassette fluid flow calculations! Just steady uniform colors denoting uniform flows and optimal residence time effects. Furthermore, note the spatial ISO surface. The nose cavity effect, which rendered up to 25% of the chemical media useless within Product P and Product R, is greatly reduced in the AAF cassette and is virtually nonexistent.

These features, while possibly an over design for commercial applications, are very much a value-add for certain critical and industrial uses. AAF cassettes provide a significant quality improvement in extremely critical applications, such as in the intakes of large air compressors, air intakes into hospitals, pharmaceutical chambers, laboratories, or microelectronic cleanrooms.

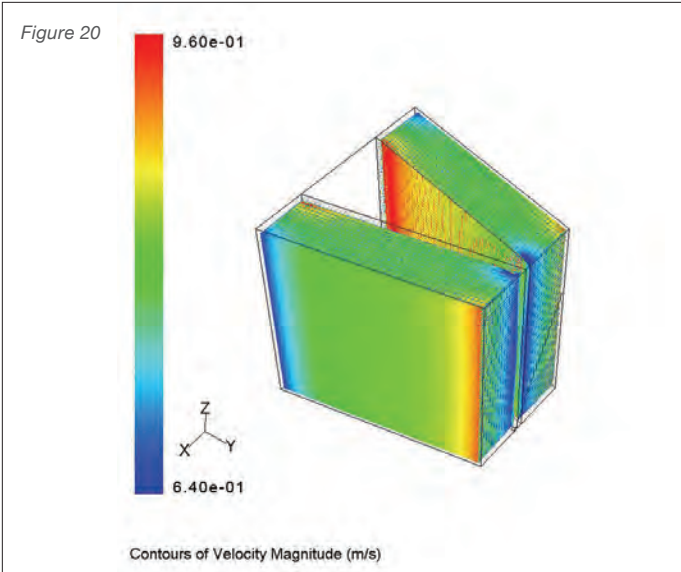
The next area of focus was to ensure that the V formation within the cassette was a true V; i.e., without a predominant nose cavity. This was done to offer complete chemical media utilization, uniform pressure drop, steady velocity gradients, and increased residence time distribution for optimum chemical media reaction. The resulting design is shown in the schematic (Figure 17).



AAF Cassette: Velocity magnitude on media exterior surface.



AAF Cassette: Velocity magnitude on media planar section.



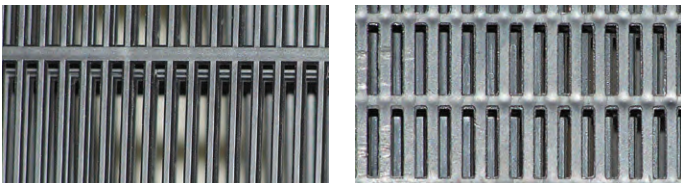
AAF Cassette: Spatial velocity isosurface.

**Comparing The Technologies**

The figures below provide easy side-by-side visuals between AAF's new cassette technology, Product P and Product R. The differences are very clear and self explanatory.



The open design of the AAF cartridge cassette allows improved air flow- The design of the competitive filters will result in restricted airflow.



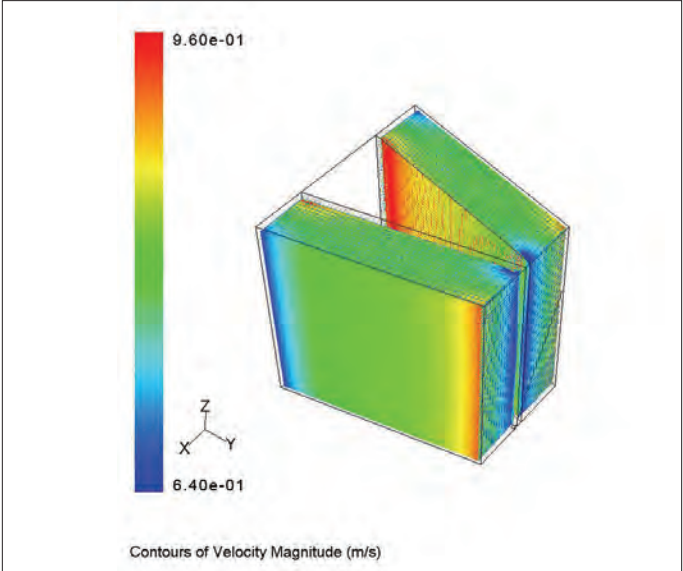
Compare the open design of the AAF cartridge (left) to the restricted design of the competitive filter (right).



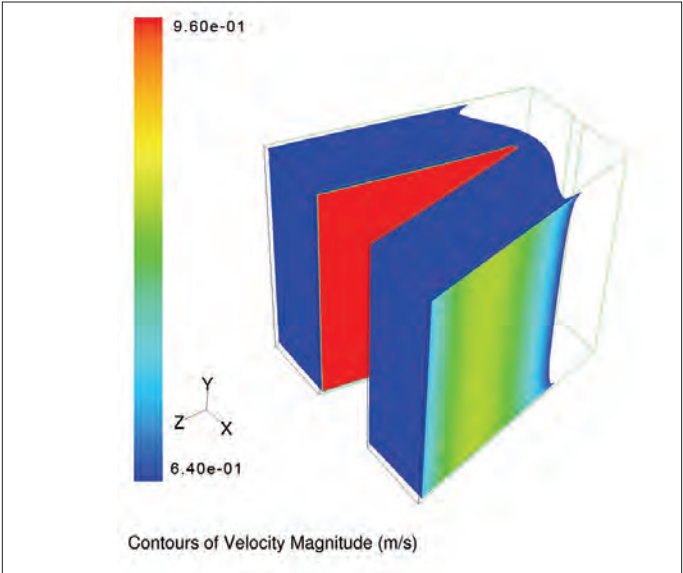
AAF cartridges are built with endplates to ensure holding strength (left). Competitive filters use stickers to retain the media (right).



The AAF cartridge endplates provide secure retention of the carbon media. The competitive product on the right shows media bulging out the sticker.

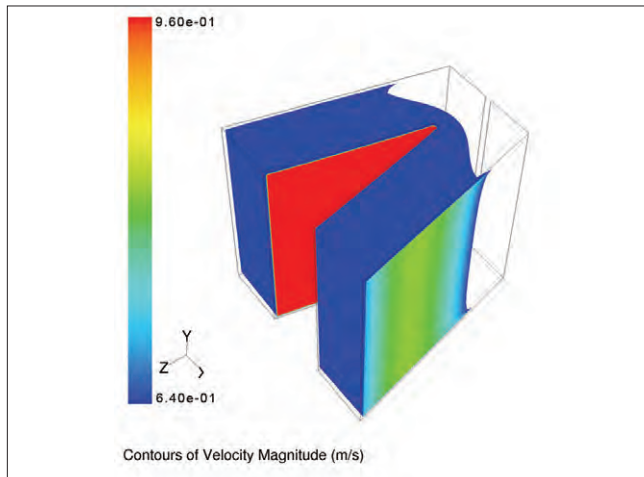


AAF Cassette: Spatial velocity isosurface.



Product R: Spatial velocity isosurface.

# The PERFECT Cassette — AAF's SAAF™ Cassette



Product P: Spatial velocity isosurface.

## Definition of Analysis Terms:

### Velocity Magnitude on a Horizontal Planar Section

This is the magnitude of the spatial velocity through the cross section of the media bed.

### Velocity Magnitude on Media Exterior and Interior Surfaces

This is the magnitude of the spatial velocity at the chemical media exterior and interior screen surfaces.

### Spatial Isosurface Velocity

This is the velocity across the volume of chemical media bed and evaluates the percentage effective utilization of the chemical media, i.e. volumetric efficiency. The lower the volumetric efficiency, the lower the utilization of the chemical media within the bed before premature breakthrough occurs.

## References:

1. CDC
2. NAFA
3. NIOSH
4. Environment air quality

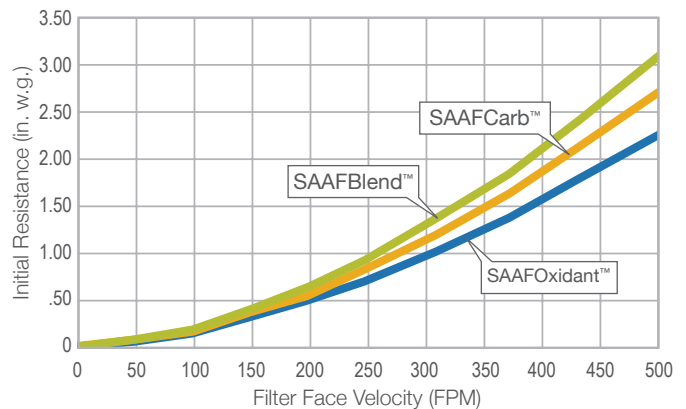
The results are gratifying—the highest effective chemical media utilization (CMU) index of 92% for AAF redesigned cassette vs. 69% in Product P and 62% in Product R!

## Does Good Design = Cost Savings?

**If you operate in today's economic conditions it does.**

Aerodynamics + High CMU Index = Greater operating life + Low energy consumption + Better Gas-phase air cleaning. Below are pressure gradients of AAF cassettes with different chemical media as tested by an independent, reputable air filter testing authority. AAF cassettes were tested and found to provide pressure drops lower than both Product P and Product R claims.

## Initial Resistance vs. Filter Face Velocity



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AAF has a policy of continuous product research and improvement. We reserve the right to change design and specifications without notice.

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