Fans, Ducts and Air Handling Systems: Design, Performance and Commissioning Issues

Filters

Instructor:

David Sellers

Senior Engineer

Facility Dynamics Engineering

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Conventional Thinking = HVAC is Filtration

Filtration and HVAC Go Hand in Hand

Air conditioning is the control of the humidity of the air by either increasing or decreasing its moisture content. Added to the control of the humidity are the control of temperature either by heating or cooling the air, the purification of the air by washing or filtering the air, and the control of air motion and ventilation.

Dr. Willis Carrier

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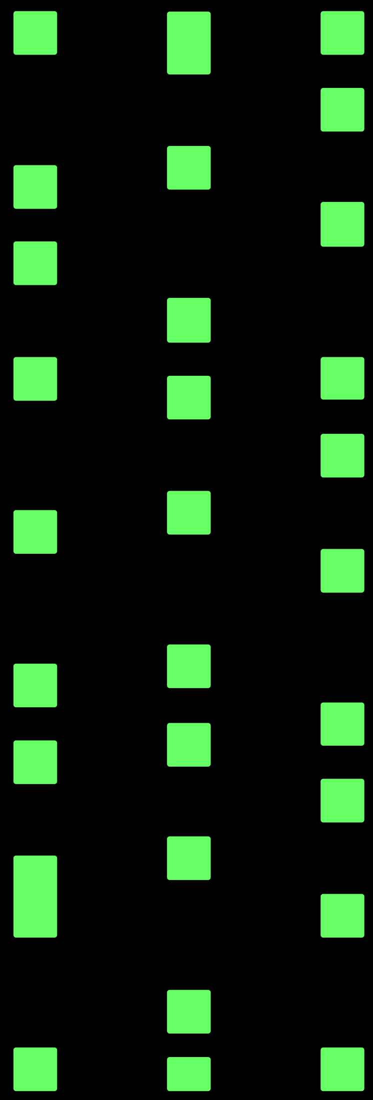
LEED® Requirements Push Towards Higher Filtration Levels

IE Q Credit 5: Indoor Chemical and Pollutant Source Control

- *Particle filters or air cleaning devices shall be provided to clean the outdoor air at any location prior to its introduction to occupied spaces.*
- *These filters or devices shall be rated a minimum efficiency reporting value (MERV) of 13 or higher in accordance with ASHRAE Standard 52.2.*

Face Loading Filters

Depth Loading Filters



Filtration Mechanisms

- **Straining**
- **Impingement**
- **Interception**
- **Diffusion**
- **Electrostatic Effects**

Conventional Thinking = They're All About the Same

Camfil Farr HI-FLO

- MERV11 (60-65% ASHRAE Dust-spot Efficiency)
- 24” high, 12” wide, 22” deep
- 4 flexible pockets
- 29 sq.ft. of high lofted air laid micro fiber glass media
- ΔP_{Clean} at 500 fpm = 0.28 in.w.c.
- $\Delta P_{MaxDirty}$ = 1.00 in.w.c.
- Dust holding capacity – Not published
- $16.68

Filtrair FMV

- MERV14 (95% ASHRAE Dust-spot Efficiency)
- 24” high, 12” wide, 11.5” deep
- 4 rigid pockets
- 77.5 sq.ft. of wet laid scrim laminated to a proprietary gradient density melt blown matrix of synthetic fibers
- ΔP_{Clean} at 500 fpm = 0.34 in.w.c.
- $\Delta P_{MaxDirty}$ = 1.50 in.w.c.
- Dust holding capacity = 125 grams
- $85

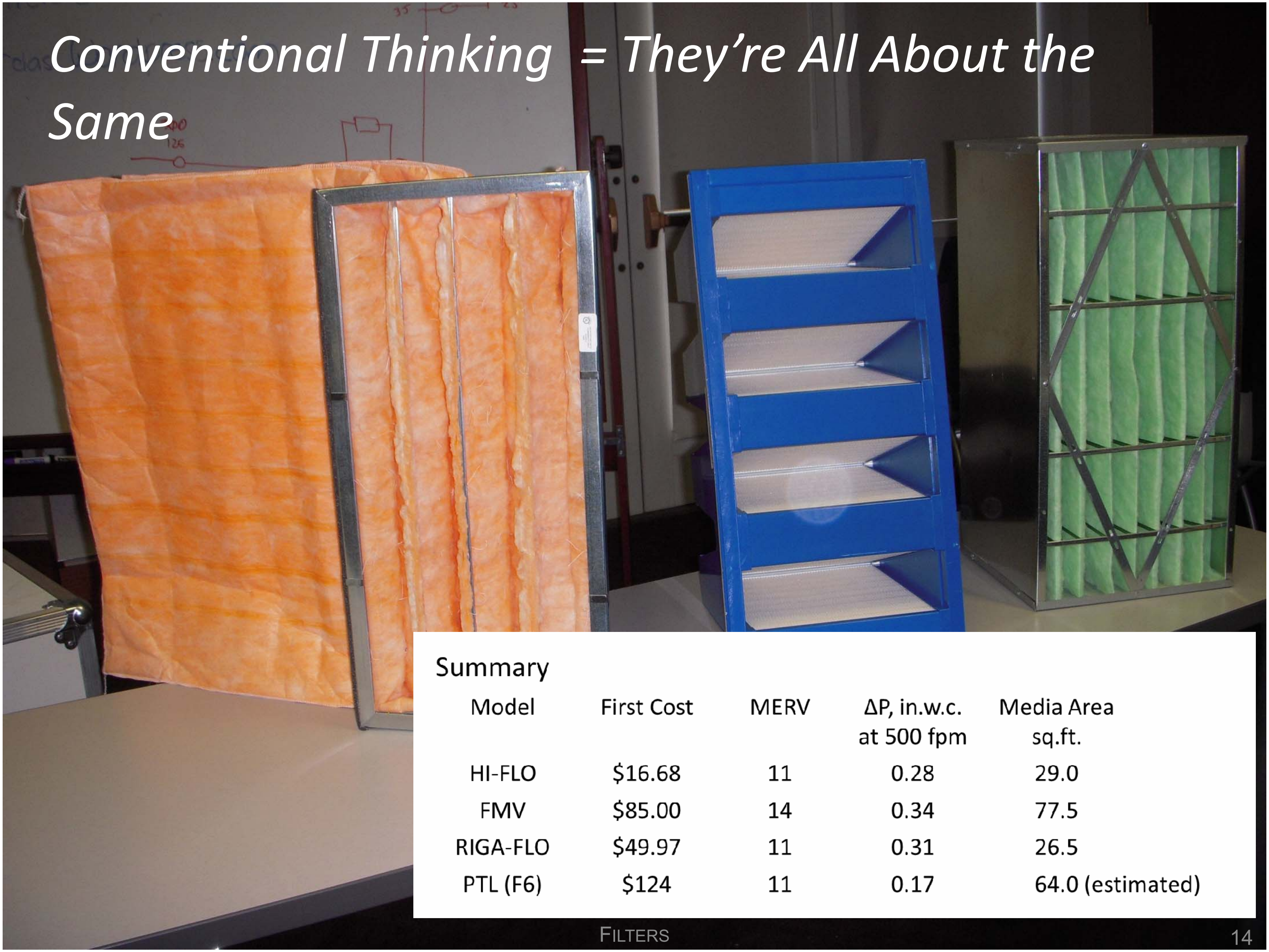
Camfil Farr RIGA-FLO

- MERV11 (60-65% ASHRAE Dust-spot Efficiency)
- 24” high, 12” wide, 11.5” deep
- 8 semi-rigid pockets
- 26.5 sq.ft. of high-lofted, depth-loading, microfine glass media
- ΔP_{Clean} at 500 fpm = 0.31 in.w.c.
- $\Delta P_{MaxDirty}$ = 1.50 in.w.c.
- Dust holding capacity = not published
- $49.97

FILTRAIR PTL (F6)

- MERV11 (60-65% ASHRAE Dust-spot Efficiency)
- 24” high, 24” wide, 24” deep
- 8 rigid pockets
- High performance depth loading fibers laid using a progressive density multi-layering technique
- ΔP_{Clean} at 500 fpm = 0.17 in.w.c.
- $\Delta P_{MaxDirty}$ = 1.60 in.w.c.
- Dust holding capacity = 1,150 grams
- $124

Conventional Thinking = They're All About the Same



Summary

Model	First Cost	MERV	ΔP, in.w.c. at 500 fpm	Media Area sq.ft.
HI-FLO	$16.68	11	0.28	29.0
FMV	$85.00	14	0.34	77.5
RIGA-FLO	$49.97	11	0.31	26.5
PTL (F6)	$124	11	0.17	64.0 (estimated)

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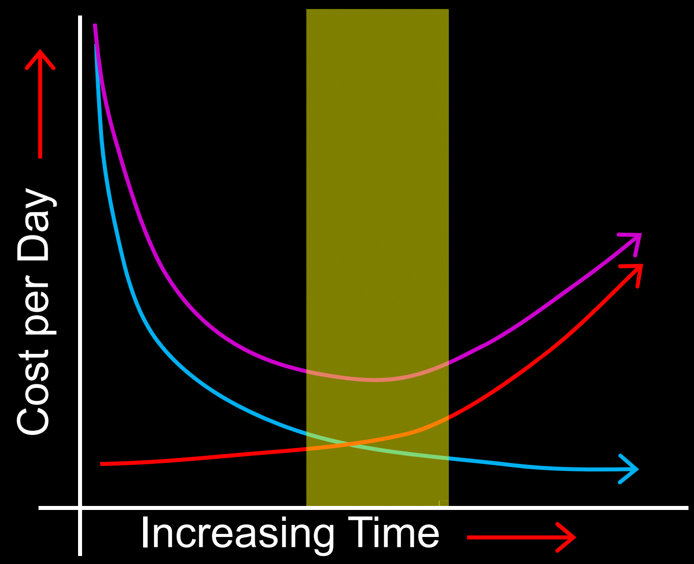
Filter Life Cycle Costs



First cost component

- Decreases over time
- Non-linear
  - Day 1 – Cost per day = Cost of filter set
  - Day X – Cost per day = (Cost of filter set)/X Days

Energy cost component

- Increases over time
- Non-linear

Total cost component

- Decreases then increases over time
- Change filters at inflection point for best life cycle cost

The Life Cycle Cost Game

Benefits of more expensive media

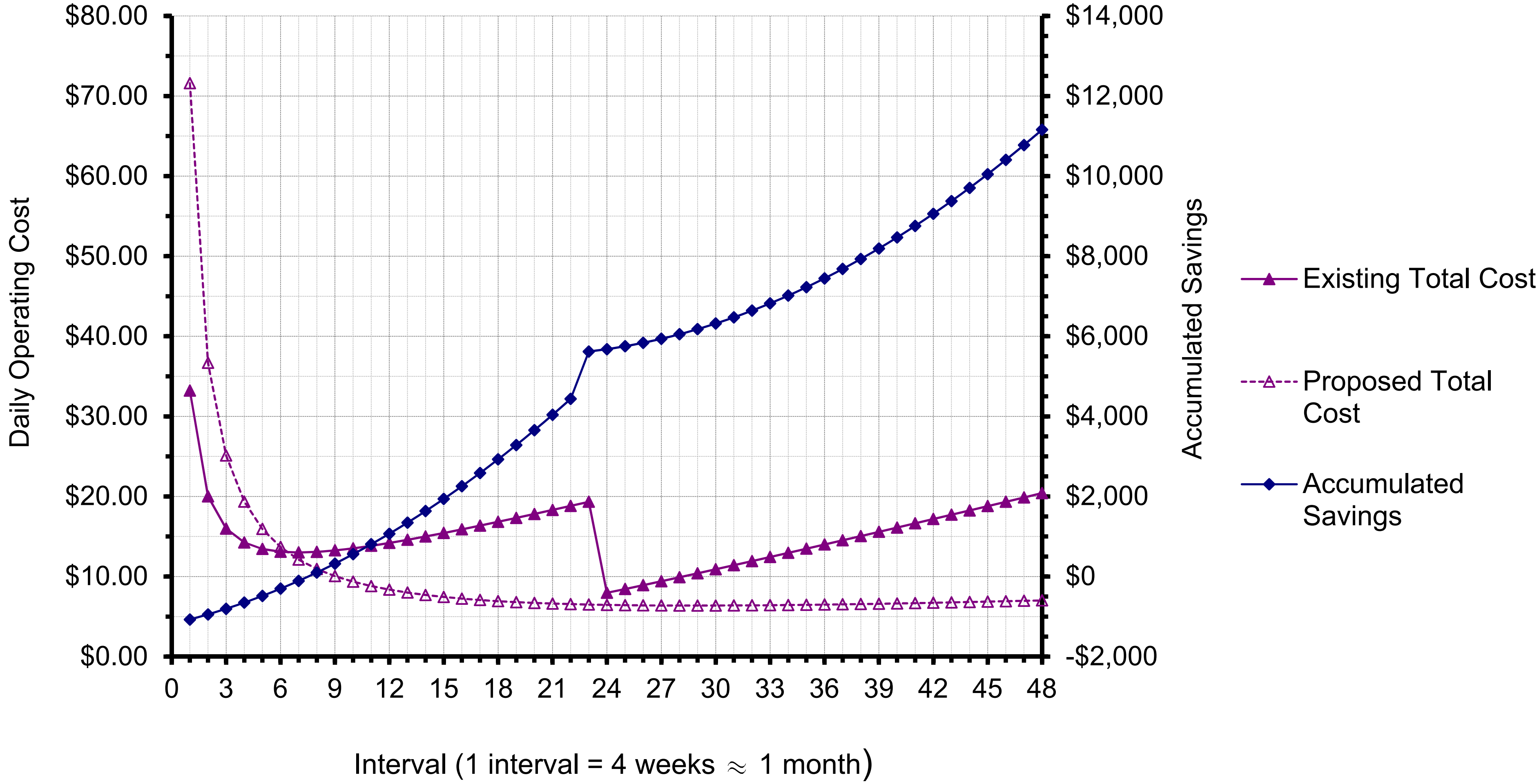
- More surface area
- Engineered loading characteristics
- Lower pressure drops (less fan energy)
- More dust holding capability

Leveraging the benefits

- Lower fan energy
- Longer life
- Eliminate prefilters
  - Eliminates related fan energy
  - Eliminates related labor
  - Eliminates related disposal
  - Allows final filters to run to a higher ΔP_{Dirty}

Filter Cost per Average Day and Accumulated Savings

UCB LeConte Hall Current Practice (65% ASHRAE Efficiency Bag filters with Prefilters) vs.
65% Efficiency Extened Surface Area Filters with No Pefilters



Savings Summary - First Year Basis

	Electricity		Filters	Total	Waste
	kWh	$	$	$	cu. yd.
Existing Approach	8,366	$837	$631	$1,468	4.9
Proposed Approach	1,966	$197	$1,860	$2,057	4.4
Savings	**6,400**	**$640**	**($1,229)**	**($589)**	**0.5**
Simple Payback	**1.92 years (energy only)**				

Savings Summary - 48 M[illegible]

Existing Approach	[illegible]	[illegible]	[illegible]	$5,909	9.9
Proposed Approach	13,646	$1,365	$1,860	$3,225	4.4
Savings	**32,816**	**$3,282**	**($598)**	**$2,684**	**5.4**
Simple Payback	**8.74 months (energy only)**				

Taking a life cycle perspective is important

An important “ripple effect”

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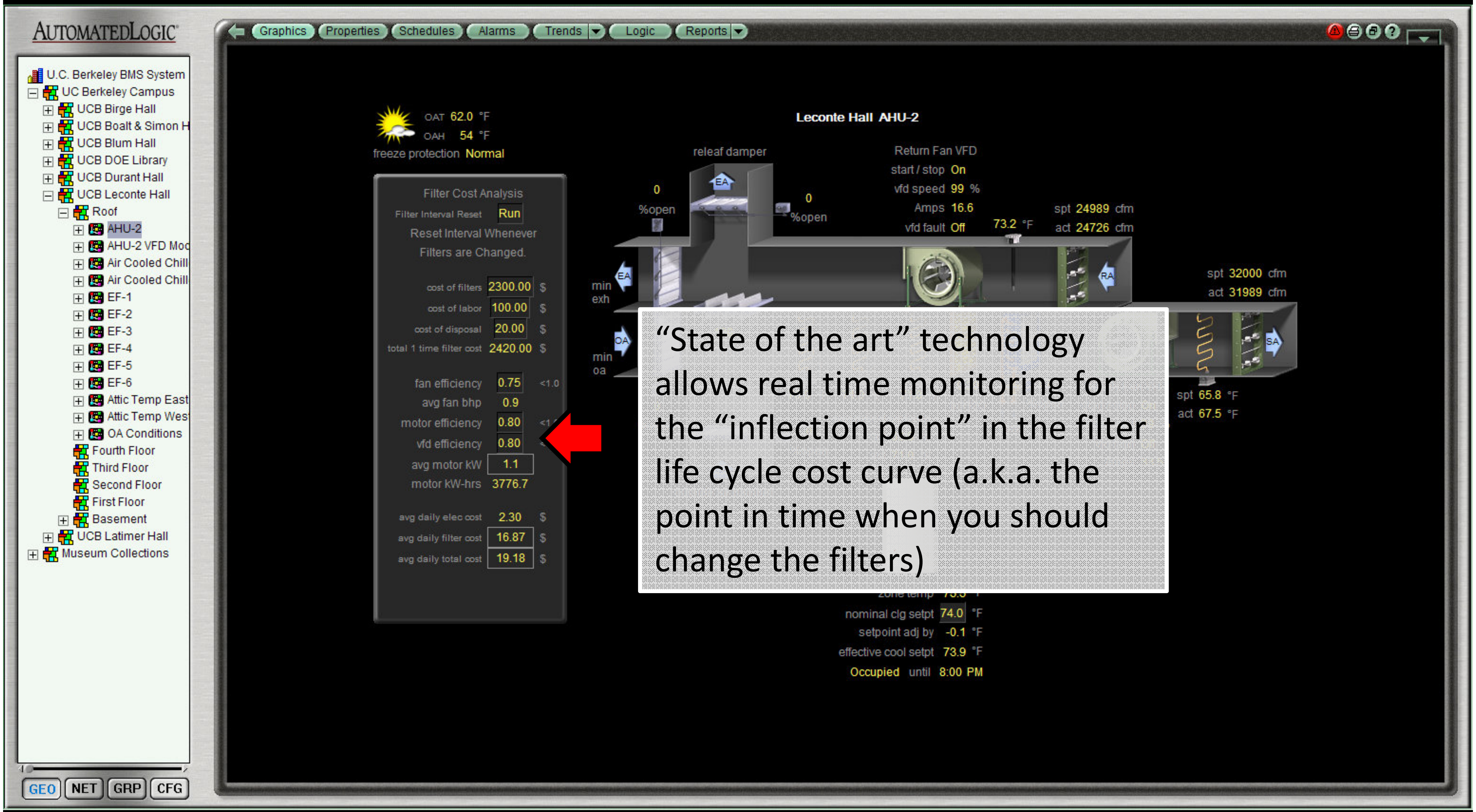
Savings	**6,400**	**$640**	**($1,229)**	**($589)**	**0.5**
Simple Payback	**1.92 years (energy only)**				

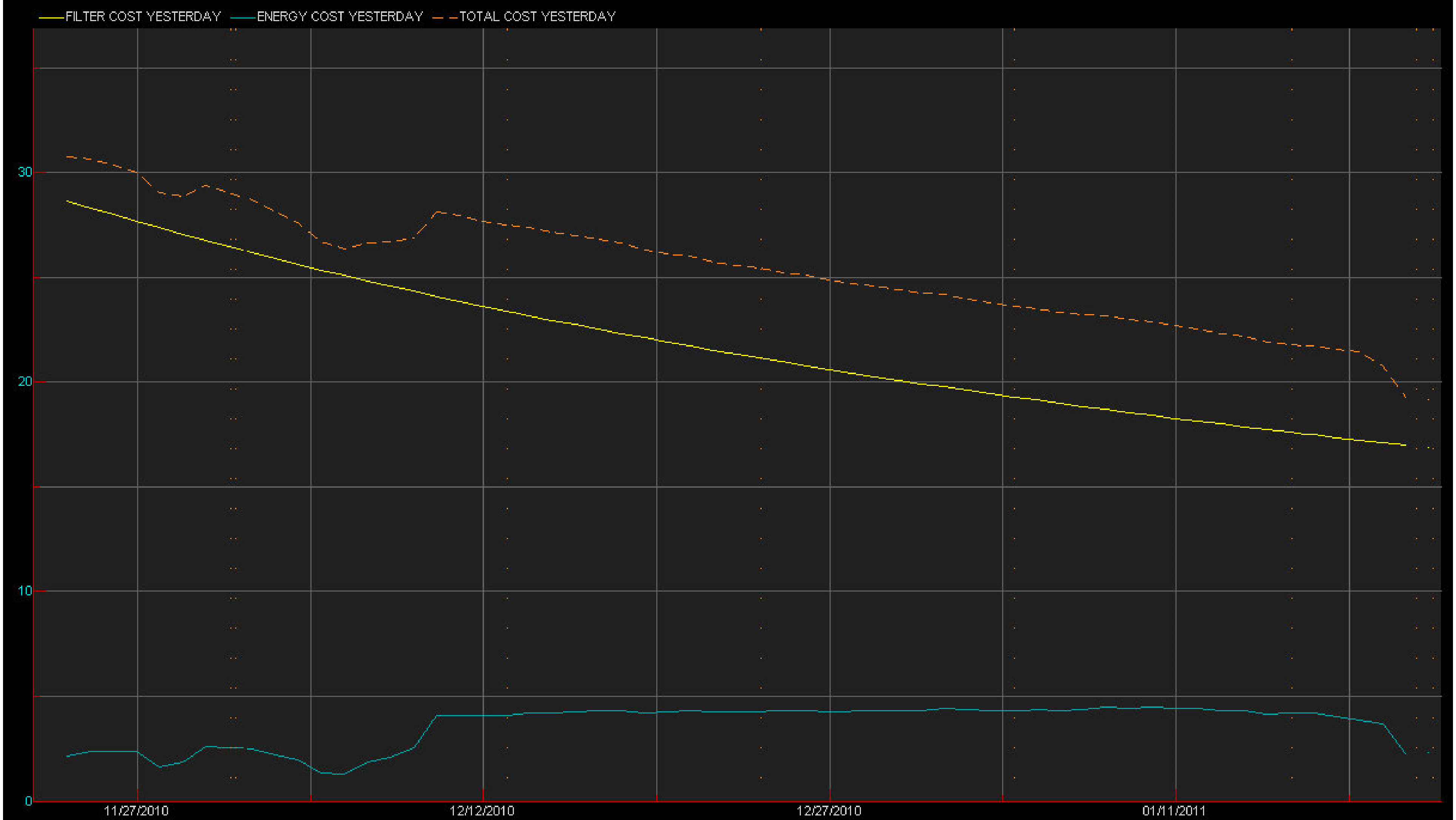
Savings Summary - 48 Month Cycle Basis

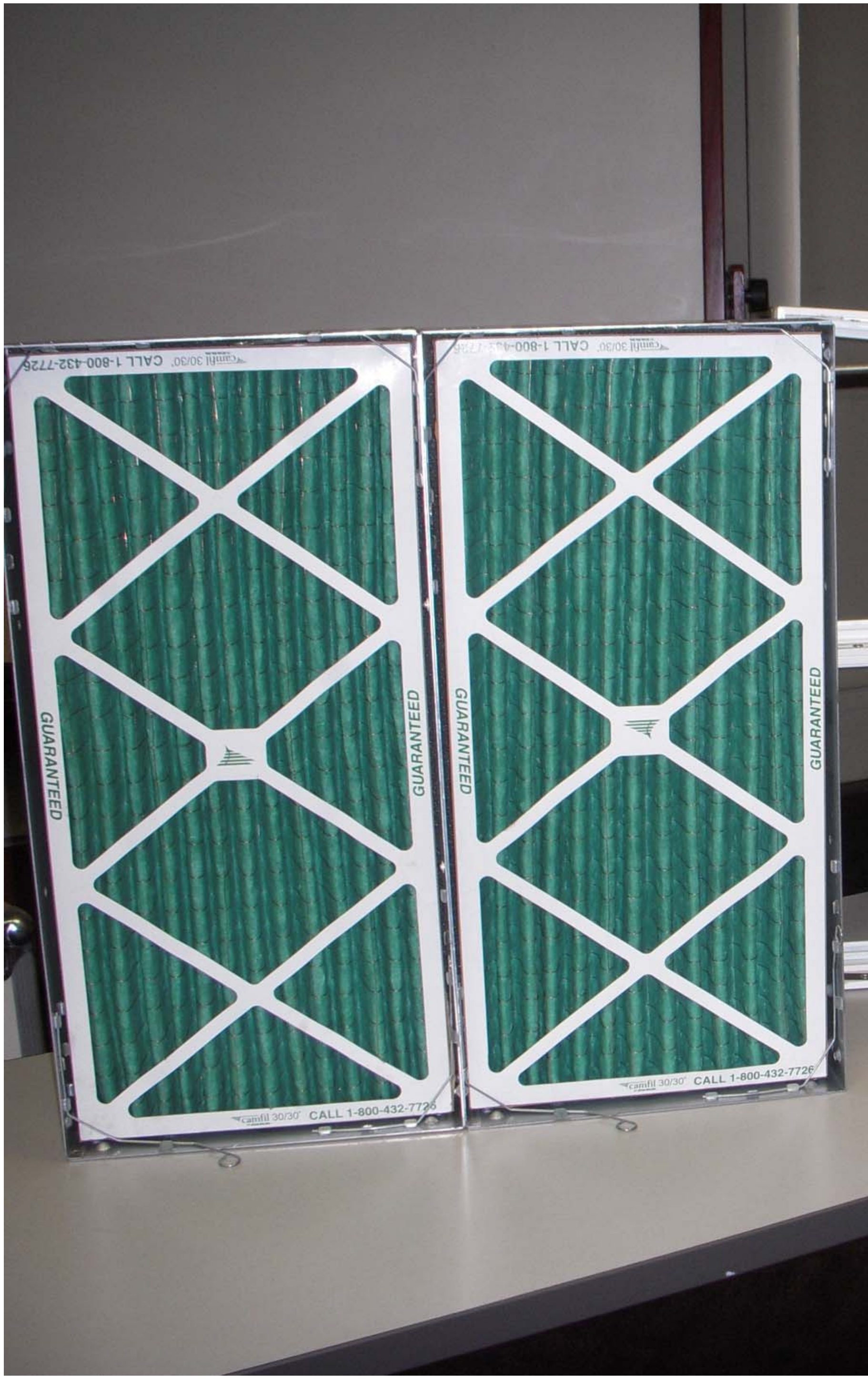
	Electricity		Filters	Total	Waste
	kWh	$	$	$	cu. yd.
Existing Approach	46,461	$4,646	$1,262	$5,909	9.9
Proposed Approach	13,646	$1,365	$1,860	$3,225	4.4
Savings	**32,816**	**$3,282**	**($598)**	**$2,684**	**5.4**
Simple Payback	**8.74 months (energy only)**				

Cost and benefit may not occur in the same purchasing group



"State of the art" technology allows real time monitoring for the "inflection point" in the filter life cycle cost curve (a.k.a. the point in time when you should change the filters)


FILTER COST YESTERDAY
ENERGY COST YESTERDAY
TOTAL COST YESTERDAY
30
20
10
0
11/27/2010
12/12/2010
12/27/2010
01/11/2011

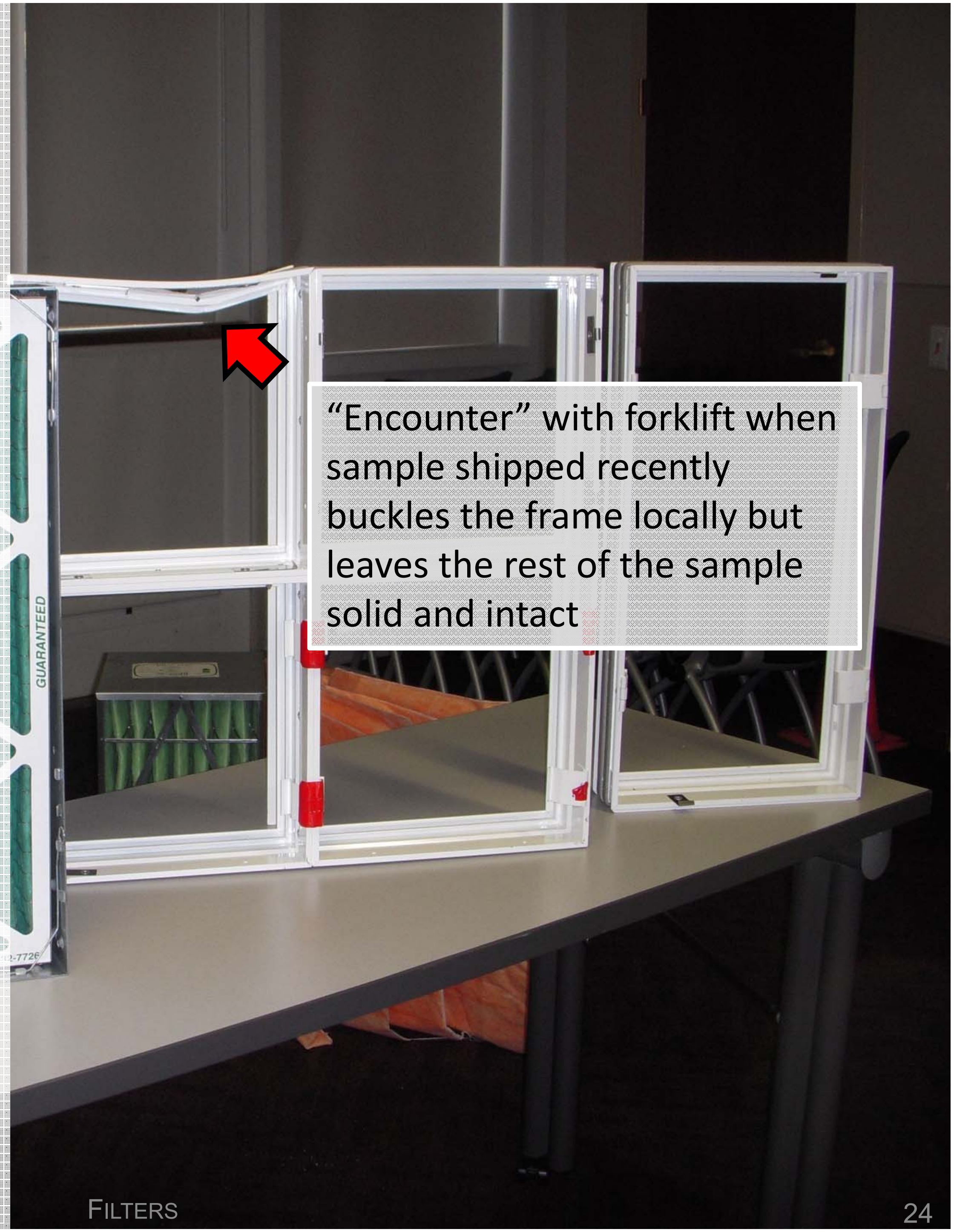


Camfil Farr Type 8

- 16 gauge galvanized steel
- Foam gaskets (optional)
- Spring clip retainers (not included)
- Riveted or bolted up assembly (not included)
- Structural steel supports required between every-other vertical row (not included and frequently omitted)
- $66.97 per “hole” (materials only)

Total Filtration Manufacturing Optiframe/H

- Extruded, epoxy powder coated framing material
- Tongue and groove joints between modules
- Quadruple closed cell foam gaskets between modules
- Knife edge filter seals
- 1.5” I beam structural support between rows
- Over-center and swing bolt retainers
- $125 per “hole” (installed)



“Encounter” with forklift when sample shipped recently buckles the frame locally but leaves the rest of the sample solid and intact

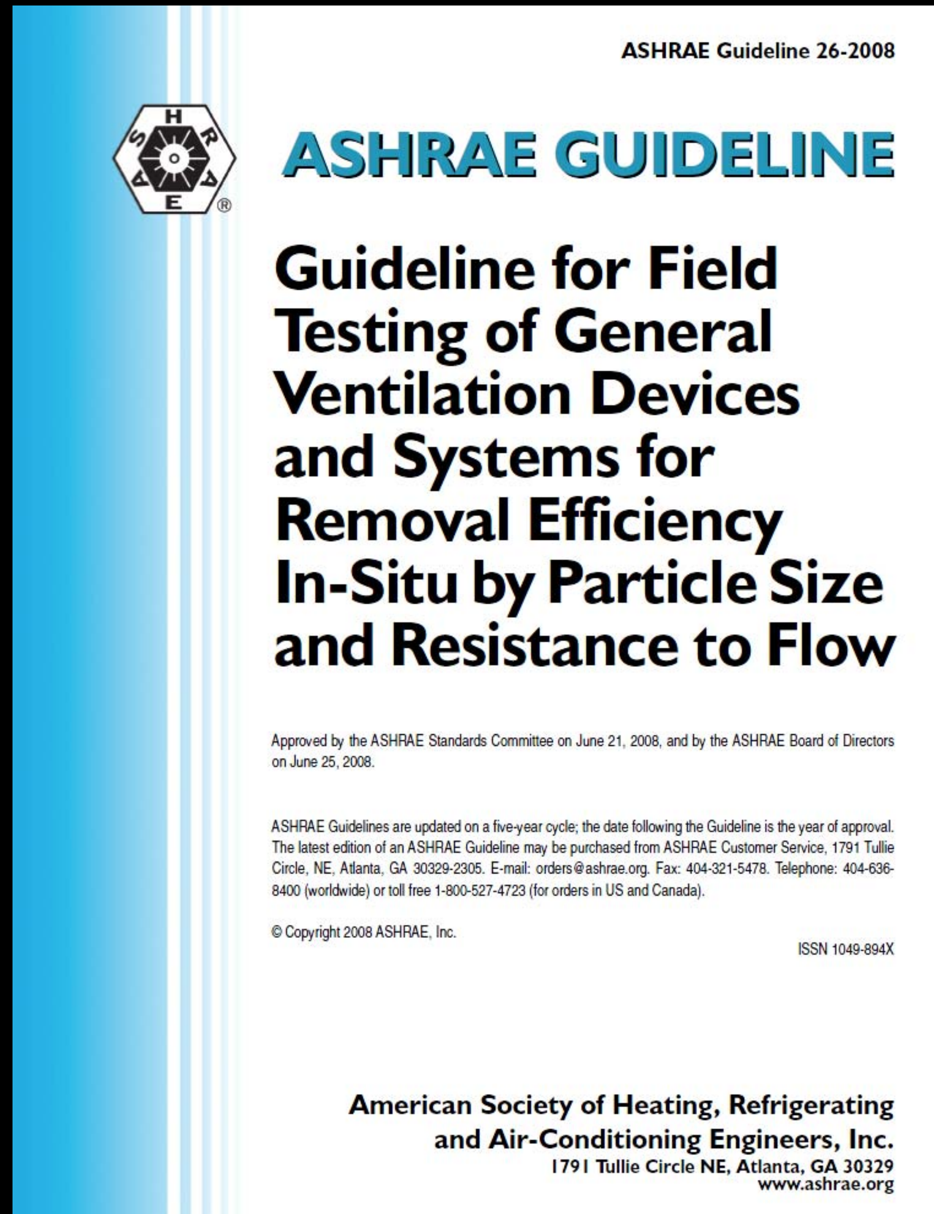
Assessing Reality

Tests for installed efficiency and pressure drop

Captures the impact of field realities

- Real world dust
- Frame impacts
- System impacts

Provides for correlation with lab test



ASHRAE Guideline 26-2008

ASHRAE GUIDELINE

Guideline for Field Testing of General Ventilation Devices and Systems for Removal Efficiency In-Situ by Particle Size and Resistance to Flow

Approved by the ASHRAE Standards Committee on June 21, 2008, and by the ASHRAE Board of Directors on June 25, 2008.

ASHRAE Guidelines are updated on a five-year cycle; the date following the Guideline is the year of approval. The latest edition of an ASHRAE Guideline may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide) or toll free 1-800-527-4723 (for orders in US and Canada).

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Practice Due Diligence

- ASHRAE Journal article based on research in Denmark found a correlation between perceived air quality and filter life for flexible bag filters
- Scheduled operation seemed to make things worse
- Active carbon seemed to mitigate the problem
- For our field trails to date this has not been an issue

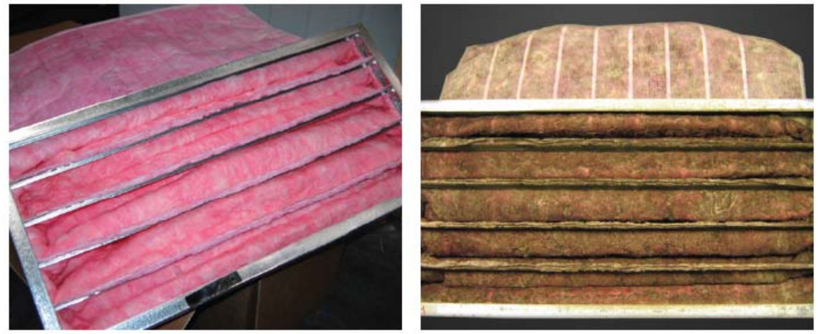

Figure 1a (left): New F7 (~MERV13) fiberglass bag filter. Figure 1b (right): The same filter after five months of continuous operation.

Used Filters

And Indoor Air Quality

By Gabriel Bekö, Ph.D.

The presence of used filters in a ventilation system can have an adverse impact on perceived air quality, Sick Building Syndrome symptoms, and performance of office work. This article briefly summarizes earlier works leading to this conclusion, as well as reviews our more recent studies performed to gain better understanding of this problem. Possible mechanisms responsible for the emission of noxious compounds from ventilation filters are described. Finally, the economic impact of polluting ventilation filters and possible engineering solutions are discussed.

Mechanical ventilation systems are commonly used to ensure that ventilation standards and guidelines are met. However, studies have documented that building occupants, especially in older and mechanically ventilated buildings, consider the indoor air quality unacceptable and suffer from Sick Building Syndrome (SBS) symptoms, sometimes referred to as Building-Related Symptoms (BRS).[1,2,3] Consequently, poor air quality can negatively affect occupants' productivity.[4,5] The prevalence of asthma and allergic diseases has increased during the past decades, most likely due to changes in environmental exposure.[6] Many of the particles either generated indoors or entering the buildings from outdoors can trigger allergic reactions, asthma, and upper and lower respiratory symptoms.[7] Moreover, epidemiological studies report close association between outdoor airborne particles and mortality and morbidity.[8]

Particulate pollutants (smoke, dust fibers, bioaerosols such as viruses, bacteria, and microorganisms) and gaseous pollutants may enter the buildings

About the Author

Gabriel Bekö, Ph.D., is a post-doctoral research fellow at the International Centre for Indoor Environment and Energy, Department of Civil Engineering, Technical University of Denmark in Lyngby, Denmark.

Resources on Filtration

- Follow the field trial at www.Av8rdas.Wordpress.com (starts in a September 2009 post)
- NCBC 2015 Presentation *Leveraging Filter Technology and Life Cycle Cost Based Filter Operation* (linked from my blog)
- The Art and Science of Air Filtration in Health Care
  - HPAC - October 1998
- Filtration: An Investment in IAQ
  - HPAC - August 1997
- Specifying Filters
  - HPAC - November 2003
  - All by H.E. Barney Burroughs
- National Air Filtration Association (NAFA)
  - http://www.nafahq.org/
  - *Using Extended Surface Air Filters in Heating Ventilation and Air Conditioning Systems: Reducing Utility and Maintenance Costs while Benefiting the Environment*, by Michael J. Chimack et.al., ACEEE 2000 Proceedings