Best Life Cycle Cost Filter Operation

Presented By:
David Sellers
Senior Engineer, Facility Dynamics Engineering


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.

COVID Mitigation Pushes Towards Higher Filtration Levels

ASHRAE EPIDEMIC TASK FORCE

Core Recommendations for Reducing Airborne Infectious Aerosol Exposure

- Use combinations of filters and air cleaners that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems

A Bit About Me and My Interest In this Topic

1972

- Set out to be an airplane mechanic and aircraft maintenance engineer

A Bit About Me and My Interest In this Topic

1976

- Reality intervenes

Image Courtesy www.kpluwonders.org/

A Bit About Me and My Interest In this Topic

1976

- Bill Coad inspires me to think a different way…

  … that is to practice our profession with an emphasis upon our responsibility to protect the long-range interests of the society we serve and, specifically, to incorporate the ethics of energy conservation and environmental preservation in everything we do.

ASHRAE Journal, vol. 42, no. 7, p. 16-21

www.ASHRAE.org

Energy Conservation Is an Ethic

William J. Coad, P.E.
Fellow/Life Member ASHRAE

Professionalism means different things to different people. For some, professionalism in engineering describes a method of charging for services; others believe it simply describes a credential achieved. But *Webster's Collegiate Dictionary* defines "professional" as: "...characterized by or conforming to the technical or ethical standards of a calling requiring specialized knowledge and often long and intensive academic preparation."

Thus, a "professional" is a person who can be so described.

Just what is it that the mechanical/electrical engineering professional does to earn that title?

In a way, the engineering professional hasn't had good "press" or public relations for the past 150 years. It started in the early to mid-19th century when Maxwell, Sadi Carnot, Diesel, Otto, and the other thermodynamicists and energy engineers unlocked the secrets to turning the resources of the world into the slaves of mankind. Since that time, the mechanical/electrical engineering community has held the goose that laid the golden egg. And somewhere within that community, they became so intent upon serving humanity in the short run that they lost sight of their long-range responsibility.

This is a good news/bad news story, and, as society stands here today, they cannot be too critical of their performance over the past 150 years. The mechanical/electrical engineering professionals have provided humanity with a massive population of "mechanical slaves." That analogy is borrowed from Oscar Wilde, who wrote in an essay in 1894:

"The fact is that civilization requires slaves. The Greeks were quite right there. Unless there are slaves to do the ugly horrible uninteresting work, culture and contemplation become almost impossible. Human slavery is wrong, insecure and demoralizing. On mechanical slavery, on the slavery of the machine, the future of the world depends."

The result of our success in creating this mechanical slave is the world in which we live today. We have the mechanical slave at our bidding to wash our clothes, cook our food, wash our dishes, move us about over long and short distances, stoke our fires, keep us cool, clean our homes, operate our factories, perform complicated calculations at unbelievable speeds, keep our records, and on and on. Oscar Wilde could not have envisioned, in his wildest dreams, the prophetic significance of that statement.

It is not within the context of this article to expound on the influence of technology upon the state of mankind—the social structures, economy, and human relationships. In his book, *The Fifties*, David Halberstam, discussing the sociological revolution unfolding in the fifties, said:

"The list of technological and scientific changes that transformed America in those years (the fifties) is an extraordinary one—the coming of network television to almost every single home in the country changed America's politics, its leisure habits, and its racial attitudes; the arrival of air conditioning opened up southern and southwestern regions; the early computers were transforming business and the military; the coming of jet planes revolutionized transportation."

And that was but one decade! And in one country! So, looking back, the engineering community can bask in the knowledge that they did a pretty good job. They certainly changed the world.

But going back to Oscar Wilde's mechanical slave—the mechanical slave, like the human slave, needs food. The food for the mechanical slave is energy. The most available energy sources, those that are most readily available and which we have been using for these 150 years, are the *nonreplenishable energy resources of the earth.*

Now, returning to the topic of *professionalism*, and paraphrasing the definition for engineering professionalism:

Engineering professionalism is characterized by conformance to the technical and ethical standards related to the practice of engineering.

The technical standards are self-evident. So, focusing on the ethical standards, the definition of ethics is "...a set of moral principles or standards."

Now, consider our situation as we stand

About the Author

William J. Coad, P.E., is with McClure Engineering Associates in St. Louis. He serves on the ASHRAE executive committee as treasurer, and is vice chair of Regions Council. He has held various leadership positions within ASHRAE and is presently active on Technical Committees 1.10, 6.1, and 8.10.

A Bit About Me and My Interest In this Topic

1976

- I change career paths and am blessed with great mentors

A Bit About Me and My Interest In this Topic

1976

- I encounter my first commercial HVAC system filter bank

A Bit About Me and My Interest In this Topic

1976

- I encounter my first commercial HVAC system filter bank
- It's different from the one in Mom and Dad's furnace

A Bit About Me and My Interest In this Topic

1976

- I encounter my first commercial HVAC system filter bank
- It's different from the one in Mom and Dad's furnace
- Cleaner air = Cleaner equipment in addition to better IEQ

A Bit About Me and My Interest In this Topic

1979/1980

- I begin a long-term relationship with the team at Memorial Hospital of Carbondale

A Bit About Me and My Interest In this Topic

1979/1980

- Joe Cook, Bob Keller and I begin to “do battle” with the Surgery Air Handling System

A Bit About Me and My Interest In this Topic

1979/1980

- Joe Cook, Bob Keller and I begin to "do battle" with the Surgery Air Handling System
  - First exposure to multiple filter beds
  - First exposure to high filtration efficiencies
  - Realize that filters are only as good as their frames
  - Realize that filters = resource consumption on multiple fronts

A Bit About Me and My Interest In this Topic

1990

- We need a few more year's from the aging surgery system
  - OR loads going up
  - OR replacement moving out the timeline
  - Looking for ways to mitigate filter pressure drop and preserve efficiency
  - Discover extended surface area filters

A Bit About Me and My Interest In this Topic

1997

- Move to Oregon to become a facilities engineer at Komatsu Silicon’s Hillsboro facility
  - HVAC system owner
  - Process exhaust system owner
  - Central chilled water plant system co-owner
  - DDC system co-owner
  - Fire protection system owner

A Bit About Me and My Interest In this Topic

1997

- Move to Oregon to become a facilities engineer at Komatsu Silicon’s Hillsboro facility
  - HVAC system owner means I own many, many, many filters
    - Learn a lot about HEPA and ULPA filters
    - Begin to observe filter loading rates
    - Confronted with what a filter change represents in terms of resources

A Bit About Me and My Interest In this Topic

1998

- Semiconductor industry downturn opens the door to alternative approaches to operations
  - Clean room envelope issues cause significant ripple effects with the make up AHU

A Bit About Me and My Interest In this Topic

1998

- Semiconductor industry downturn opens the door to alternative approaches to operations
  - Clean room envelope issues cause significant ripple effects with the make up AHU

Leakage results in the need to run the back-up fan

- 14,000 more outdoor air cfm than design (30%)

Significant HVAC process and fan energy load

- Square law means the duct system is running a or above the pressure class

Significant risk

A Bit About Me and My Interest In this Topic

1998

- Semiconductor industry downturn opens the door to alternative approaches to operations
  - Clean room envelope issues cause significant ripple effects with the make up AHU

Applying extended surface area HEPA filters:

- Eliminates about 0.50 in.w.c. of static
- Provides a “flatter” loading curve
- Particle count test meets requirements

A Bit About Me and My Interest In this Topic

1999

- Semiconductor industry downturn continues
  - Plant idled
  - I move to PECI
    - Begin to pursue life cycle cost filter based operation as a retrocommissioning measure

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1999

- Semiconductor industry downturn continues
  - Plant idled
  - I move to PECI
    - Begin to pursue life cycle cost filter based operation as a retrocommissioning measure
    - I tag along on Mike Chimack's ACEEE paper on the topic

Live cycle cost filter operation = resource savings on multiple fronts

- Fan energy
- Filter first cost
  - Supply stream
  - Embedded energy
- Installation labor
- Disposal
  - Landfill volume
  - Disposal costs
  - More embedded energy

Energy is Not the Only Resource Consumed by Air Handling Equipment

There could easily be at least one 24” x 24” filter for every 2,000 – 4,000 square feet of building space

CBECS 2018 data says there is about 96,758,000,000 square feet of commercial building space

There is More to Filter Media than Being Fuzzy

There is More to Filter Media than Being Fuzzy

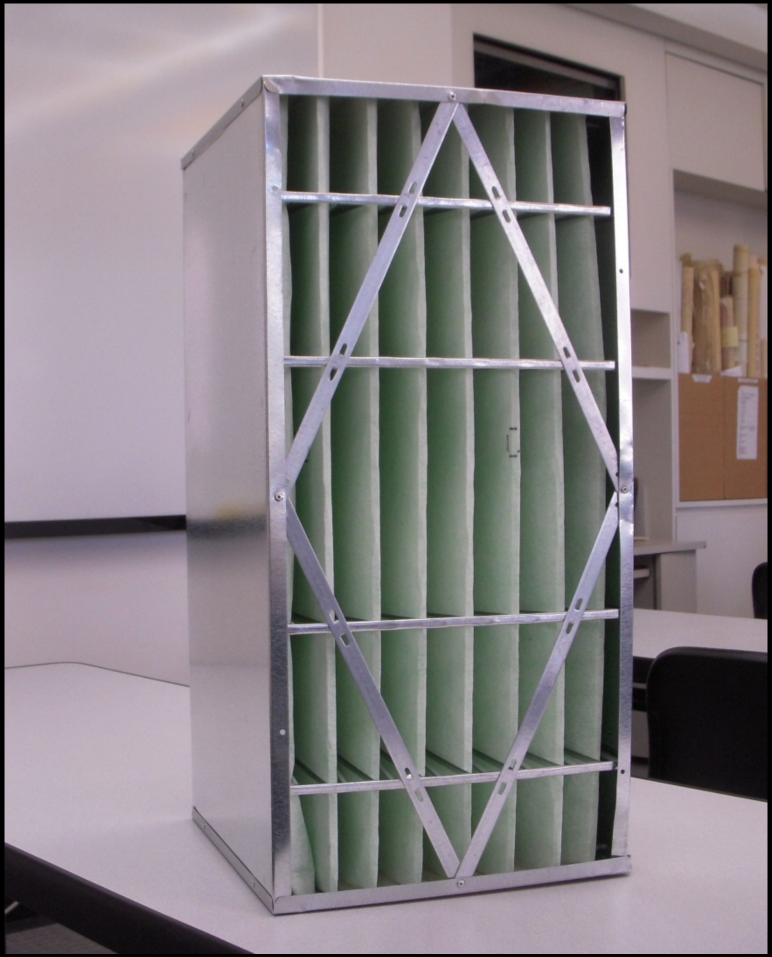
Camfil Farr HI-FLO

- 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 493 fpm = 0.30 in.w.c.
- $\Delta P_{MaxDirty}$ = 1.50 in.w.c.
- Dust holding capacity – 175 grams
- $16.68

There is More to Filter Media than Being Fuzzy

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 493 fpm = 0.35 in.w.c.
- $\Delta P_{MaxDirty}$ = 1.50 in.w.c.
- Dust holding capacity = 225 grams
- $49.97



There is More to Filter Media than Being Fuzzy

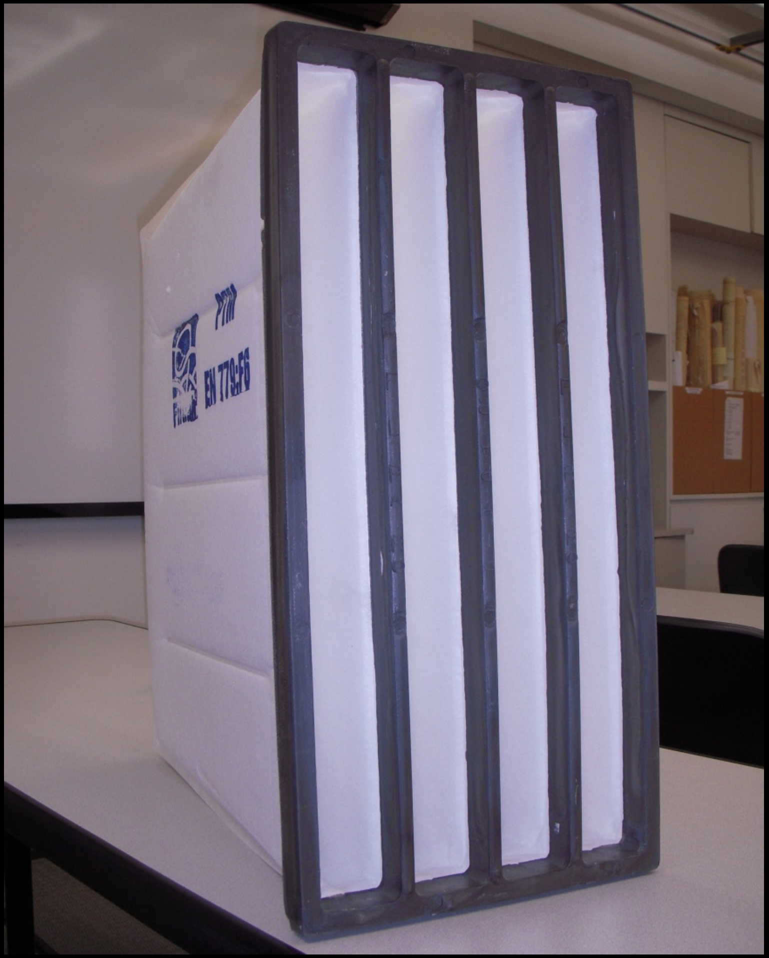
Camfil Farr DuraFil ES

- MERV11 (60-65% ASHRAE Dust-spot Efficiency)
- 24” high, 12” wide, 11.5” deep
- 4 pockets
- 100 sq.ft. of wet laid fiberglass media
- ΔPClean at 493 fpm = 0.21 in.w.c.
- ΔPMaxDirty = 1.50 in.w.c.
- Dust holding capacity = 200 grams
- $66.10

There is More to Filter Media than Being Fuzzy

FILTRAIR PTL (F6)

- MERV11 (60-65% ASHRAE Dust-spot Efficiency)
- 24" high, 12" wide, 24" deep
- 4 rigid pockets
- 30.2 sq. ft. of synthetic, high performance depth loading fibers laid using a progressive density multi-layering technique
- ΔP_{Clean} at 492 fpm = 0.22 in.w.c.
- $\Delta P_{MaxDirty}$ = 1.80 in.w.c.
- Dust holding capacity = 1,150 grams
- $124



Same MERV but Otherwise, Very Different

Summary

Model	First Cost	MERV	ΔP, in.w.c. at 500 fpm	Media Area. sq.ft.	Dust Capacity, Grams
HI-FLO	$16.68	11	0.30	29.0	175
RIGA-FLO	$49.97	11	0.35	26.5	225
DuraFil ES	$66.10	11	0.21	100	200
PTL (F6)	$124.00	11	0.22	30.2	1,150

A Clarifying Point

My focus in this session is on particle filters vs. molecular/gas phase filters

Particle Filters

Target things like:

- Dust
- Pollen
- Mold
- Bacteria

Gas Phase Filters

Target things like:

- Exhaust fumes
- Ammonia
- Nitrous oxide
- Sulphur dioxide
- Volatile organic compounds

A Clarifying Point

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Particle Filters	Gas Phase Filters
Contaminants measured in particles per unit volume	Contaminants measured in concentration levels like parts per million or parts per billion

A Clarifying Point

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Particles move via air currents

Gasses move via diffusion

A Clarifying Point

My focus in this session is on particle filters vs. molecular/gas phase filters

Gasses are captured by chemical means

- Adsorption Condensation
- Chemisorption

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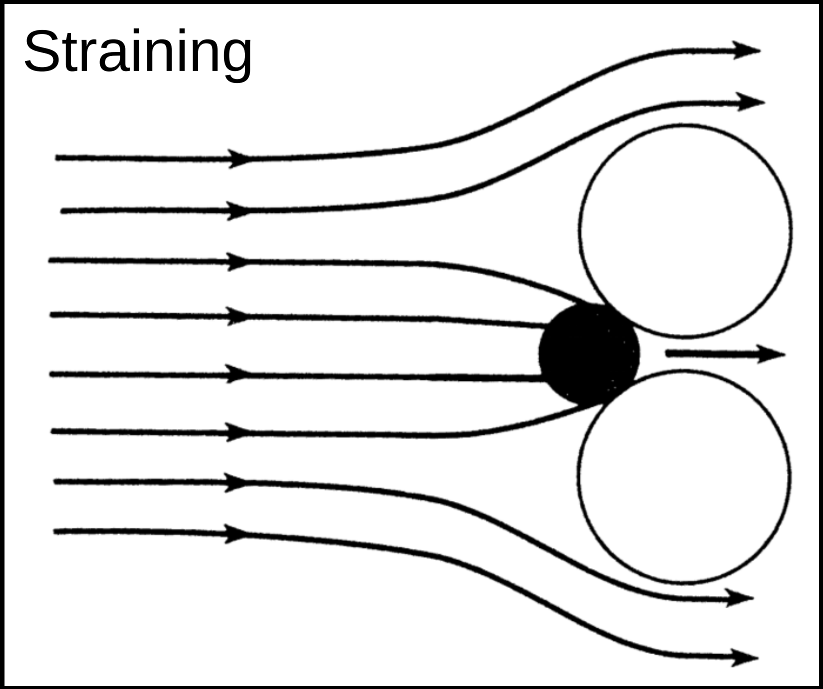

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Images courtesy ASHRAE Journal, Filters and Filtration, April 1999, Timothy J Robinson and Alan E Quellet

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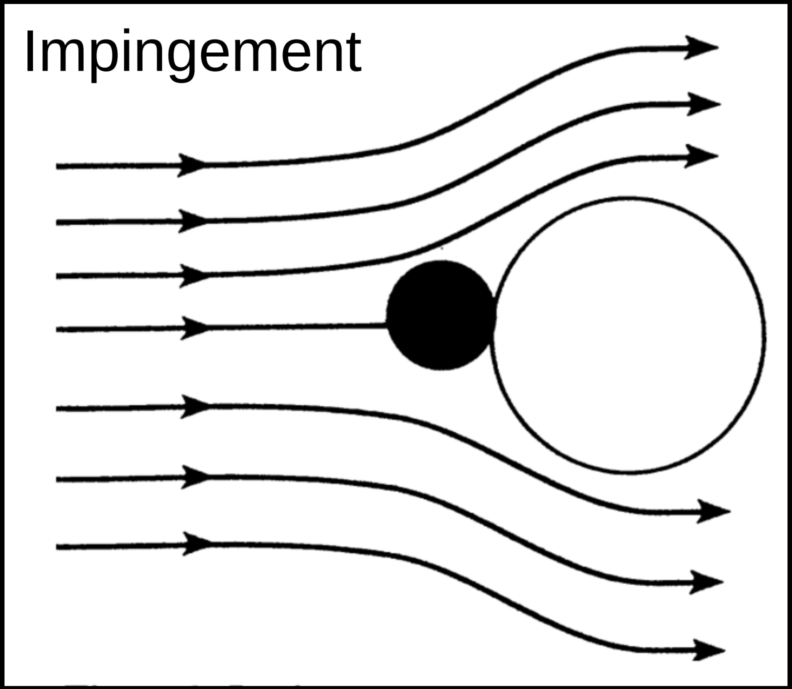

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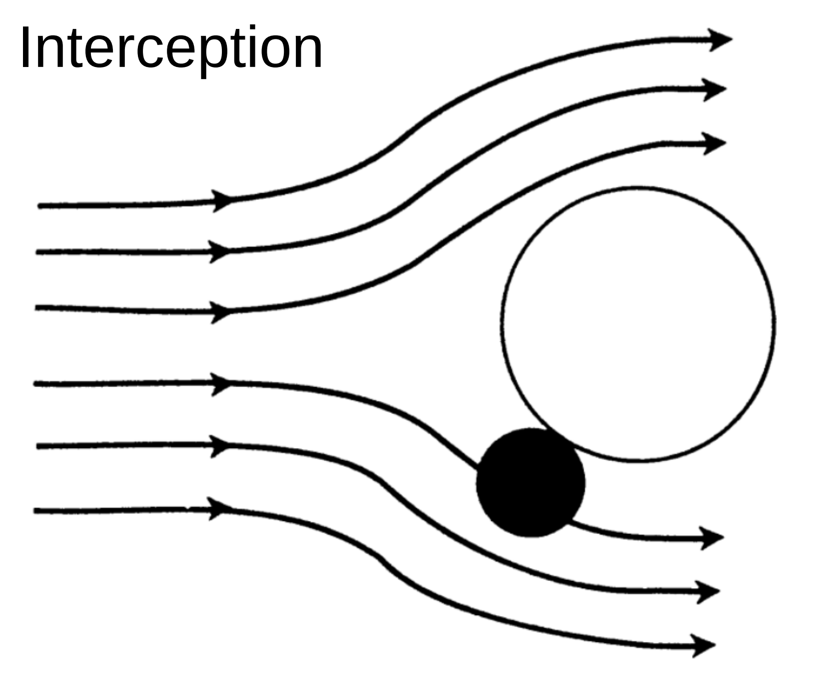

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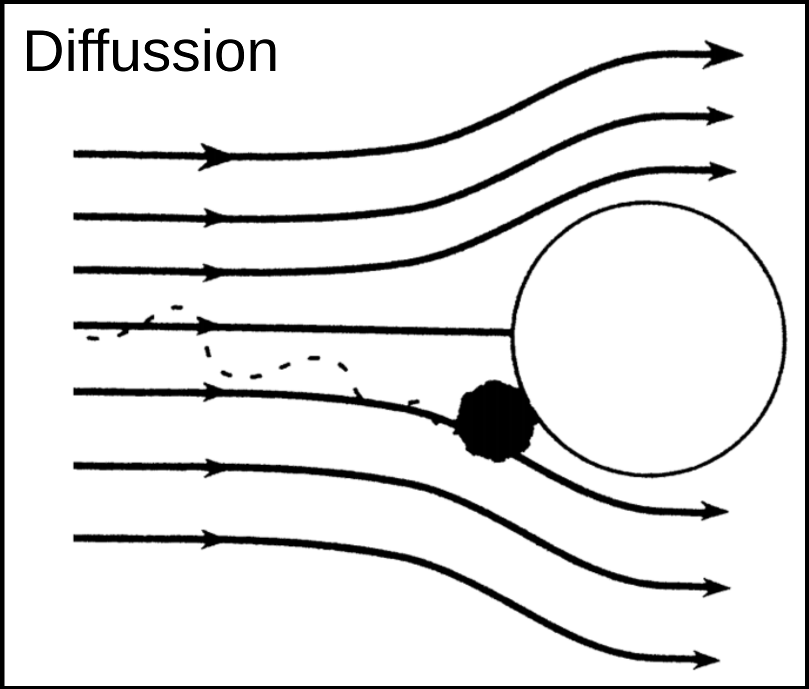

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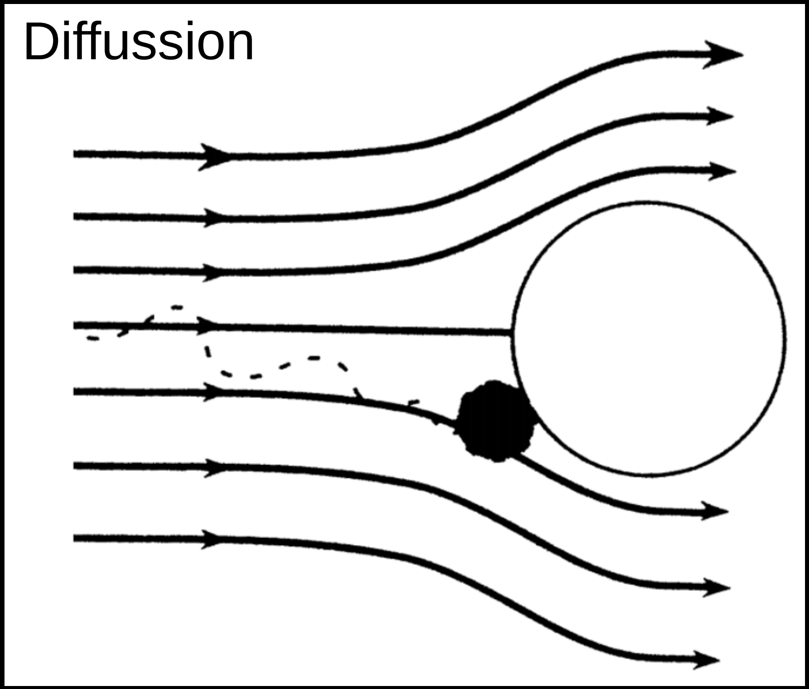


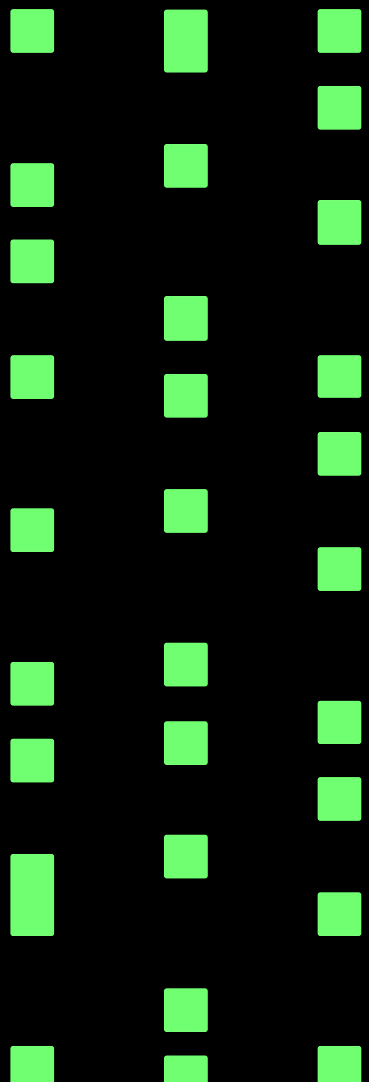
Electrostatic Effects are Also Used

- Potential to drop off over time
- Appendix J of ASHRAE 52 attempts to address this

Images courtesy ASHRAE Journal, Filters and Filtration, April 1999, Timothy J Robinson and Alan E Quellet

Face Loading Filters

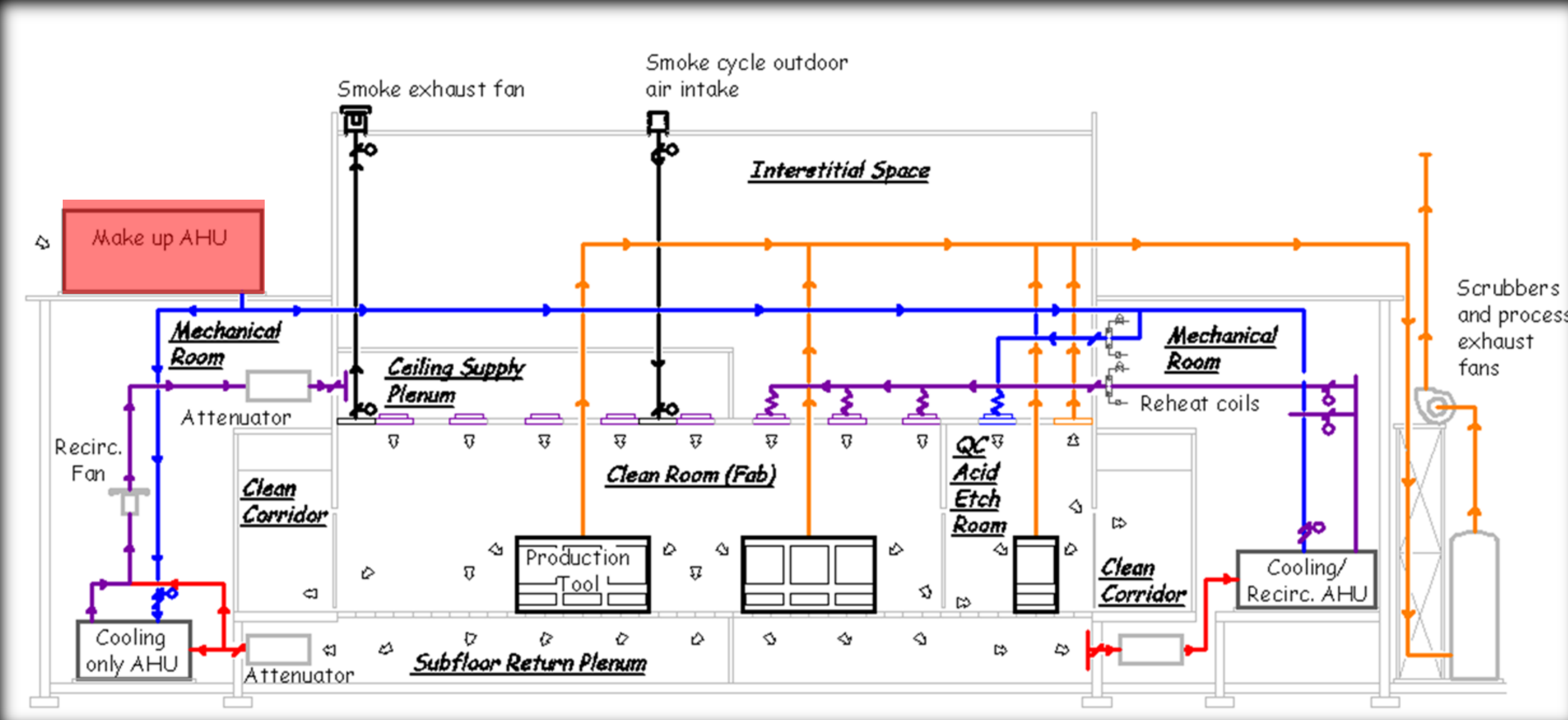
Depth Loading Filters



Conventional Thinking = Change Based on Time in Service

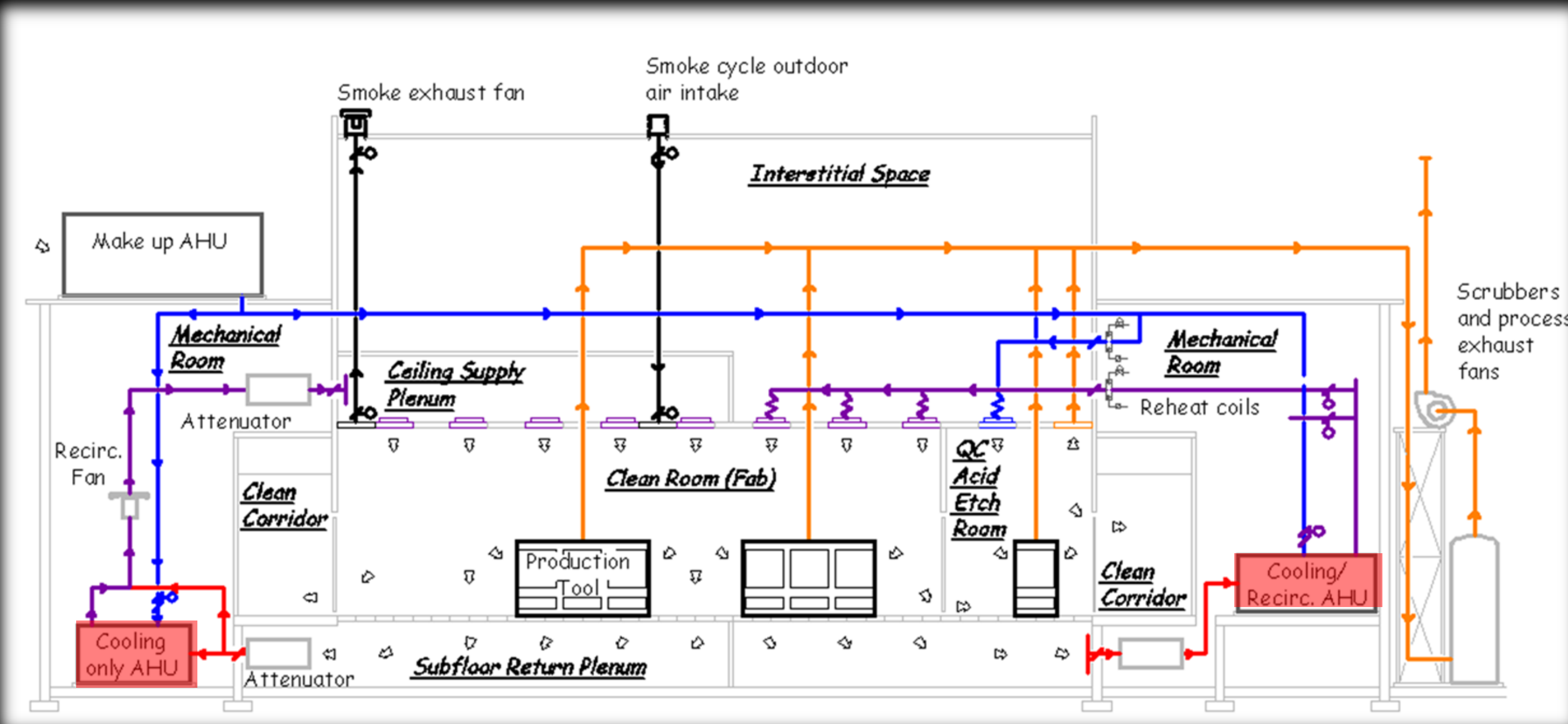
Filter Banks Load at Different Rates

Clean room make up systems loaded more quickly than other systems and loading rate varied with season



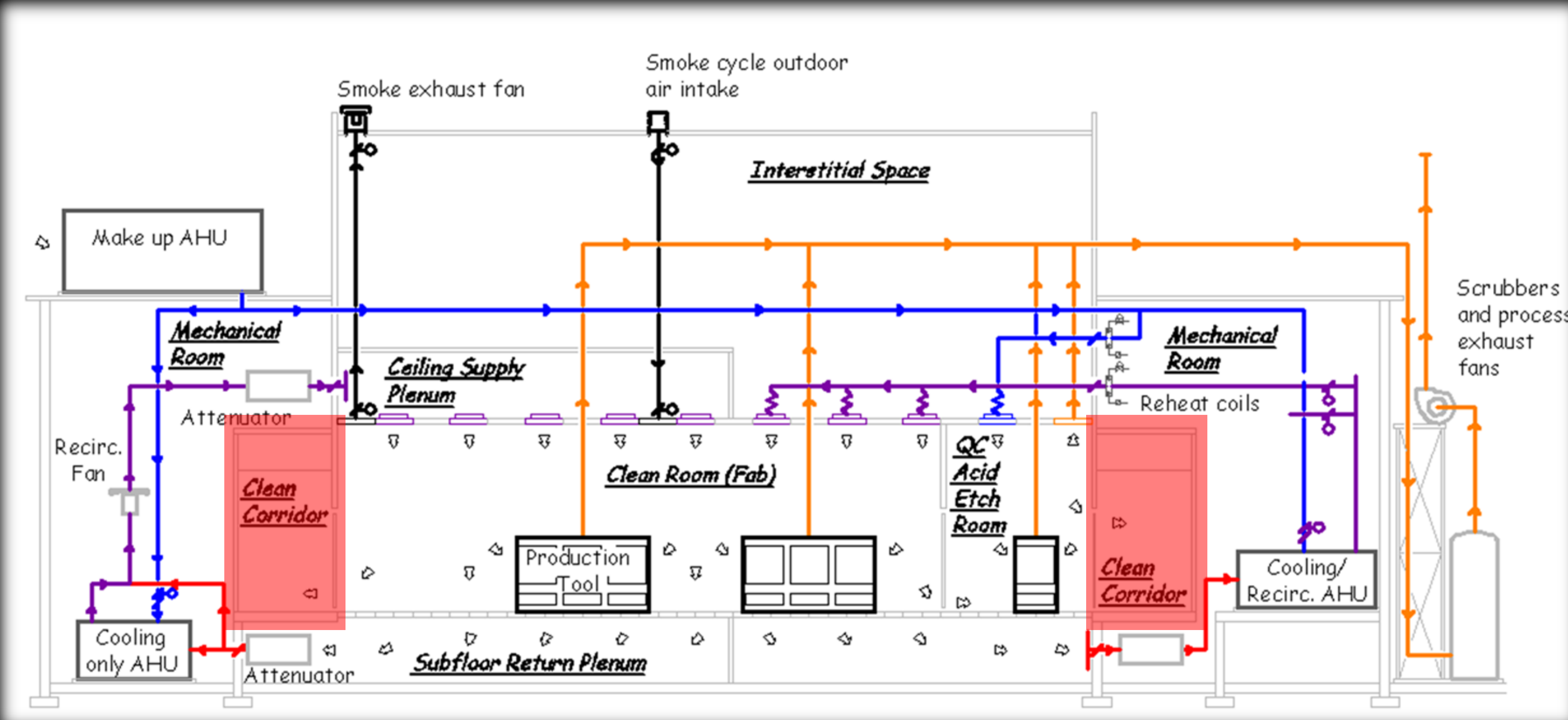
Filter Banks Load at Different Rates

Clean room recirculation systems handled extremely clean air and loaded very, very slowly



Filter Banks Load at Different Rates

Scheduled economizer equipped systems serving non-process areas were somewhere in-between in terms of loading rate



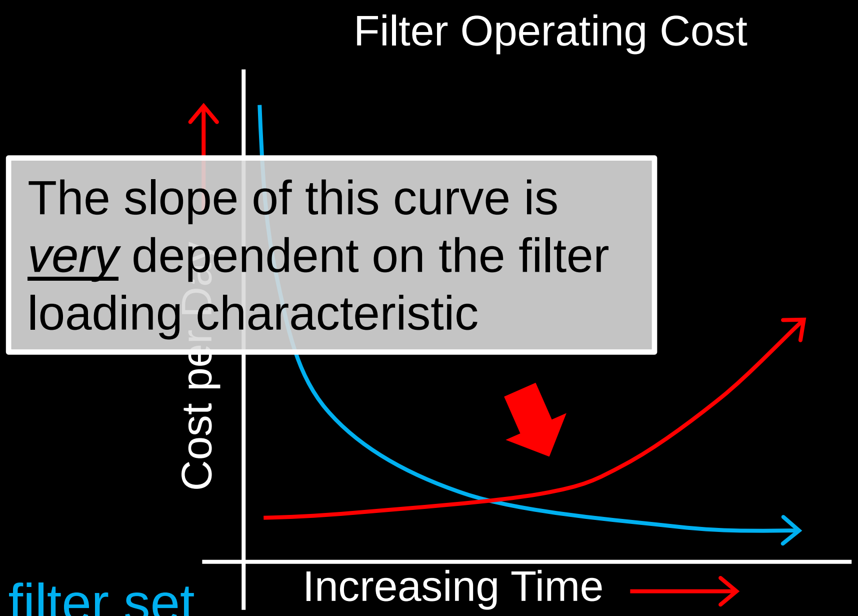
Filter Life Cycle Costs

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



Calculating Power Into the Fan Motor as kW

$$kW = \left(\frac{Flow \times Static}{6{,}356 \times \eta_{Fan} \times \eta_{Motor} \times \eta_{Drive}} \right) \times \frac{.746\ \text{kw}}{\text{hp}}$$

Where :

bhp = Brake horse power into the fan drive shaft

$Flow$ = Flow rate in cubic feet per minute

$Static$ = Fan static in inches water column

6,356 = A units conversion constant

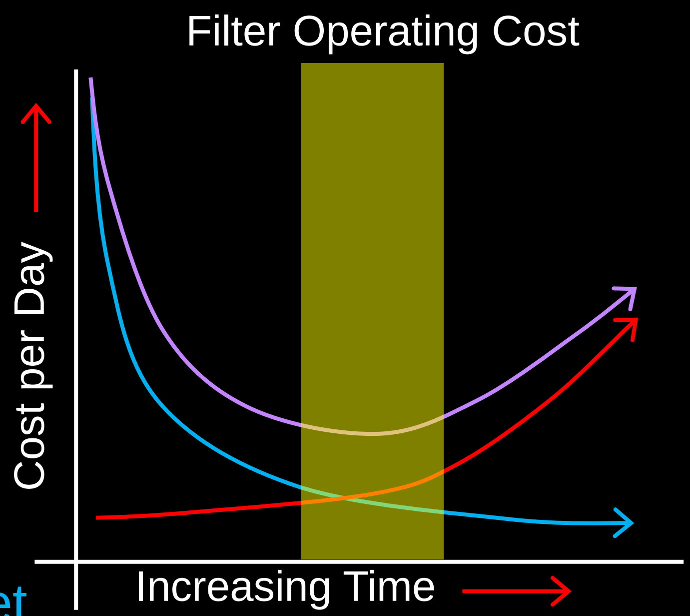
η_{Fan} = Fan efficiency

η_{Motor} = Motor efficiency

η_{Drive} = Drive efficiency; Don;'t forget about the belts if the motor is not direct drive. Well adjusted belts are 97 - 98% efficient. Poorly adjusted ones can be as low as 90% or less

$\frac{.746\ \text{kw}}{\text{hp}}$ = kW to hp conversion constant

Filter Life Cycle Costs



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- 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

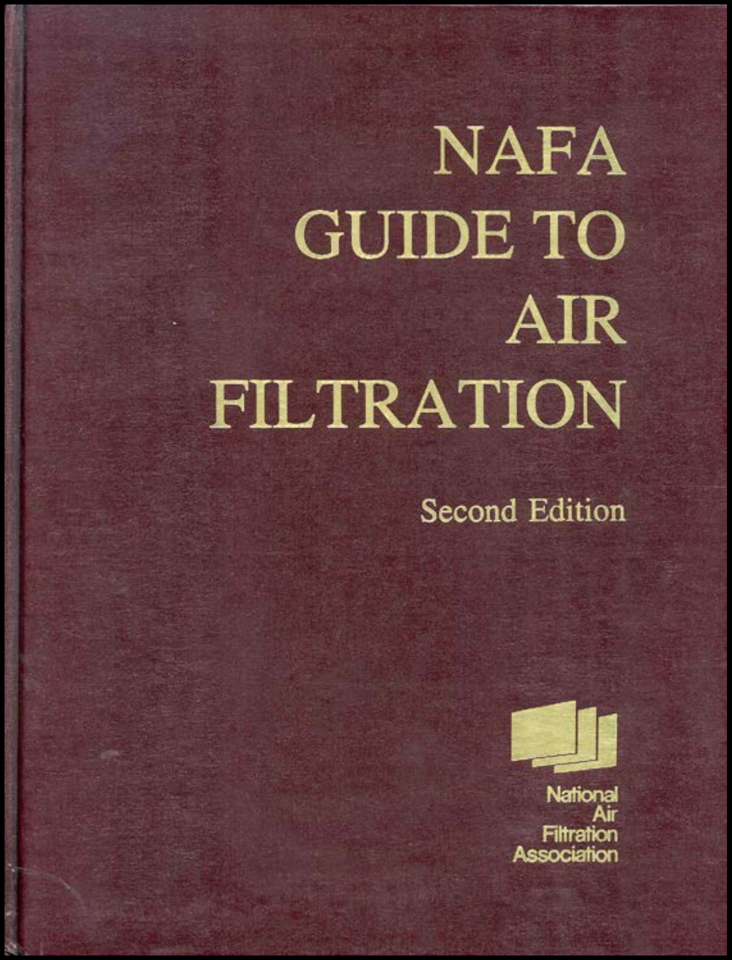
- Increases over time
- Non-linear

Total cost component

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

Key Points

1. Not a new concept
   - NAFA Guide to Air Filtration
   - 1993
   - Chapter 13 – Owning and Operating Cost



Key Points

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    - NAFA Guide to Air Filtration
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    - Chapter 13 – Owning and Operating Cost

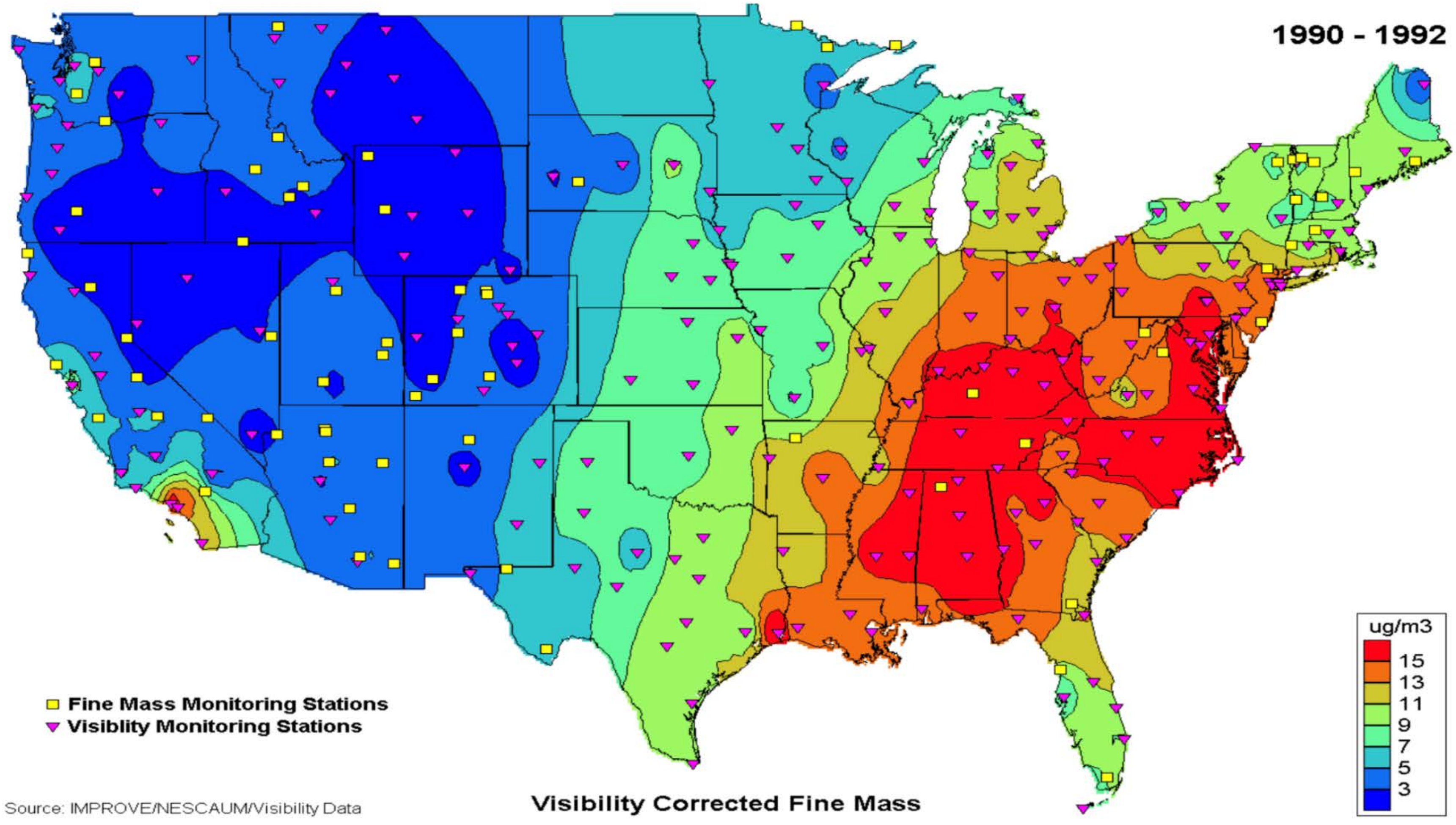
__Life Estimating__

A very important consideration is filter life …

… Because of the many variables in the environment, the development of a method for precisely estimating filter life has eluded filter experts over the years.

Most data is based on user experience or manufacturer's life tests.

… the many variables in the environment



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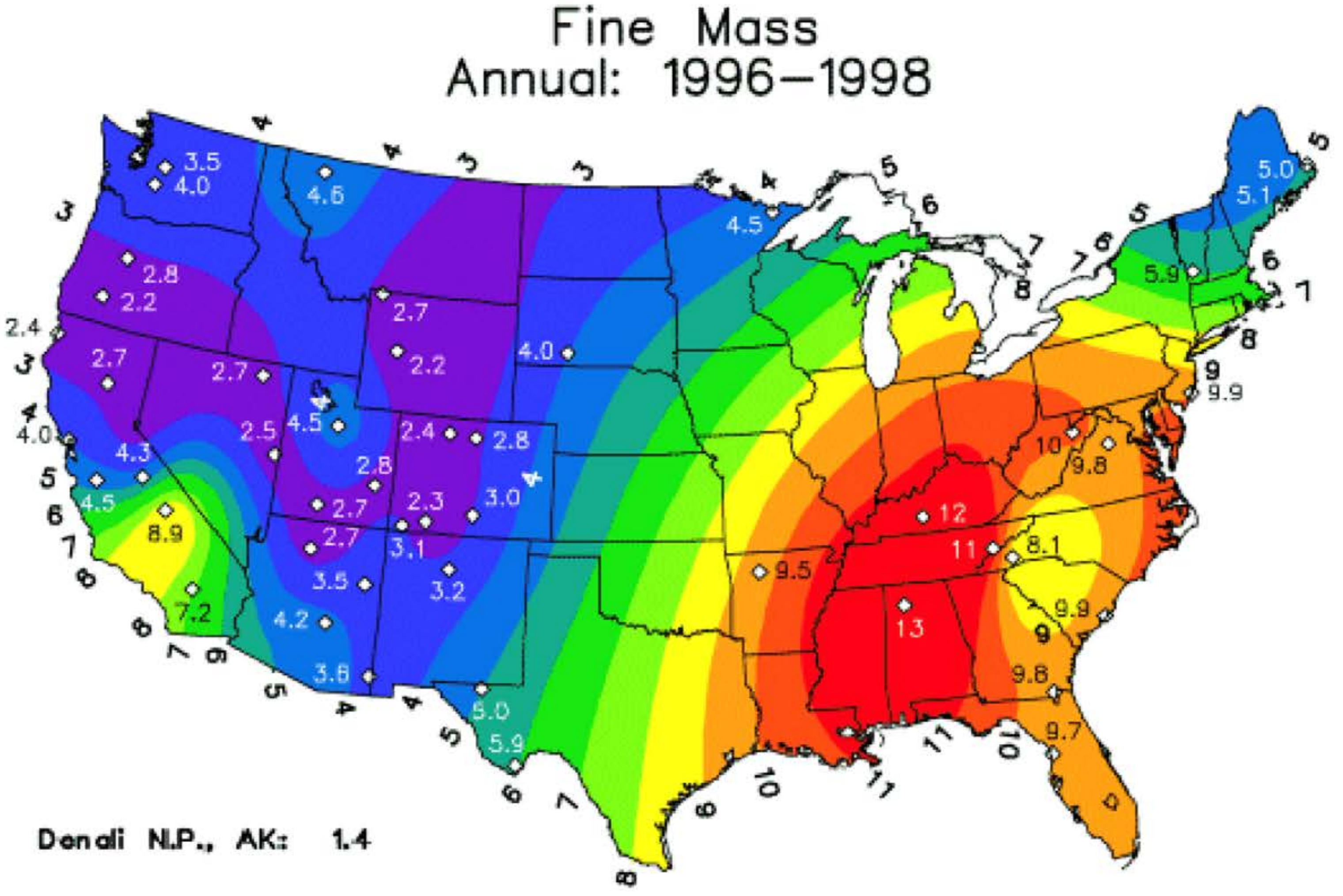

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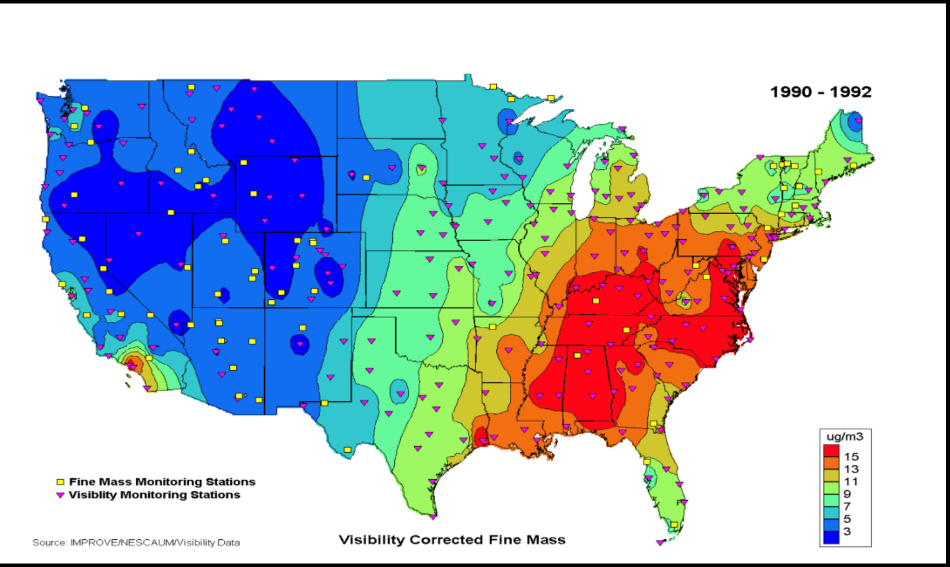
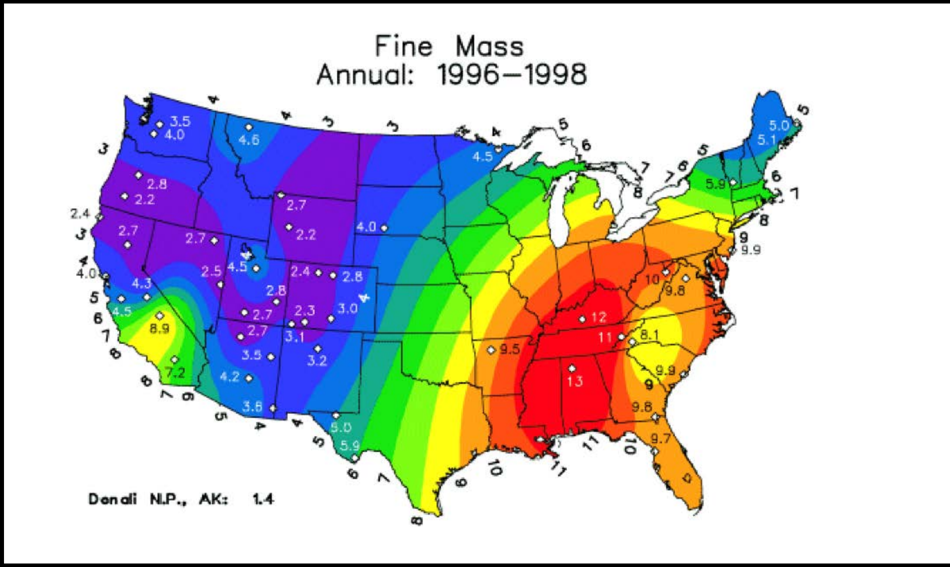




Images courtesy ASHRAE Research Project Report 1360-RP

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}

A Word about Eliminating Prefilters

- Prefilters _do not_ make the air leaving the system any cleaner
- Prefilters _do_ protect the final filter; maybe;
    - To protect the final filter, the prefilter has to be able to intercept a significant amount of the entering contaminate
    - If the entering contaminant particle size is smaller than what the prefilter can handle, then their benefit is minimized

A Word about Eliminating Prefilters

- An Example
  - Crown Plaza, Portland, OR
  - Two identical AHUs
  - Operating team wanted to switch to life cycle based filter operation with high performance filters
  - Not sure what to do about eliminating prefilters
  - Decided to experiement by running one system with and one system with out prefilters

Image courtesy http://www.ddgportland.com/

A Word about Eliminating Prefilters

- The Result
  - Prefilters did not load that much
  - Final filters in both systems tended to load at about the same rate

Image courtesy http://www.ddgportland.com/

A Word about Eliminating Prefilters

- The Reason
  - Intakes at street level next to the Naito Parkway
  - Primary contaminant was rubber duct

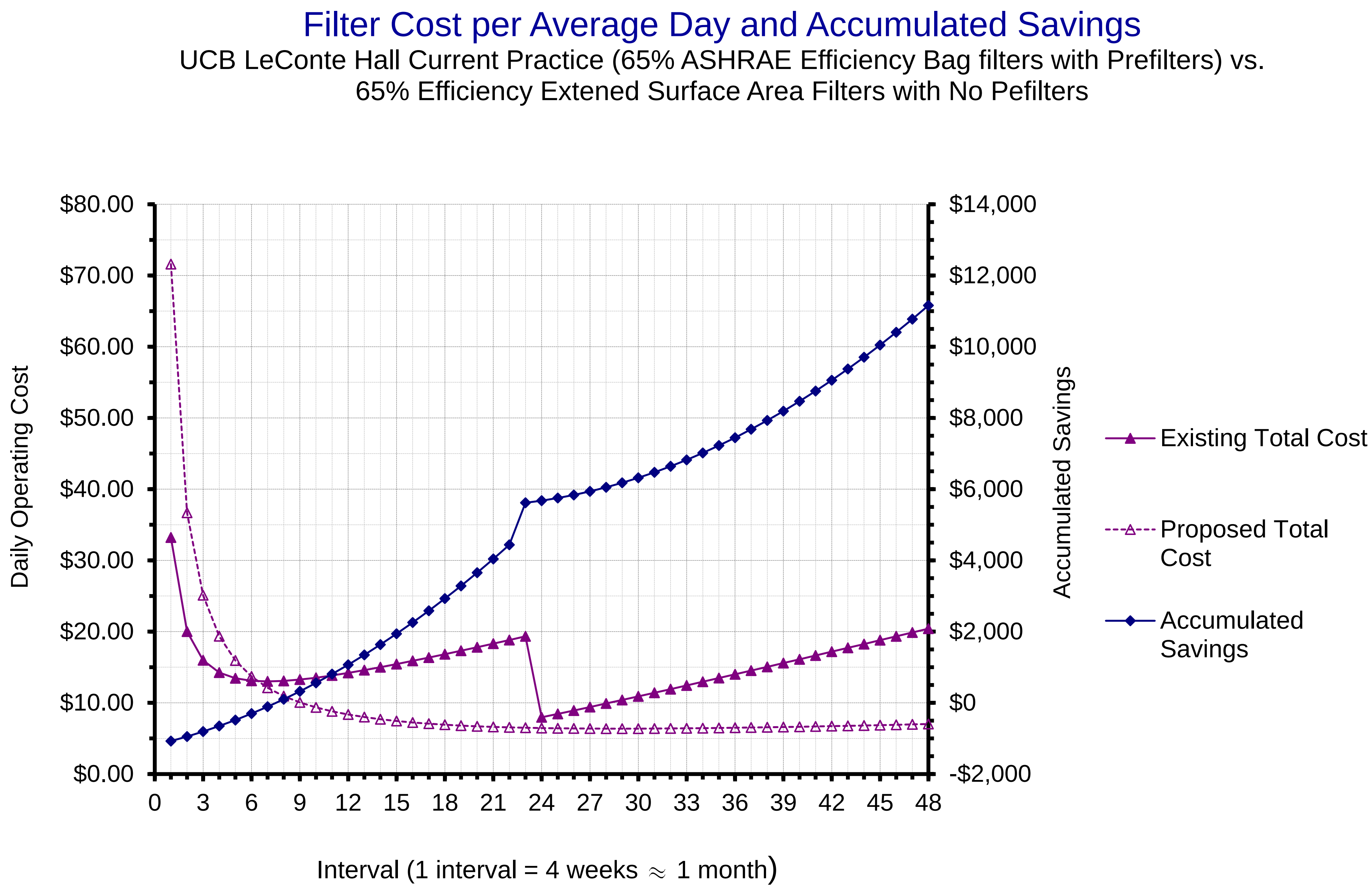
    There is a reason we have to buy new tires occasionally
  - Prefilters were not very effective against the rubber dust particles

Image courtesy http://www.ddgportland.com/

A Word about Eliminating Prefilters

- The Caveat
  - Had the building been near a grove of cotton wood trees, prefilters may have been desirable for at least part of the year to protect the final filters from cotton wood seeds

Image courtesy http://www.ddgportland.com/



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
Daily Operating Cost
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$0.00
$14,000
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$0
-$2,000
Accumulated Savings
0
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
Interval (1 interval = 4 weeks ≈ 1 month)
Existing Total Cost
Proposed Total Cost
Accumulated Savings

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 Month Cycle Basis

	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)**				

Taking a life cycle perspective is important

An important “ripple effect”

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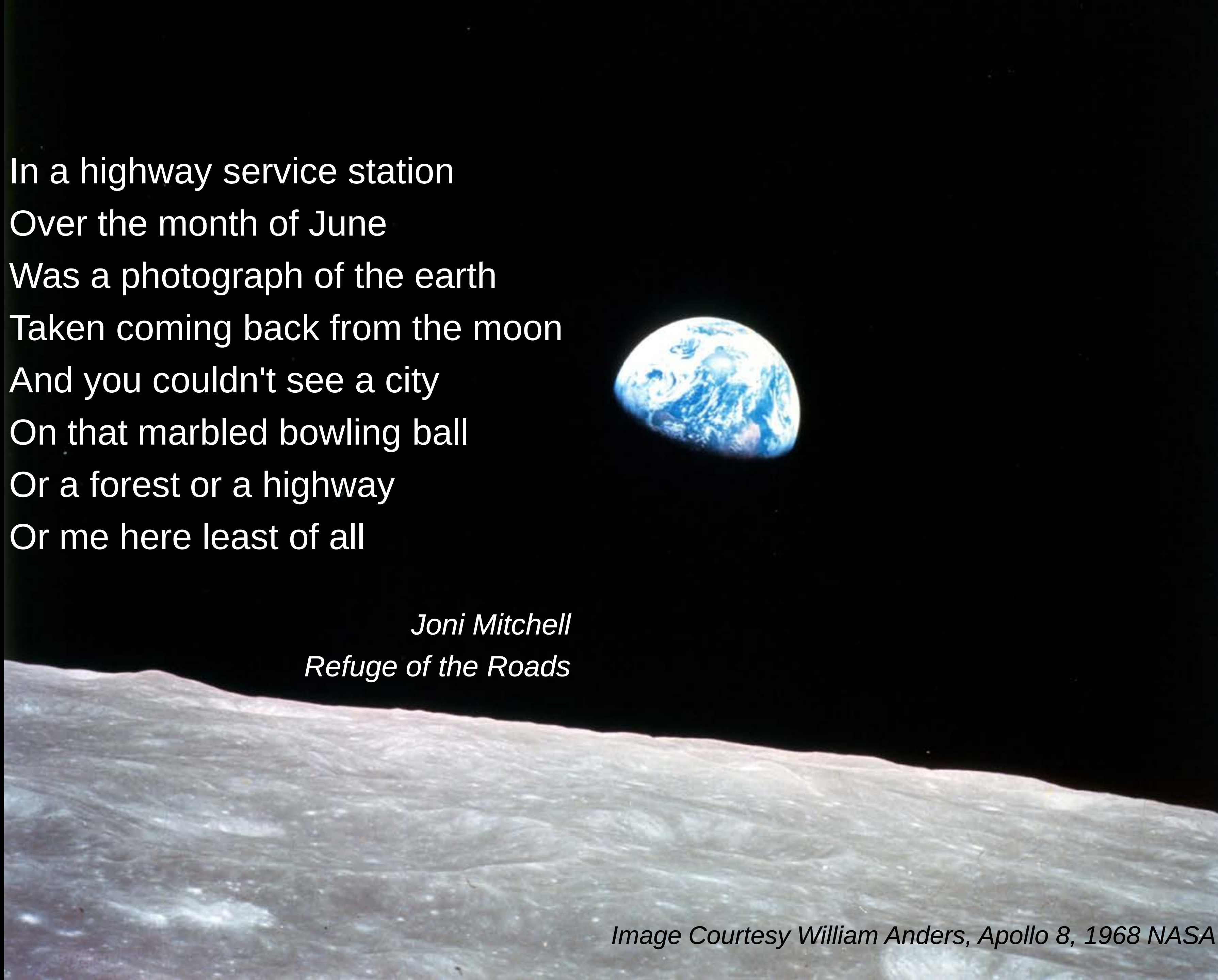
Simple Payback	**8.74 months (energy only)**				

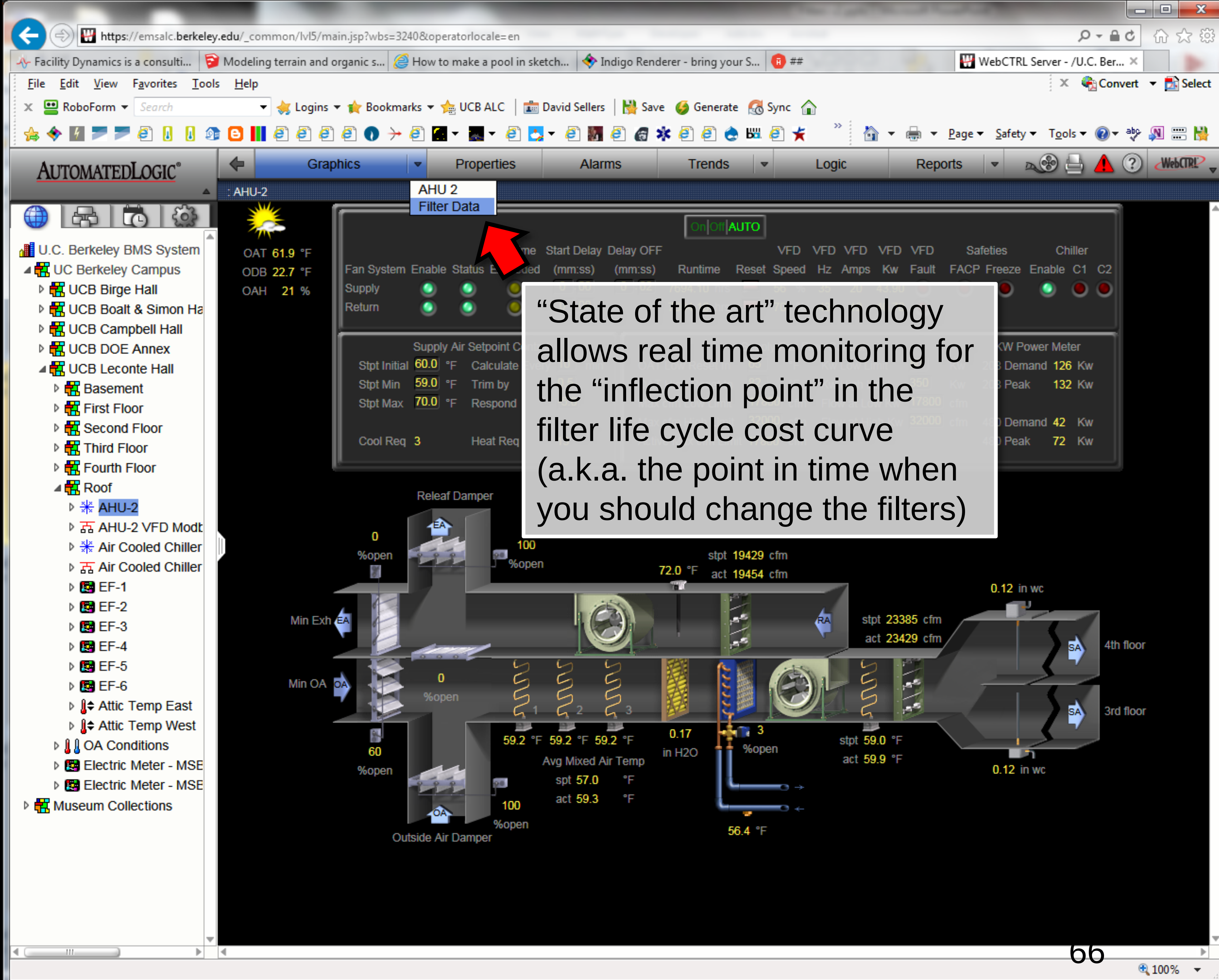
Cost and benefit may not occur in the same purchasing group


In a highway service station
Over the month of June
Was a photograph of the earth
Taken coming back from the moon
And you couldn't see a city
On that marbled bowling ball
Or a forest or a highway
Or me here least of all
Joni Mitchell
Refuge of the Roads
Image Courtesy William Anders, Apollo 8, 1968 NASA

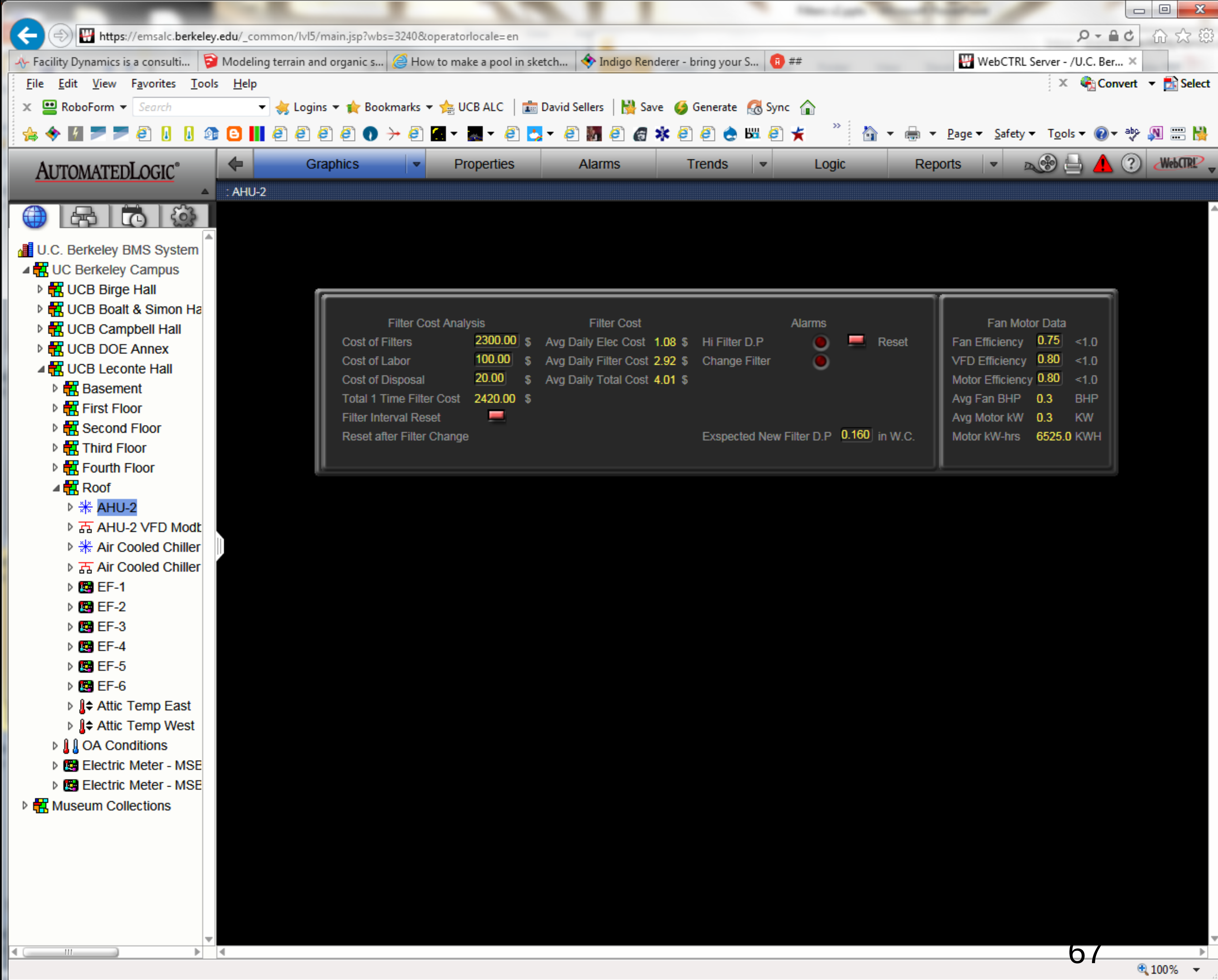
My Observations:

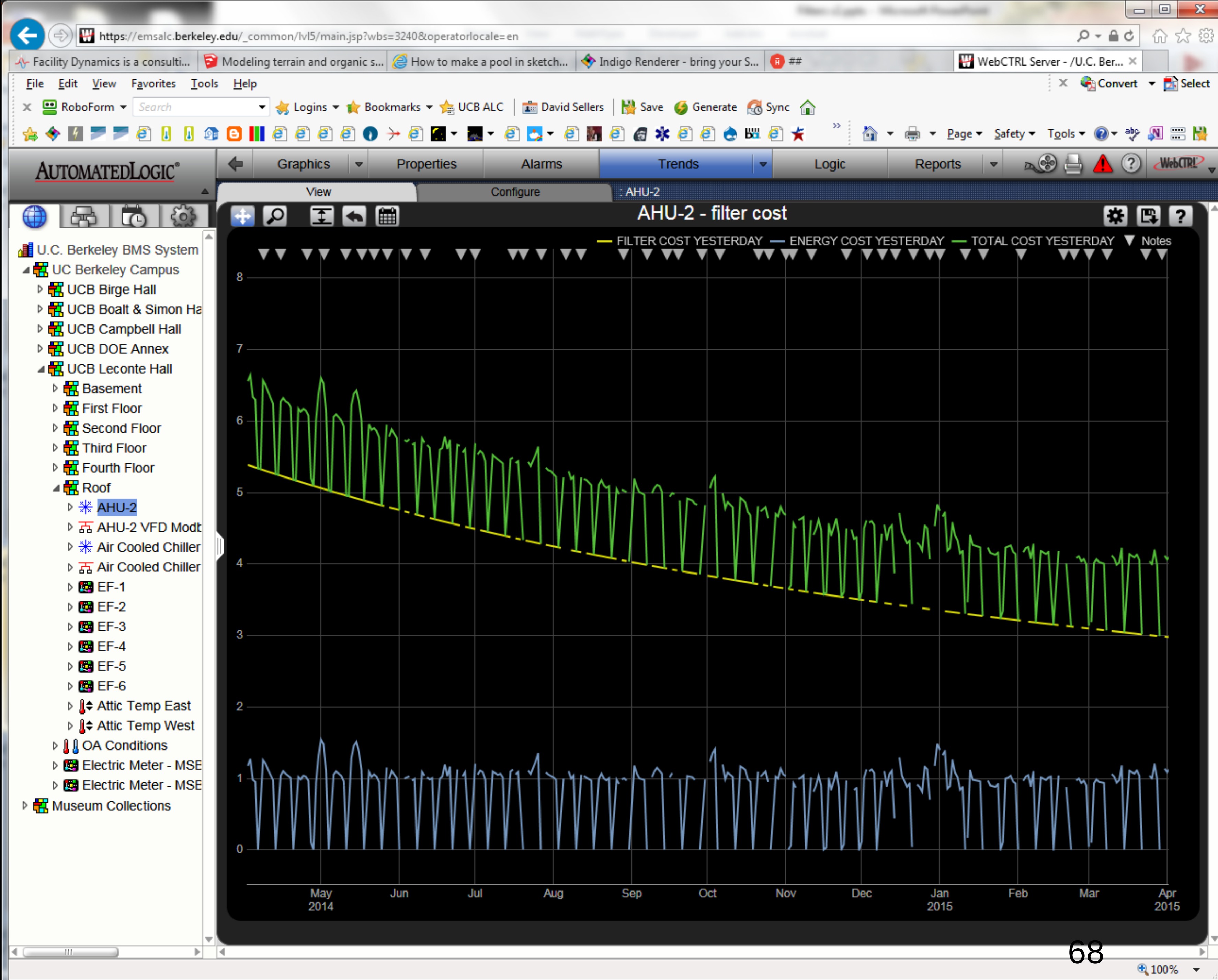
1. Only one “marbled bowling ball” in the near vicinity
2. Unable to see the Division of Design and Construction
3. Unable to see the Division of Physical Plant and Campus Services
4. I suspect they are all in this together, and us with them
5. We need to start acting and thinking as if that is the case

Image Courtesy William Anders, Apollo 8, 1968 NASA



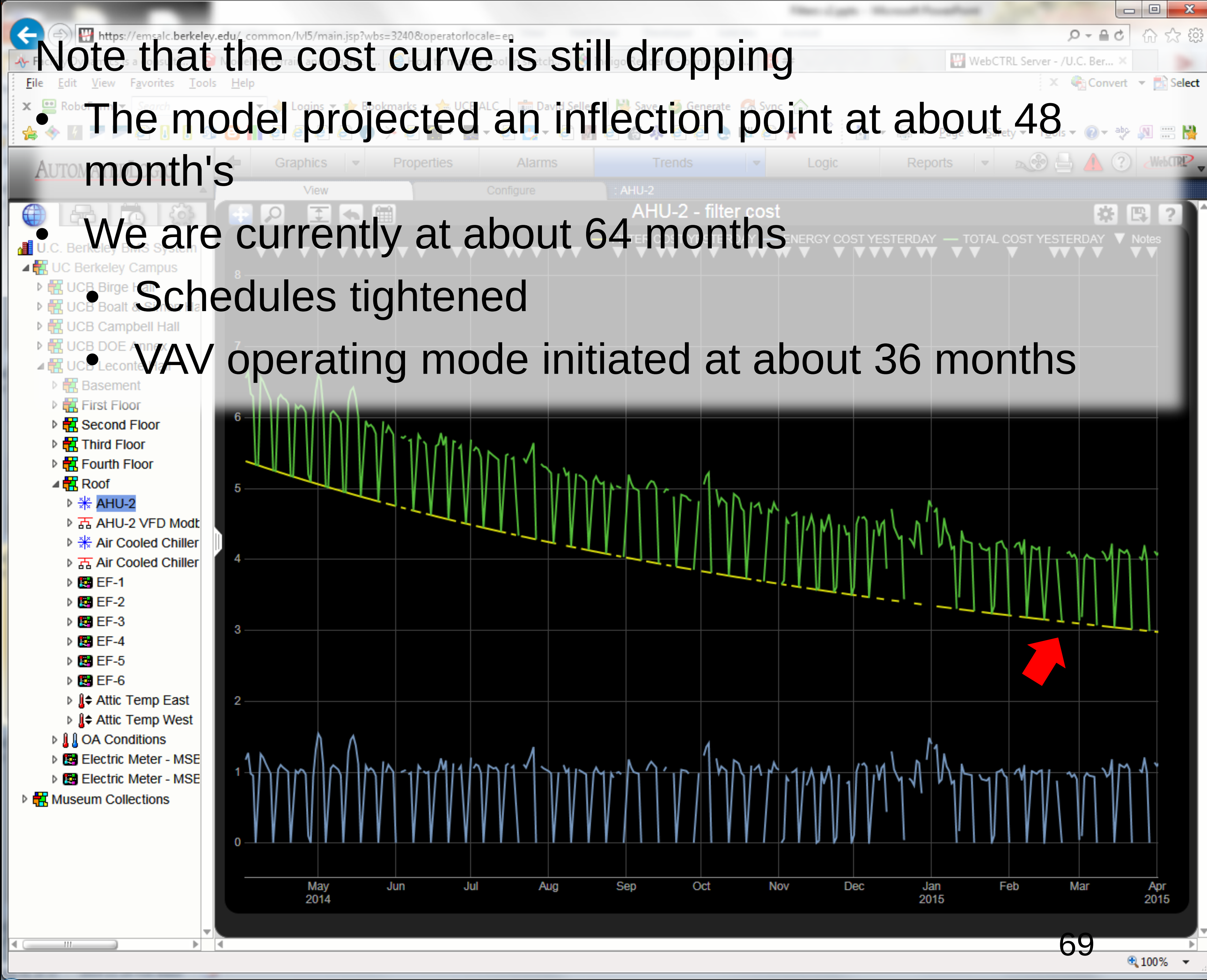
"State of the art" technology allows real time monitoring for the "inflection point" in the filter life cycle cost curve (a.k.a. the point in time when you should change the filters)


https://emsalc.berkeley.edu/_common/lvl5/main.jsp?wbs=3240&operatorlocale=en
Facility Dynamics is a consulti...
Modeling terrain and organic s...
How to make a pool in sketch...
Indigo Renderer - bring your S...
WebCTRL Server - /U.C. Ber...
File Edit View Favorites Tools Help
RoboForm
Logins
Bookmarks
UCB ALC
David Sellers
Save
Generate
Sync
Convert
Select
Page
Safety
Tools
AUTOMATEDLOGIC
Graphics
Properties
Alarms
Trends
Logic
Reports
: AHU-2
U.C. Berkeley BMS System
UC Berkeley Campus
UCB Birge Hall
UCB Boalt & Simon Ha
UCB Campbell Hall
UCB DOE Annex
UCB Leconte Hall
Basement
First Floor
Second Floor
Third Floor
Fourth Floor
Roof
AHU-2
AHU-2 VFD Modt
Air Cooled Chiller
Air Cooled Chiller
EF-1
EF-2
EF-3
EF-4
EF-5
EF-6
Attic Temp East
Attic Temp West
OA Conditions
Electric Meter - MSE
Electric Meter - MSE
Museum Collections
Filter Cost Analysis
Cost of Filters 2300.00 $
Cost of Labor 100.00 $
Cost of Disposal 20.00 $
Total 1 Time Filter Cost 2420.00 $
Filter Interval Reset
Reset after Filter Change
Filter Cost
Avg Daily Elec Cost 1.08 $
Avg Daily Filter Cost 2.92 $
Avg Daily Total Cost 4.01 $
Alarms
Hi Filter D.P
Reset
Change Filter
Exspected New Filter D.P 0.160 in W.C.
Fan Motor Data
Fan Efficiency 0.75 <1.0
VFD Efficiency 0.80 <1.0
Motor Efficiency 0.80 <1.0
Avg Fan BHP 0.3 BHP
Avg Motor kW 0.3 KW
Motor kW-hrs 6525.0 KWH
100%


https://emsalc.berkeley.edu/_common/lvl5/main.jsp?wbs=3240&operatorlocale=en
Facility Dynamics is a consulti...
Modeling terrain and organic s...
How to make a pool in sketch...
Indigo Renderer - bring your S...
WebCTRL Server - /U.C. Ber...
File Edit View Favorites Tools Help
RoboForm Logins Bookmarks UCB ALC David Sellers Save Generate Sync
Convert Select
Page Safety Tools
AUTOMATEDLOGIC
Graphics Properties Alarms Trends Logic Reports
View Configure : AHU-2
U.C. Berkeley BMS System
UC Berkeley Campus
UCB Birge Hall
UCB Boalt & Simon Ha
UCB Campbell Hall
UCB DOE Annex
UCB Leconte Hall
Basement
First Floor
Second Floor
Third Floor
Fourth Floor
Roof
AHU-2
AHU-2 VFD Modb
Air Cooled Chiller
Air Cooled Chiller
EF-1
EF-2
EF-3
EF-4
EF-5
EF-6
Attic Temp East
Attic Temp West
OA Conditions
Electric Meter - MSE
Electric Meter - MSE
Museum Collections
AHU-2 - filter cost
FILTER COST YESTERDAY
ENERGY COST YESTERDAY
TOTAL COST YESTERDAY
Notes
8
7
6
5
4
3
2
1
0
May 2014
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan 2015
Feb
Mar
Apr 2015
100%

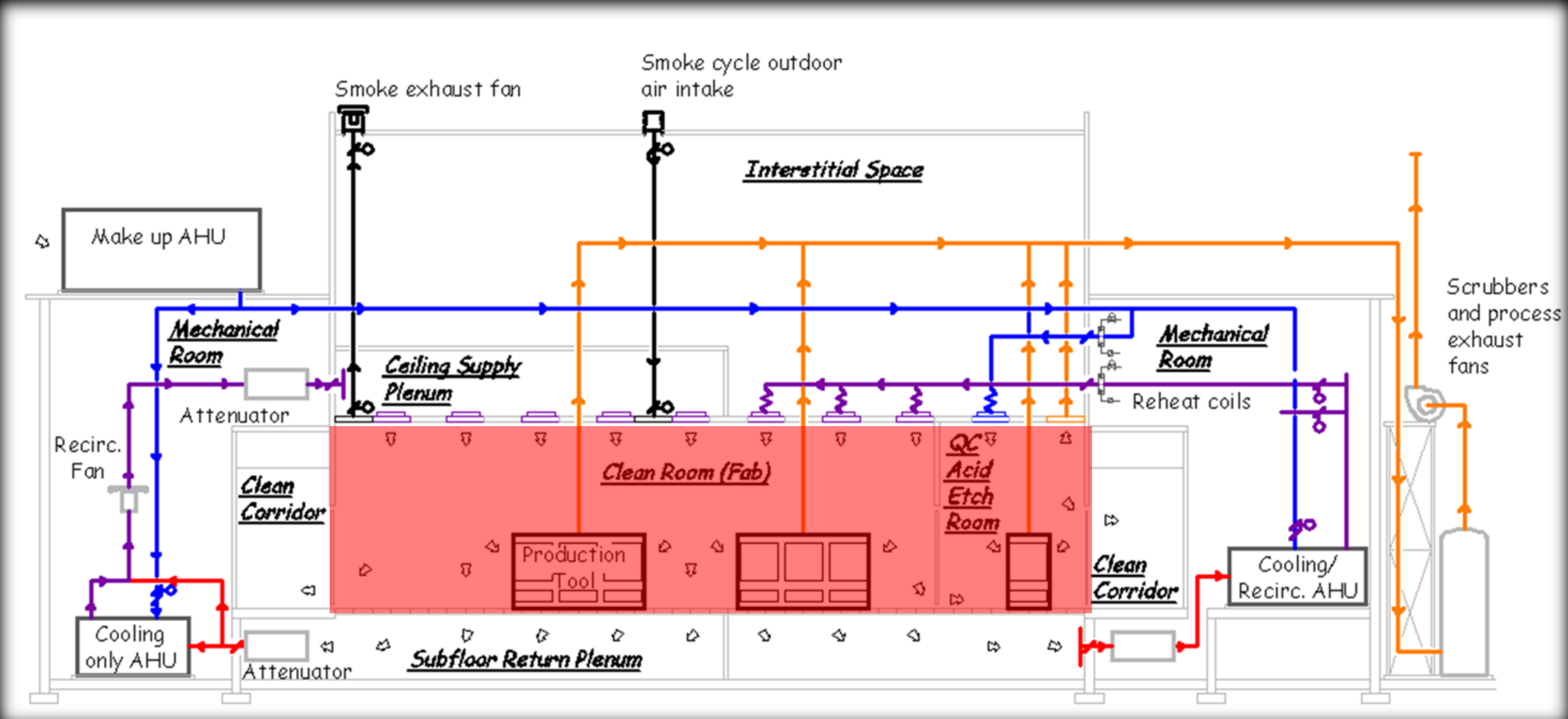
Note that the cost curve is still dropping

- The model projected an inflection point at about 48 month's
- We are currently at about 64 months
  - Schedules tightened
  - VAV operating mode initiated at about 36 months



CAUTION

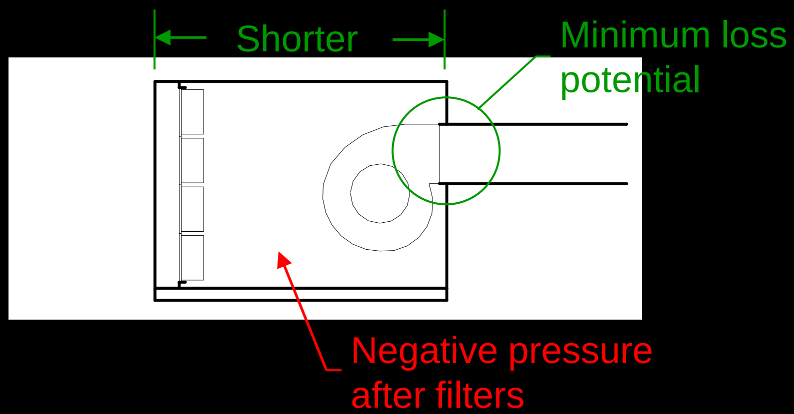
Changing filter types or replacement approaches for process areas may involve changing a quality control standard

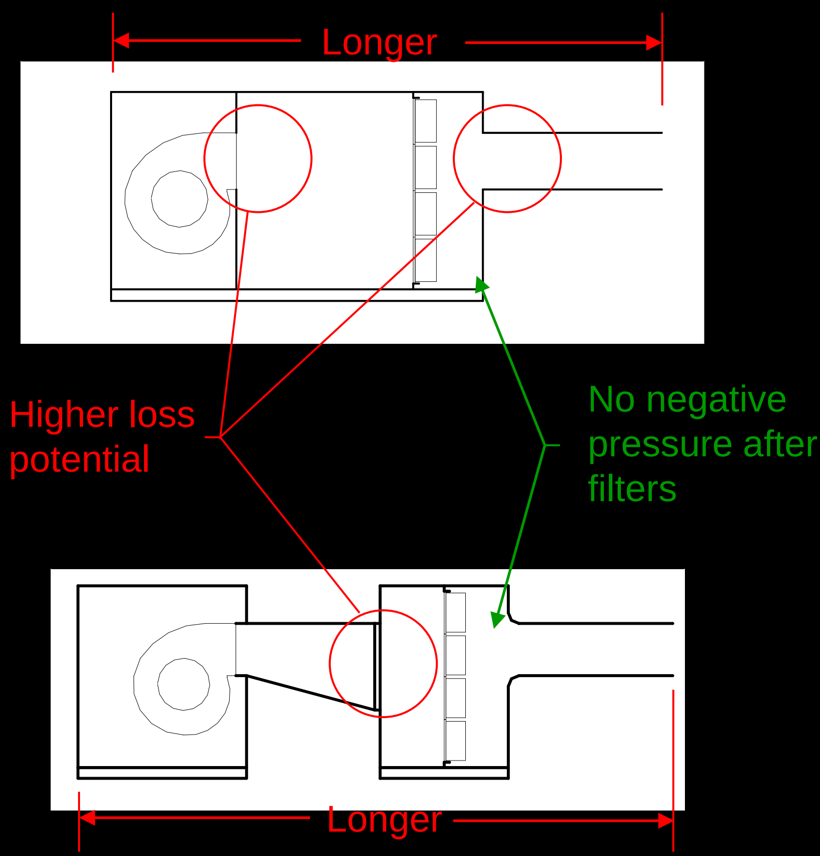


CAUTION

- Non-VSD Equipped System Caution
  - Lower pressure = fan moving out its fan curve
  - Fan moving out its fan curve = more fan energy
  - Fan moving out its fan curve = more reheat energy in a constant volume reheat system
- Include a sheave change or VFD in the cost to upgrade to lower pressure drop filters
- Leveraging the VSD if you add it

Filter Location Impacts Fan Energy





Different configurations

Different dimensions

Different fan static requirements

Details Matter, Even with Filters

First cost increase = $220

Pressure drop reduction improvement = 0.08 in.w.c.

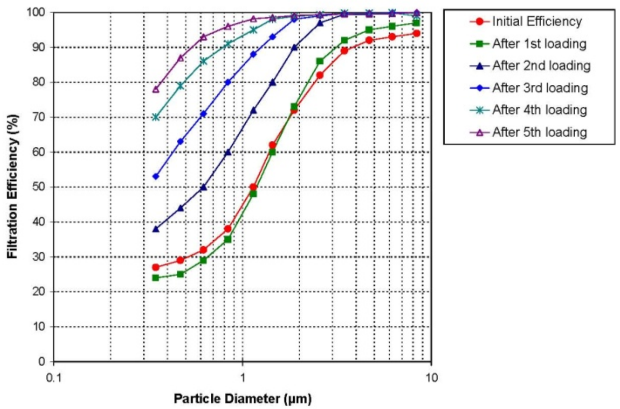
Annual energy savings improvement = $841

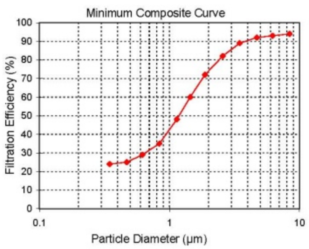
- 24/7 operation
- Nominal 67,000 cfm constant volume system
- $0.10 per kWh electricity

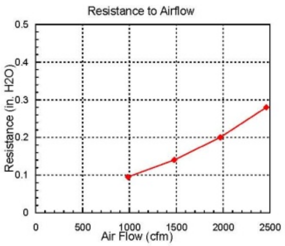
Independent Laboratory Testing

Verifying Manufacturer's Claims

Report No. BXmmddyy00
Research Triangle Institute







TABULATED DATA SUMMARY
Report No. BXmmddyy00
Research Triangle Institute

Summary of Test Conditions:

Product Manufacturer	Filter Company
Product Name	Air Filter
Nominal Dimensions (in.)	24 x 24 x 2
Airflow (cfm)	1968
Final Resistance (in. H2O)	1.00

Efficiency (%) per Indicated Size Range

	Run No.												
OPC Channel Number		1	2	3	4	5	6	7	8	9	10	11	12
Min. Diam. (µm)		0.3	0.4	0.55	0.7	1	1.3	1.6	2.2	3	4	5.5	7
Max. Diam. (µm)		0.4	0.55	0.7	1	1.3	1.6	2.2	3	4	5.5	7	10
Geo. Mean Diam (µm)		0.35	0.47	0.62	0.84	1.14	1.44	1.88	2.57	3.46	4.69	6.20	8.37
Initial efficiency	BXmmddyy01	27	29	32	38	50	62	72	82	89	92	93	94
after first dust load	BXmmddyy02	24	25	29	35	48	60	73	86	92	95	96	97
after second dust load	BXmmddyy03	38	44	50	60	72	80	90	97	99	99	100	100
after third dust load	BXmmddyy04	53	63	71	80	88	93	96	99	100	100	100	100
after fourth dust load	BXmmddyy05	70	79	86	91	95	96	99	99	100	100	100	99
after fifth dust load	BXmmddyy06	78	87	93	96	98	99	99	99	100	100	100	100
Minimum Composite Efficiency		24	25	29	35	48	60	72	82	89	92	93	94

E1 = 28
E2 = 66
E3 = 92

MERV = 11

Resistance to Airflow:

Airflow (%)	Airflow (m3/s)	Airflow (cfm)	Air Velocity (fpm)	Air Velocity (m/s)	Resistance (in. H2O)	Resistance (Pa)
50	0.464	984	246	1.250	0.10	24
75	0.697	1476	369	1.875	0.14	35
100	0.929	1968	492	2.499	0.20	50
125	1.161	2460	615	3.124	0.28	70

Resistance to Airflow with Loading at 1968 cfm

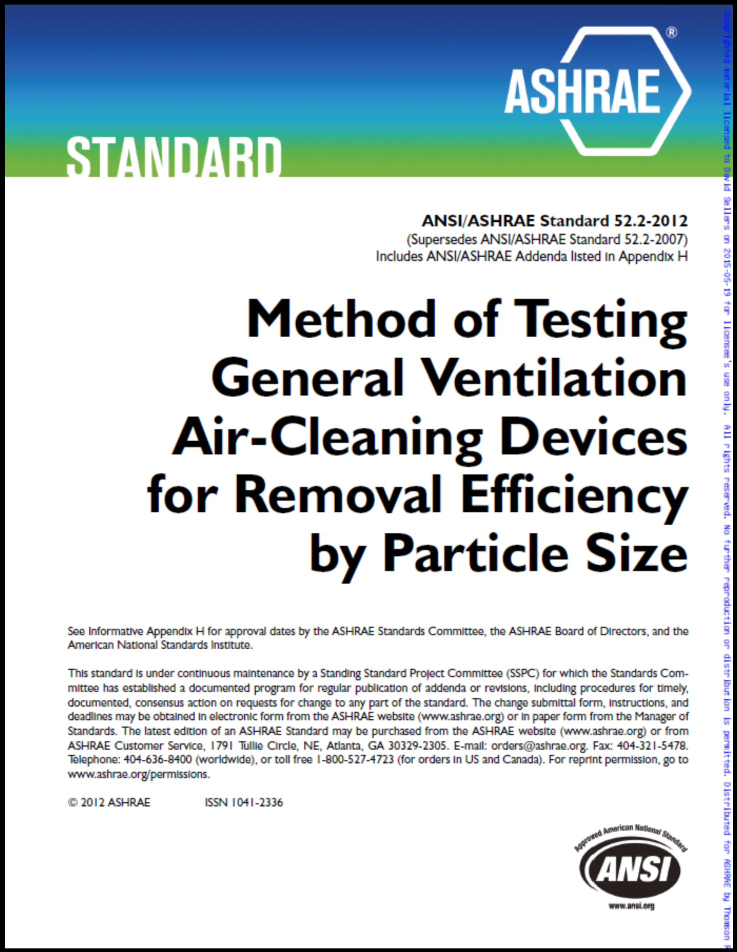
	Resistance (in. H2O)	Resistance (Pa)
Initial	0.20	50
After first dust load	0.24	60
After second dust load	0.40	100
After third dust load	0.60	149
After fourth dust load	0.80	199
After fifth dust load	1.00	249

Weight Gain of filter after completion of dust loading steps 35.2 g

ASHRAE Standard 52

The Basis for the Manufacturer's claims

- Test dust ≠ Real dust
- Tested efficiency ≠ Installed efficiency
- Tested efficiency ≠ <u>*Persistent*</u> installed efficiency
    - See Appendix J



STANDARD

ASHRAE

ANSI/ASHRAE Standard 52.2-2012
(Supersedes ANSI/ASHRAE Standard 52.2-2007)
Includes ANSI/ASHRAE Addenda listed in Appendix H

Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

See Informative Appendix H for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

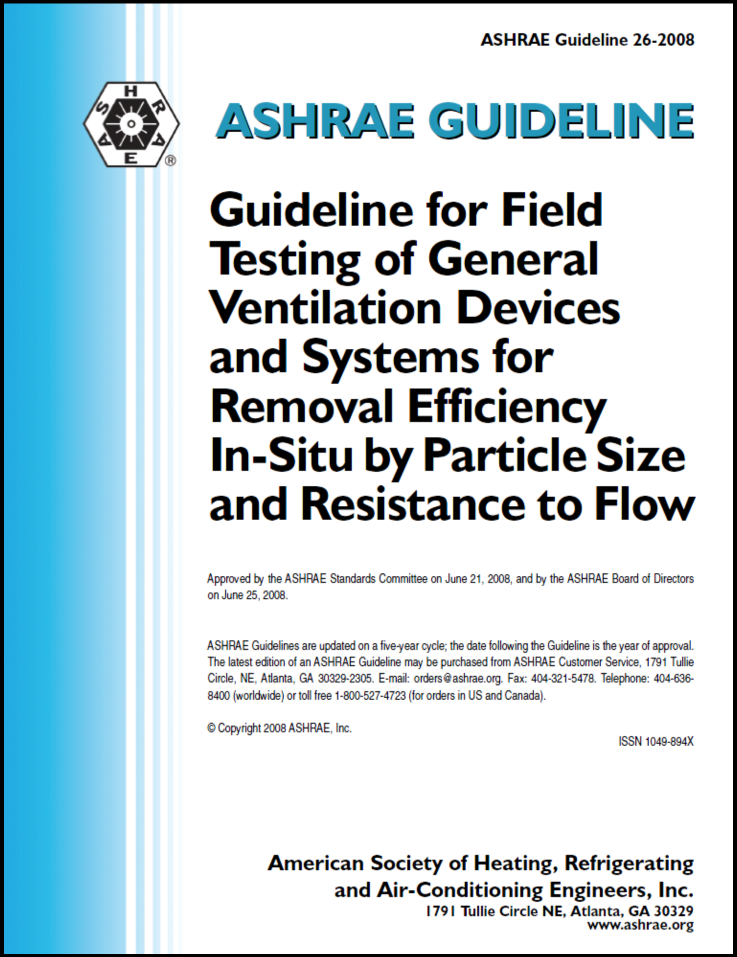
This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or 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). For reprint permission, go to www.ashrae.org/permissions.

 ISSN 1041-2336

Approved American National Standard
ANSI
www.ansi.org

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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ISSN 1049-894X

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle NE, Atlanta, GA 30329
www.ashrae.org

Good Filter + Mediocre Frame = Mediocre Filtration

- 95% (MERV14) filters
- Frame Construction
  - 16 gauge riveted
  - No stiffeners between sections
  - No caulk
  - Foam gaskets
  - No knife edge seals
  - Spring clip retainers
- Net filtration efficiency likely less than MERV 14
- Structural loads can become significant
  - At the design dirty pressure drop, each filter has 30 pounds of force acting on it

Intermittent turbulence associated with the position of the economizer dampers in this system cause the filter bank to vibrate under some air flow conditions, knocking particles loose on the downstream side

A Filter is Only as Good as its Frame

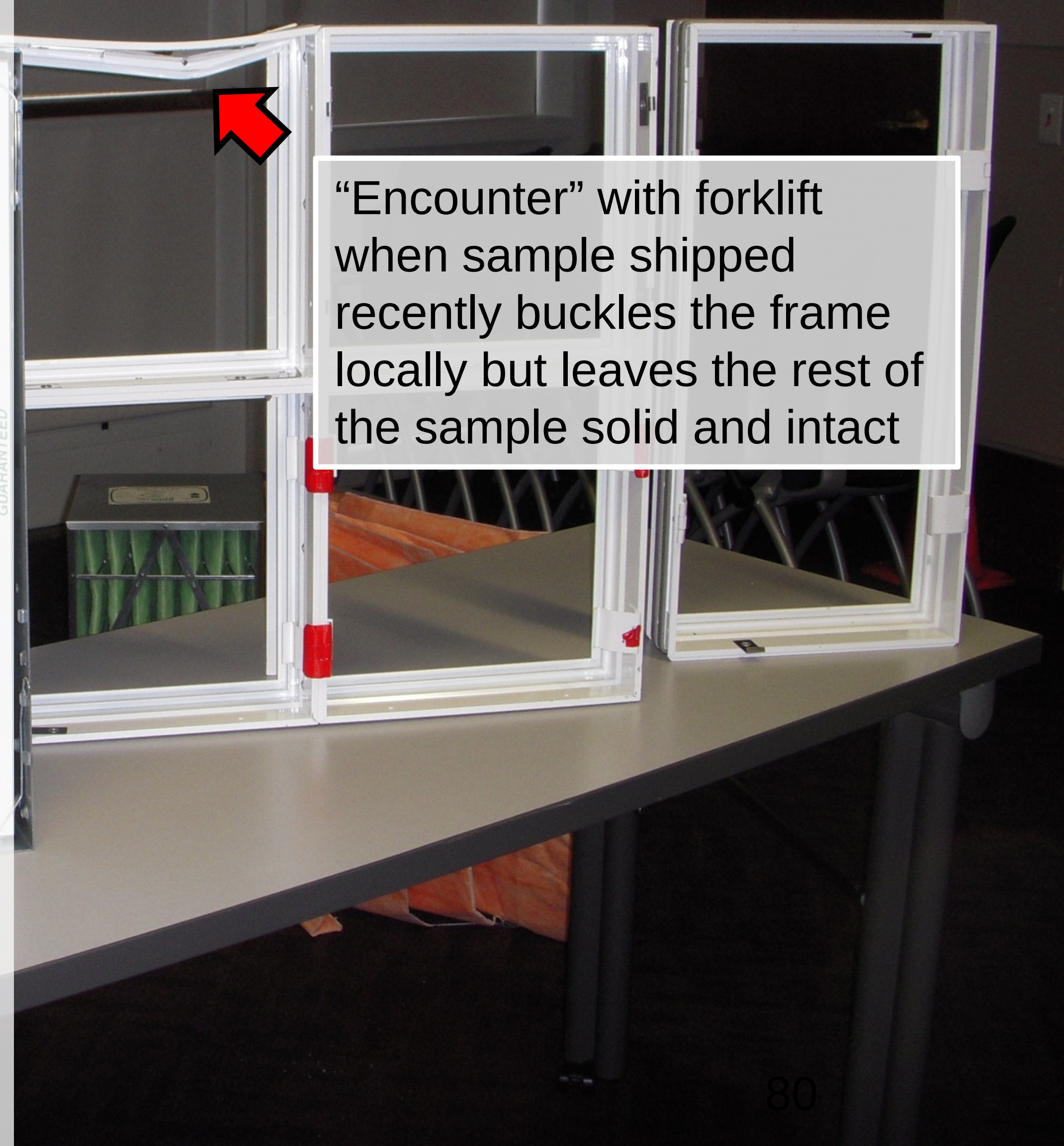
Camfil Farr Type 8

- 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)

A Filter is Only as Good as its Frame

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)



Kaiser Permanente Building
Portland, Oregon

- Lead facilities engineer interested in life cycle cost based operation
- Had concerns regarding flexible bag filters in VAV systems
- Challenges
  - Mandatory operating policy to change filters every 2 years
  - Relatively low electric rates ($.037/kWh vs $.08/kWh)
- Authorized to perform a side by side comparison
  - FDE contributes engineering support

Proposed Comparison

Condition	Filter Bank	Number	Filter Cost	Labor Cost	Waste, cu. Yd	Disposal Cost	Make	Model
Current Practice	Prefilter	2	$104.00	$50.00	0.8	$0.00	Koch	Koch Filter Corporation MD-10, MERV 3
	Final Filter	101	$27.85	$5.00	0.3	$0.00	Aerostar	85% ASHRAE Dust Spot Aerostar Non-Supported Pocket
Proposed Practice	Prefilter	0	$0.00	$0.00	0.0	$0.00	None	None
	Final Filter	101	$113.00	$5.00	0.3	$0.00	EFS	MERV11 Self supported pocket with spacers

Final Filter	Current	Proposed
Manufacturer	Filtration Group	Engineered Filtration Systems
Model	18324	EFS-F6
MERV Rating/ASHRAE Dust Spot Rating	13/85%	11/65%
Size, h x w x d, inches	24 x 24 x 22	24 x 24 x 26
Initial Pressure Drop at 500 fpm	0.30 inches w.c.	0.22 inches w.c.
Final Pressure Drop	1.50 inches w.c.	1.50 inches w.c.
Dust Holding Capacity	189.8 grams	3,400 grams

Proposed Comparison – Prefilter

Current Practice

Proposed Practice

Koch Filter Corporation
Filtration Products Crafted with Pride

Bulletin No. PB-001-B

Synthetic Air Filter Media

A complete line of pads, blankets and bulk rolls

Koch offers nine styles of Synthetic Air Filter Media for use in air filtration systems of all types.

This broad spectrum of products is designed for use in Koch Pad Frames, and is also available in bulk rolls for customers preferring to cut their own pads. Koch Synthetic Air Filter Media is primarily used as a prefilter for more expensive final filters, often extending the life-cycle of these final filters by 50% or more. Other popular applications include gas turbine air intake systems, commercial/ industrial central air handlers, unit ventilators, fan coil units, or any system where fiberglass or other filtering materials are not preferred. **Regardless of system design, Koch offers a Synthetic Air Filter Media to meet the requirement.**

Type SS5 is the standard 1/2" media for use as a prefilter in 1" applications. The media is solid white in color and is available in pads or 135' bulk rolls. SS5 is completely dry to the touch. With a nominal loft of 1/2" and a weight of 4 ounces per square yard, SS5 is an excellent media for use in 1" frames and blanket installations.

Type SS10 is an all white, completely dry media consisting of polyester fibers. SS10 is the most versatile uses of any media in the SS series. The pad or blanket has a nominal loft of 1" and a weight of 6 ounces per square yard. This media can be used as a prefilter in a 2" frame or blanket installation where clean air and reliability are paramount. The media is available in pads or 90' bulk rolls.

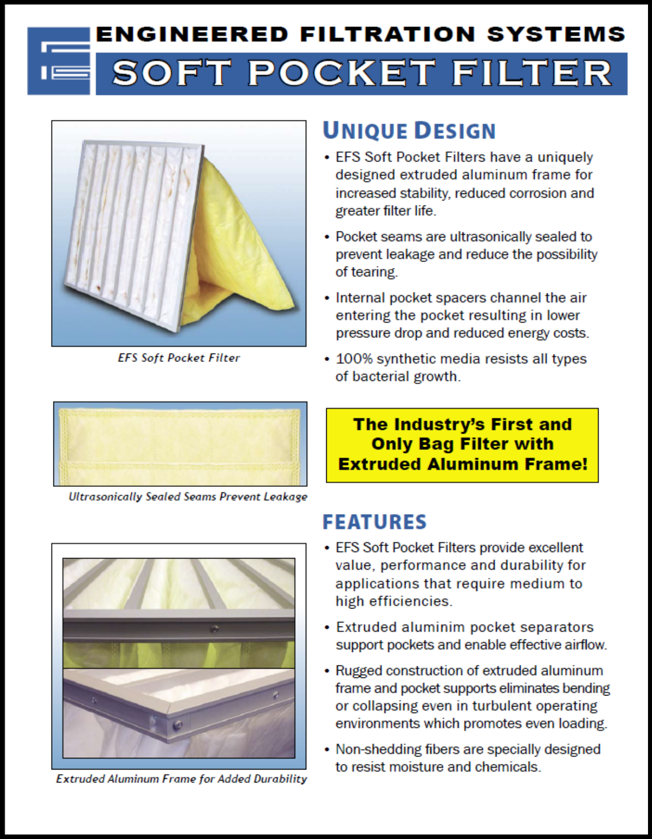
Type MD-10 is a nominal one inch, specially processed polyester media for 1" applications. This media is an excellent all-polyester **replacement for fiberglass** in service applications or any situation where a polyester media is desirable. MD-10 is dry, light blue in color and has a weight of 6 ounces per square yard. It is available in pads or 90' bulk rolls.

(*continued on reverse side*)

Corporate Offices
P.O. Box 3186 • 625 West Hill Street (40208) • Louisville, KY 40201 • 502.634.4796 • Fax: 502.637.2280 • E mail: info@kochfilter.com •www.kochfilter.com
Local Sales Offices/ Distribution Centers
Louisville • Charlotte • Cincinnati • Denver • Houston • Indianapolis • Kansas City • Nashville • St. Louis

Proposed Comparison – Final Filter

Current Practice



ENGINEERED FILTRATION SYSTEMS

SOFT POCKET FILTER

EFS Soft Pocket Filter

UNIQUE DESIGN

- EFS Soft Pocket Filters have a uniquely designed extruded aluminum frame for increased stability, reduced corrosion and greater filter life.
- Pocket seams are ultrasonically sealed to prevent leakage and reduce the possibility of tearing.
- Internal pocket spacers channel the air entering the pocket resulting in lower pressure drop and reduced energy costs.
- 100% synthetic media resists all types of bacterial growth.

Ultrasonically Sealed Seams Prevent Leakage

The Industry's First and Only Bag Filter with Extruded Aluminum Frame!

FEATURES

- EFS Soft Pocket Filters provide excellent value, performance and durability for applications that require medium to high efficiencies.
- Extruded aluminim pocket separators support pockets and enable effective airflow.
- Rugged construction of extruded aluminum frame and pocket supports eliminates bending or collapsing even in turbulent operating environments which promotes even loading.
- Non-shedding fibers are specially designed to resist moisture and chemicals.

Extruded Aluminum Frame for Added Durability

Proposed Practice

ENGINEERED FILTRATION SYSTEMS

F6 RIGID POCKET FILTER

The EFS F6 Rigid Pocket Filter

RIGID CONSTRUCTION

- The EFS F6 Rigid Pocket Filter is constructed to withstand extreme humidity, high velocities and turbulence and is excellent for all types of air handling systems.
- Self-supported filter pockets stay rigid in the air stream.
- The filter element is free of metal parts, eliminating the risk of corrosion and punctures.
- Corrosion-free polyurethane header ensures a leak-proof bonding of pockets to header.

SYNTHETIC MEDIA

- Synthetic media rated at ASHRAE 65%, MERV 11.
- Non-shedding fibers are specially designed to resist moisture and chemicals.
- Resists all types of bacterial growth.

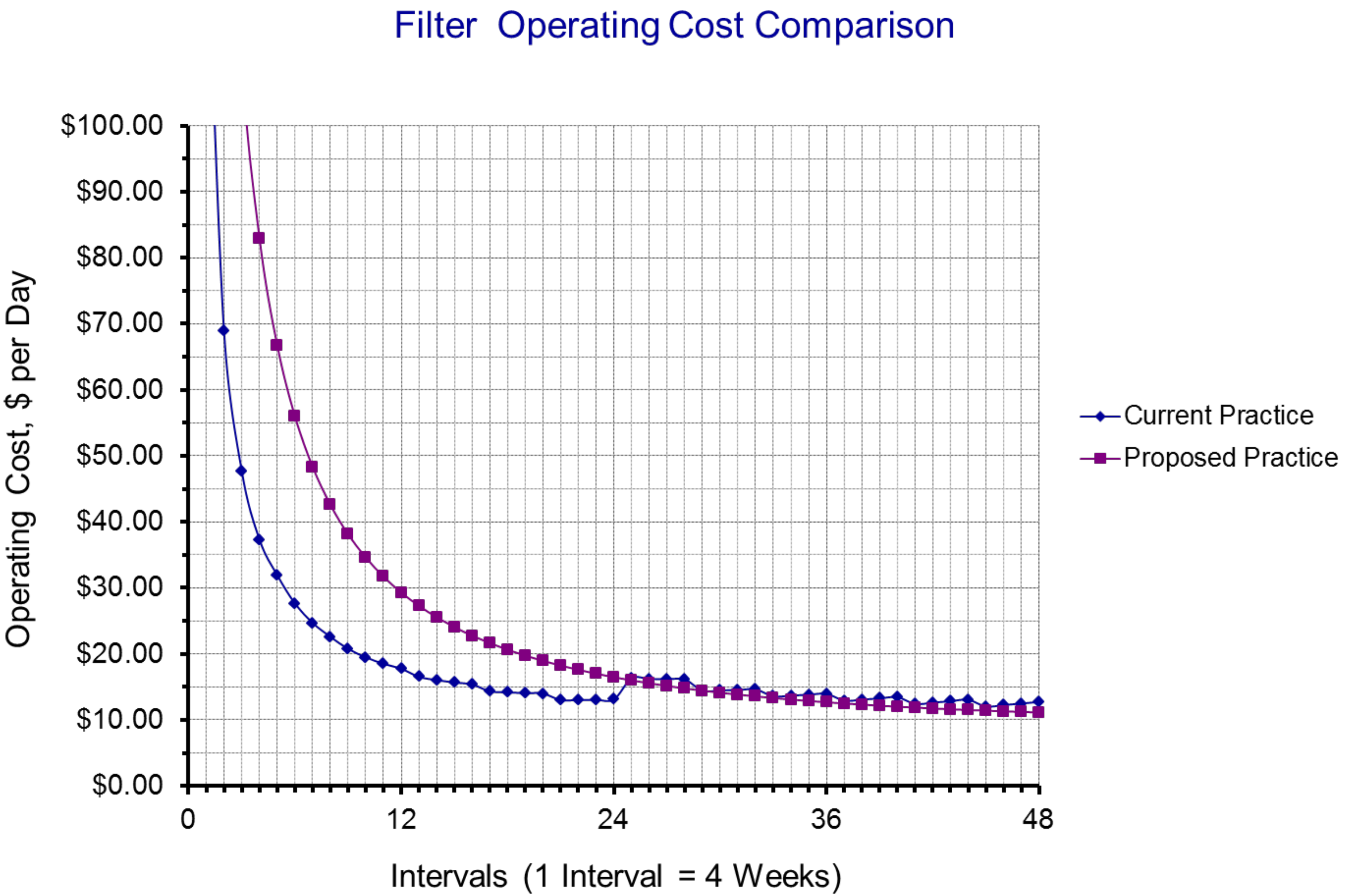
Spacers Stabilize Pocket Shape

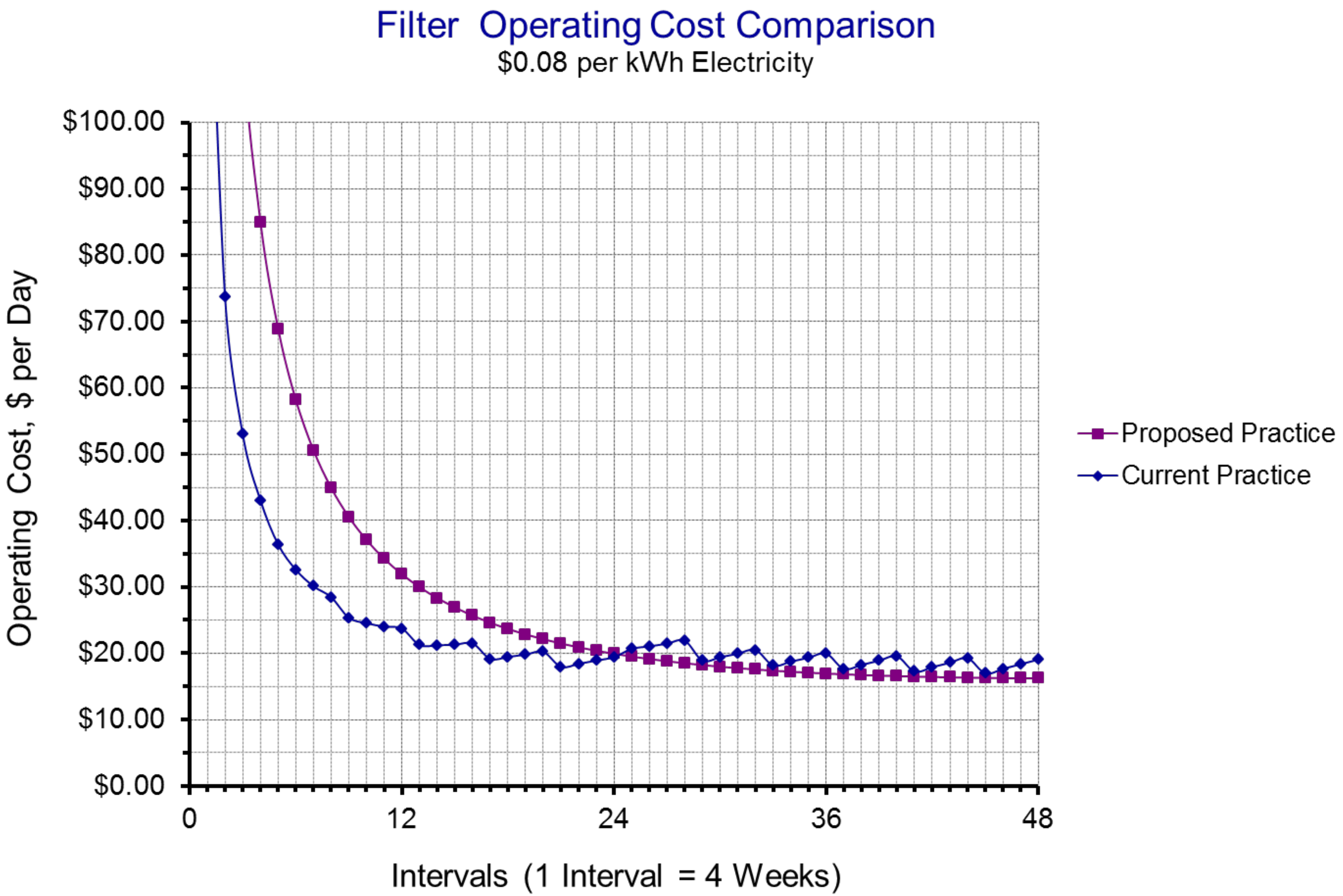
DISTRIBUTED BY . . .
AFNW
Phone: 503.968.3261 • www.AirFiltersNW.com

UNIQUE DESIGN

- The EFS F6 Rigid Pocket Filter is light-weight and easy to handle which provides for low-cost transport and disposal.
- Progressively structured design provides exceptionally low pressure drop at high efficiency levels.
- Spacers channel the air entering the pocket resulting in lower pressure drop and reduced energy costs.

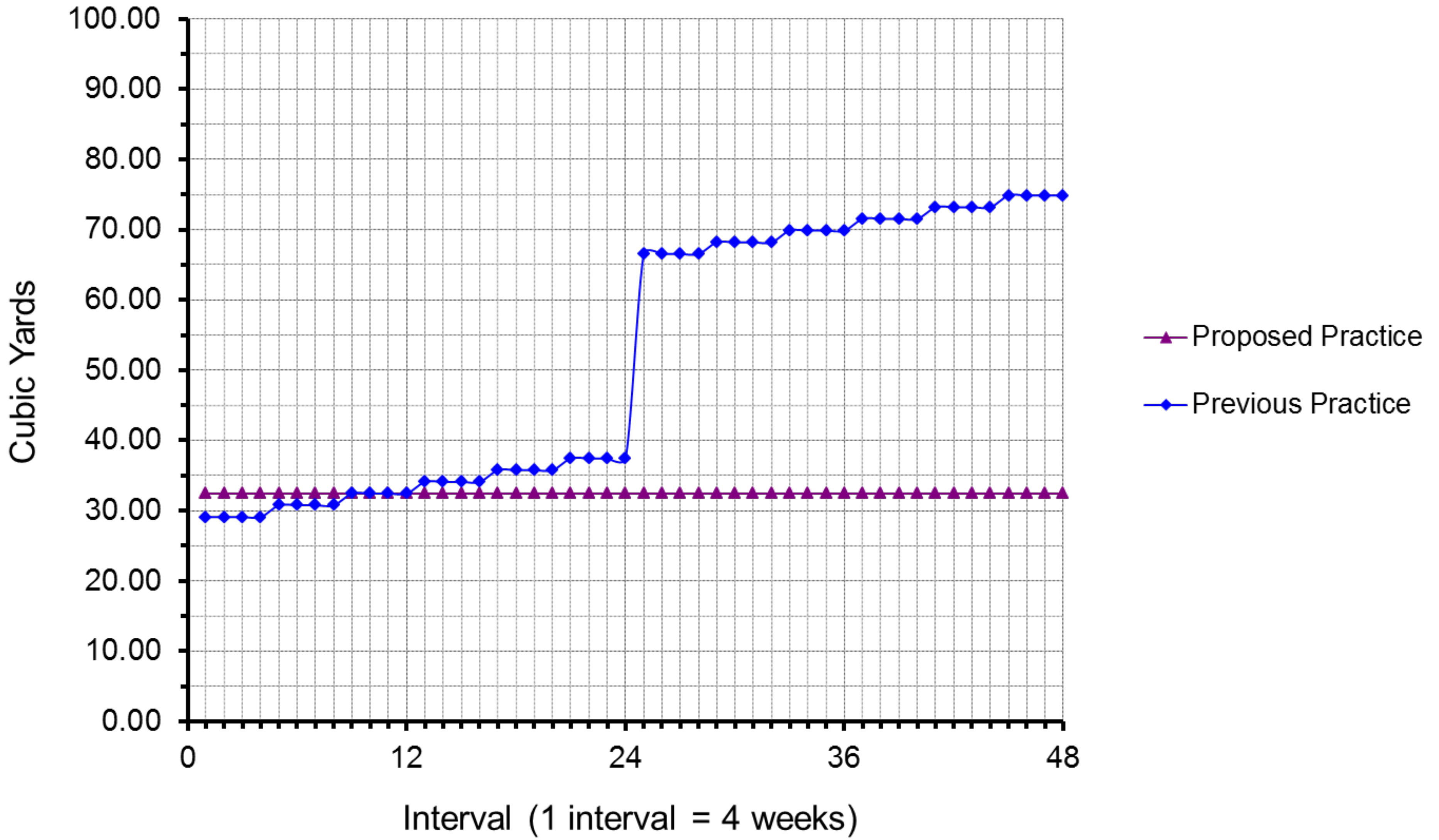
Corrosion-Free Panels


Filter Operating Cost Comparison
$100.00
$90.00
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$0.00
Operating Cost, $ per Day
0
12
24
36
48
Intervals (1 Interval = 4 Weeks)
Current Practice
Proposed Practice



Filter Operating Cost Comparison
$0.08 per kWh Electricity
Operating Cost, $ per Day
$100.00
$90.00
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$0.00
0
12
24
36
48
Intervals (1 Interval = 4 Weeks)
Proposed Practice
Current Practice

Waste Stream - South AHU



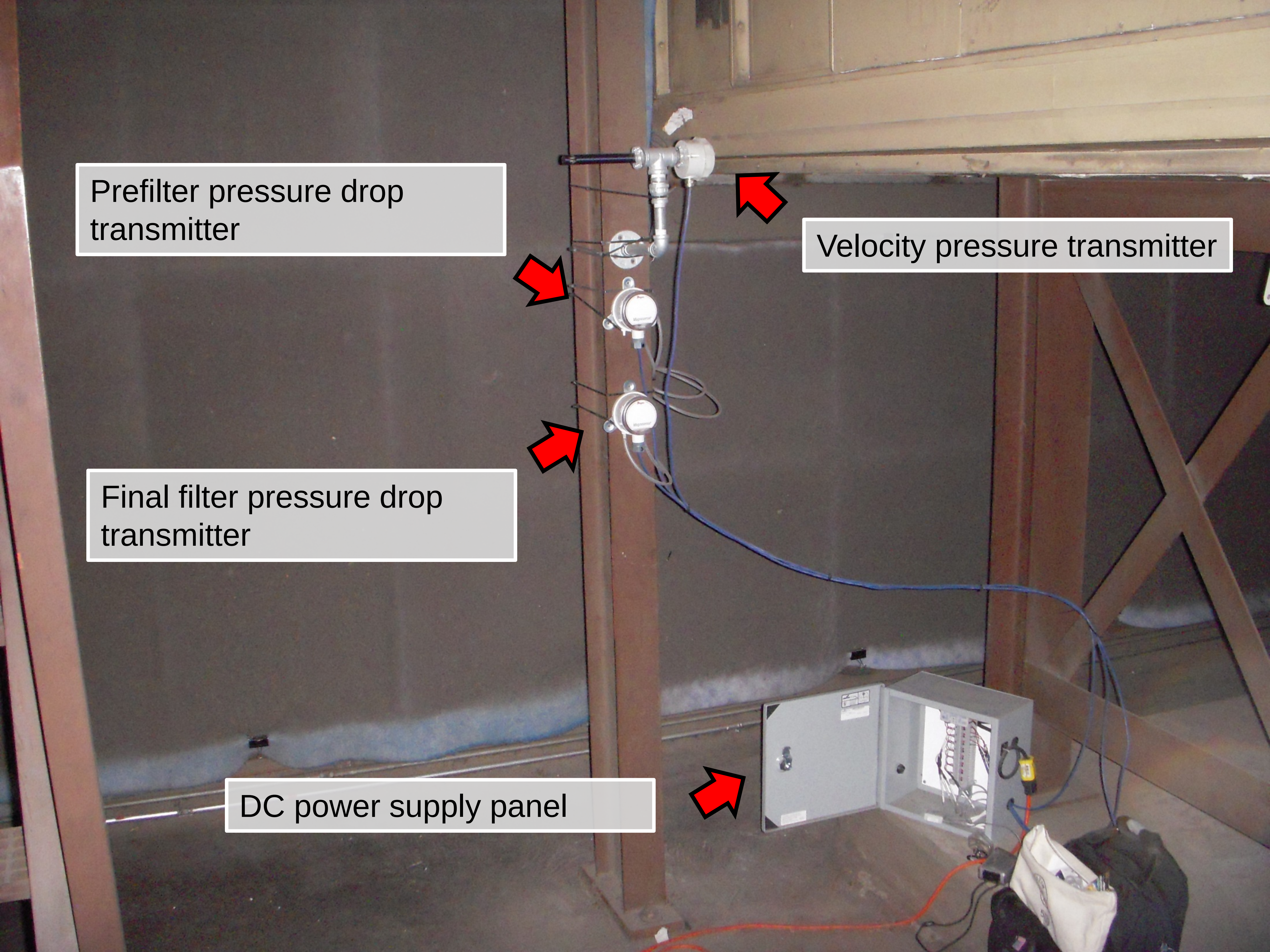
Kaiser Permanente Building
Portland, Oregon

Field Test of Conventional vs. Extended Surface Area Filters

- Near Identical Systems
- Near Identical Load Profiles
- 5 Minute Logged Data

EFS MERV 11 soft pocket bag filter with MERV 7 roll type prefilter

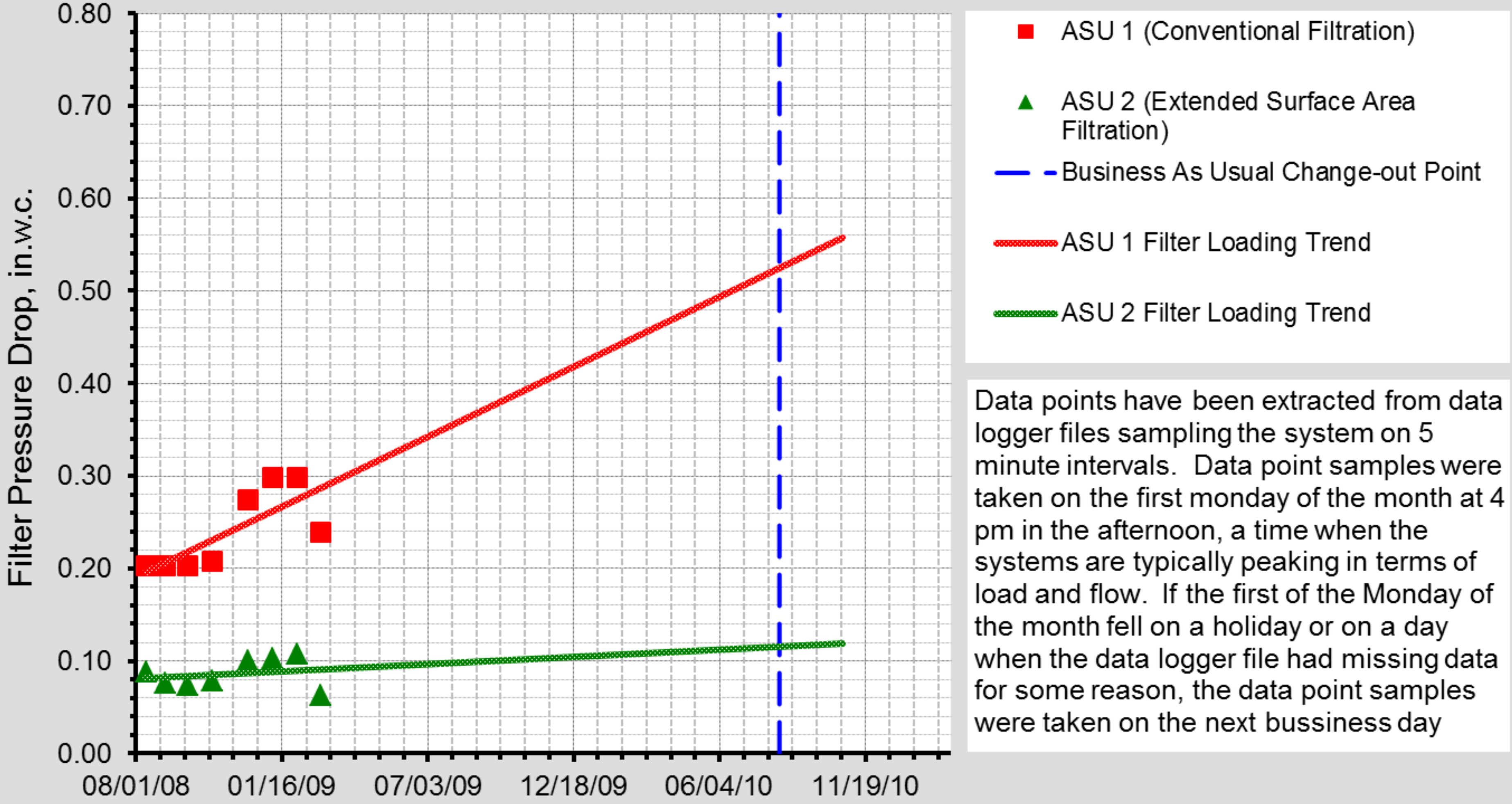
EFS MERV 11 rigid pocket bag filter with no prefilter


Prefilter pressure drop transmitter
Velocity pressure transmitter
Final filter pressure drop transmitter
DC power supply panel

Visit My Blog for Details

Real-time Data from Conventional vs. Extended Surface Area Filters

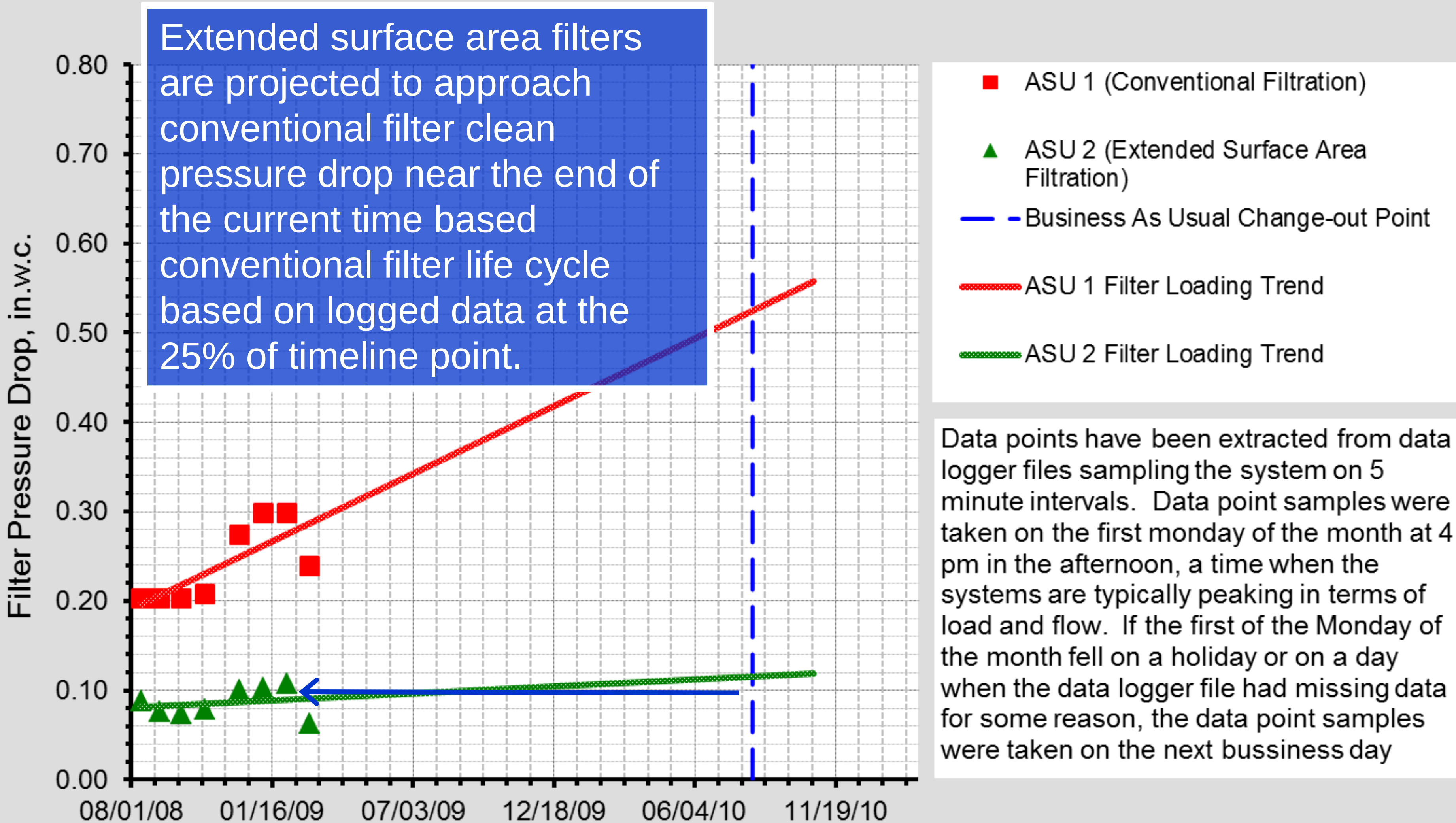
Near Identical 160,000 cfm VAV Systems and Occupancies, Same Building



Data points have been extracted from data logger files sampling the system on 5 minute intervals. Data point samples were taken on the first monday of the month at 4 pm in the afternoon, a time when the systems are typically peaking in terms of load and flow. If the first of the Monday of the month fell on a holiday or on a day when the data logger file had missing data for some reason, the data point samples were taken on the next bussiness day

Real-time Data from Conventional vs. Extended Surface Area Filters

Near Identical 160,000 cfm VAV Systems and Occupancies, Same Building



Data points have been extracted from data logger files sampling the system on 5 minute intervals. Data point samples were taken on the first monday of the month at 4 pm in the afternoon, a time when the systems are typically peaking in terms of load and flow. If the first of the Monday of the month fell on a holiday or on a day when the data logger file had missing data for some reason, the data point samples were taken on the next bussiness day

Bottom Line

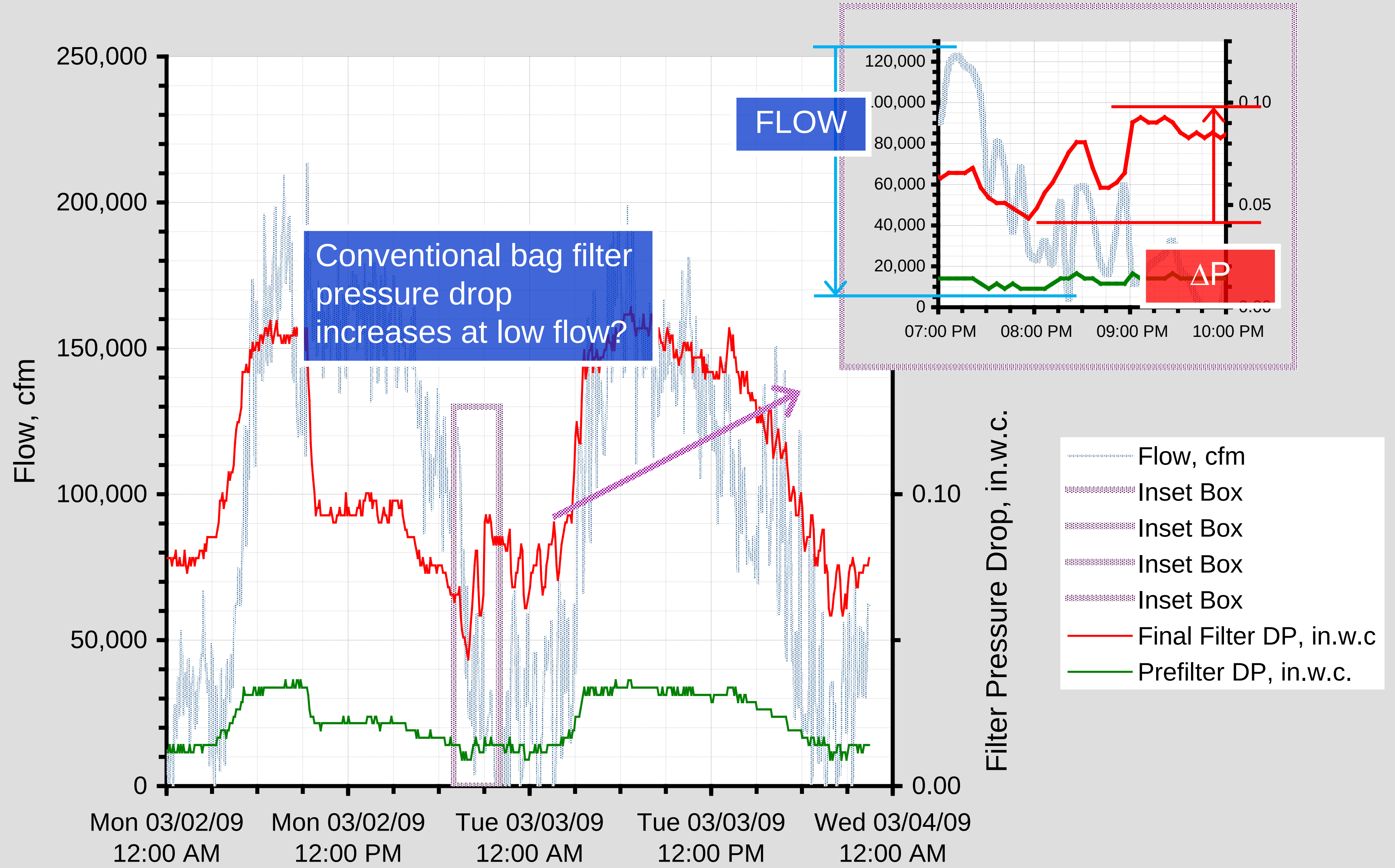
New Approach

- New approach matching projections
- 277 grams of dust accumulated
- No signs of microbiological problems

Original Approach

- Conventional approach below projection but about twice the new approach
- Dust accumulated to be determined, but the dust accumulated by the new approach exceeds the rated capacity of this filter

Typical Daily Flow and Filter Pressure Drop Pattern



Conventional

Extended Surface Area

Electrostatic Filters
(Re)Emerging Technology

Good News

- Approaches MERV 13 efficiency
- MERV 8 depth
- MERV 8 pressure drop
  - Allows LEED requirements to be achieved with out an excessive fan energy penalty
  - Allows LEED requirements to be achieved in less space

Bad News

- Power supplies required to power up electrostatics
  - Small number per filter
  - Each filter requires the small number
  - Eat’s away at the fan energy savings
  - Adds some complexity

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

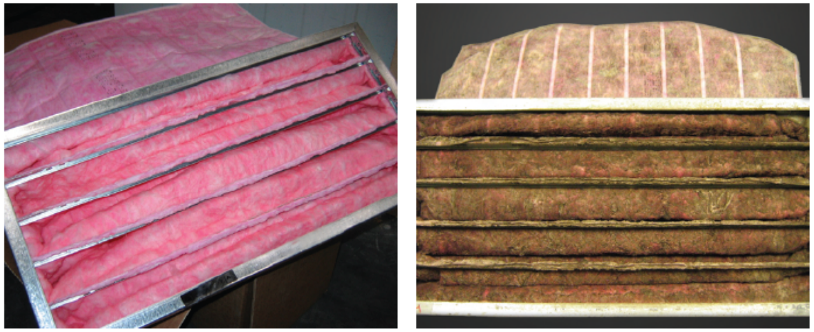


Figure 1a (left): New F7 (~MERV13) fiberglass bag filter. Figure 1b (right): The same filter after five months of continuous operation.

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.

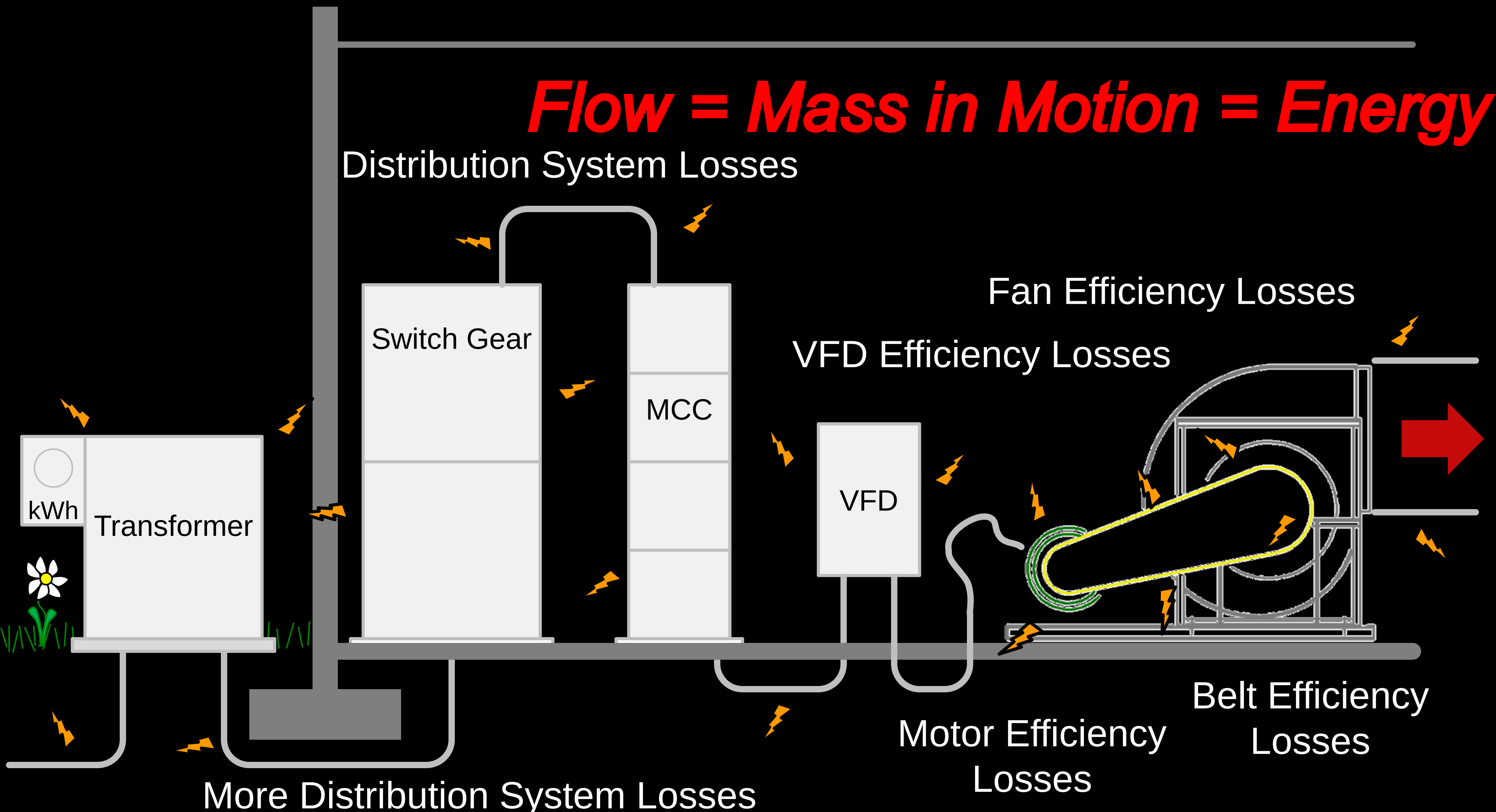
Mechanical ventilation systems are commonly used to ensure that ventilation standards and guidelines are met. However, studies have documented that building occupants, especially in older and mechanically ventilated buildings, consider the indoor air quality unacceptable and suffer from Sick Building 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

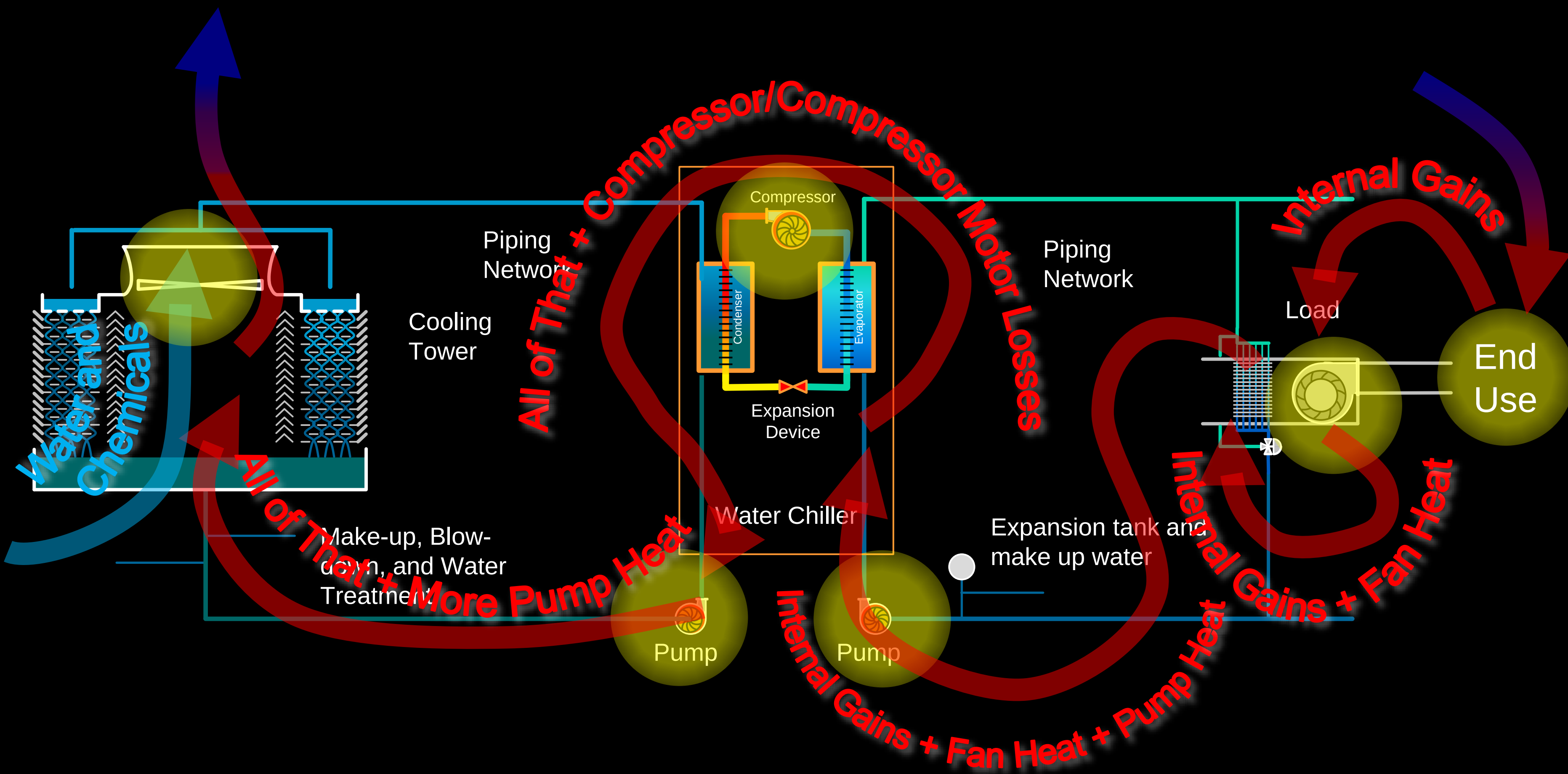
About the Author

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.

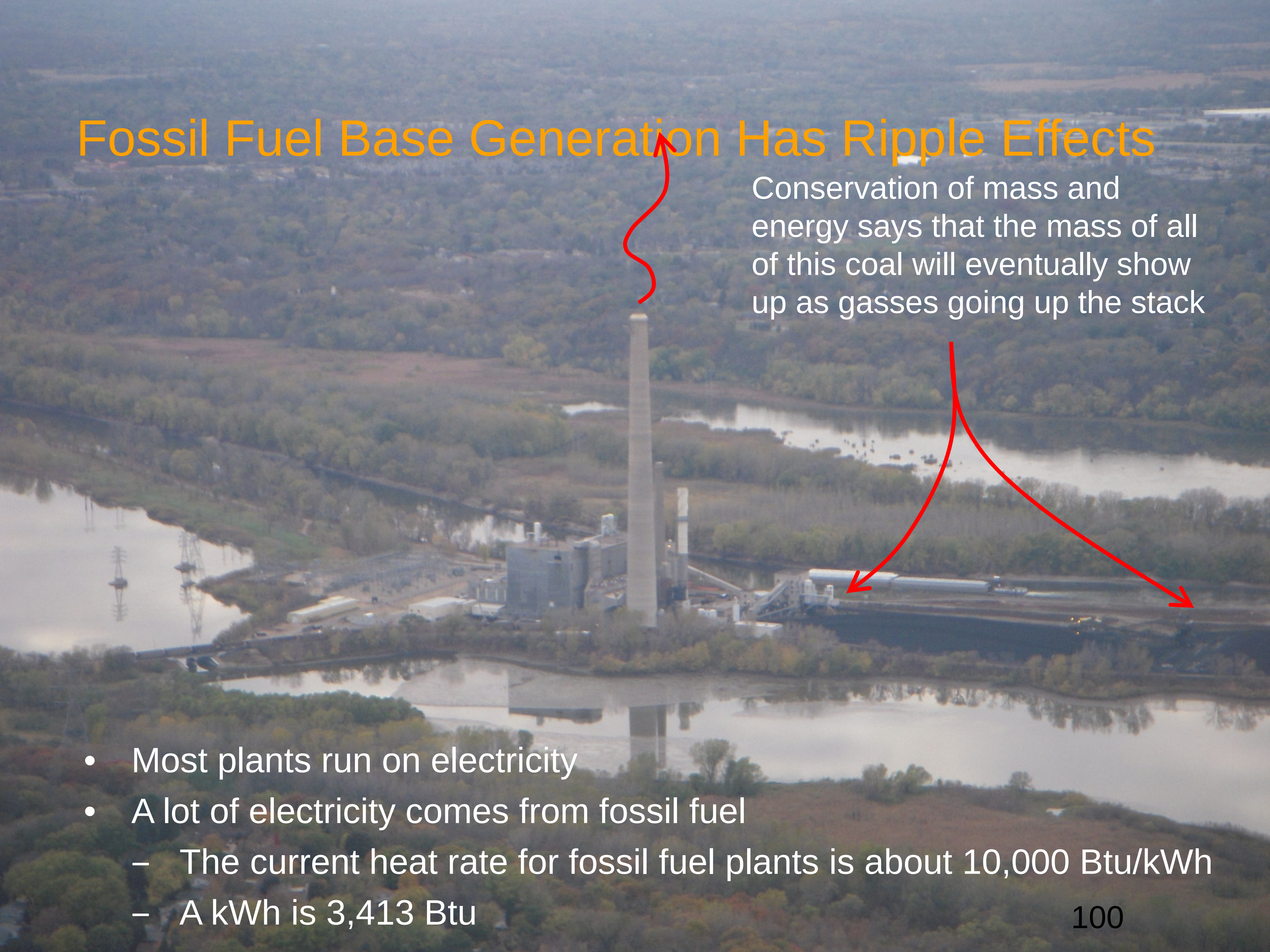
The Savings Ripple Out Beyond the AHU



The Savings Ripple Out Beyond the AHU



Fossil Fuel Base Generation Has Ripple Effects



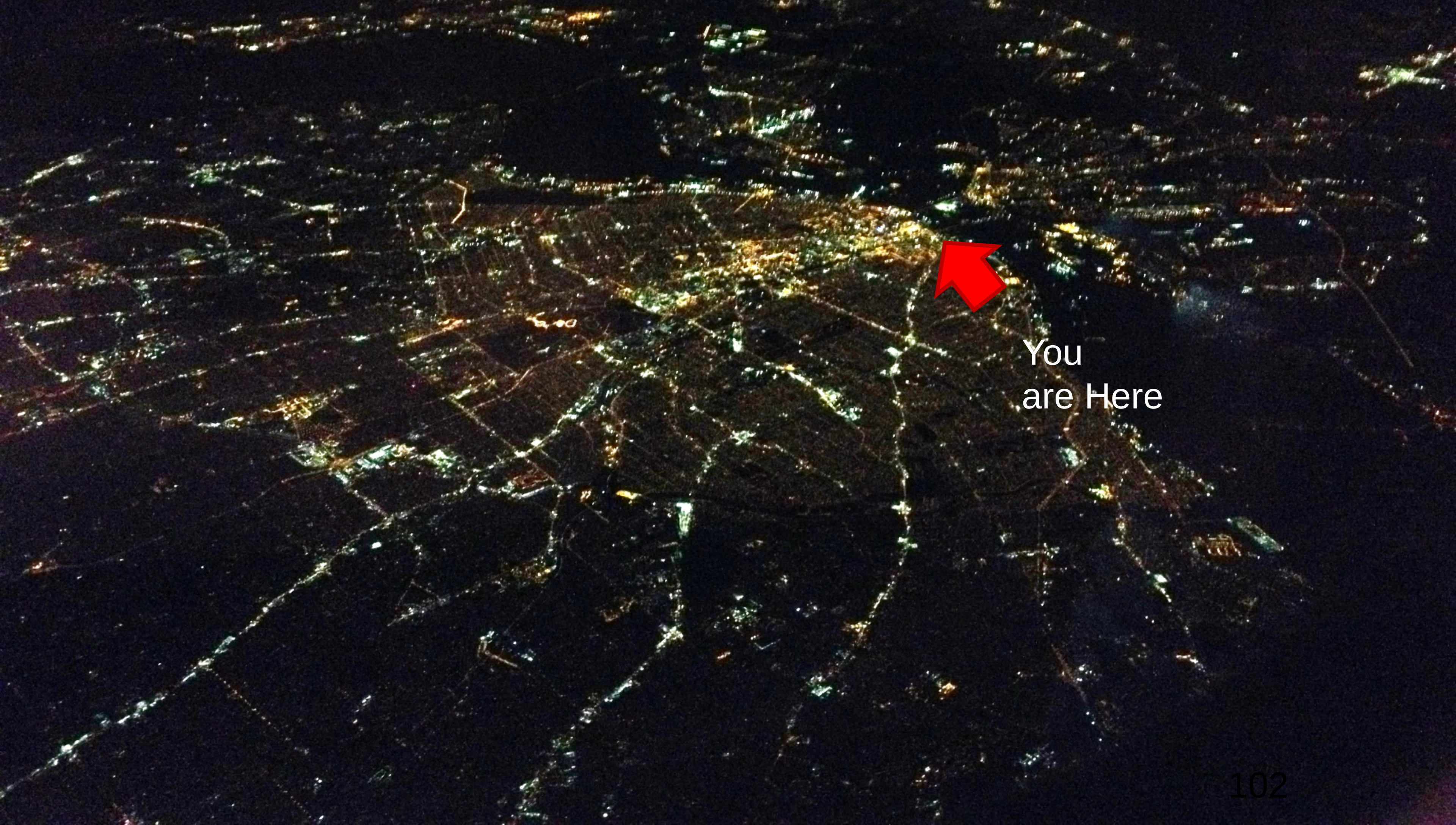
- Most plants run on electricity
- A lot of electricity comes from fossil fuel
  - The current heat rate for fossil fuel plants is about 10,000 Btu/kWh
  - A kWh is 3,413 Btu

State	% of Total Electric Power Generation											Non-renewable Percent of Total	Renewable Percent of Total	Non-hydro Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
	Non-Renewable					Renewable					Nuclear					
	Combustion Processes						Non-Combustion Processes									
	Coal	Oil	Gas	Other Fossil Fuel	Purchased, Fuel Generated	Biomass	Hydro	Wind	Solar	Geothermal						
AK	9.2	13.9	55.6	0.0	0.0	0.1	21.1	0.2	0.0	0.0	0.0	78.7	21.3	[illegible]	78.7	21.3
AL	41.4	0.1	25.8	0.2	0.0	1.8	5.7	0.0	0.0	0.0	24.9	92.5	7.5	1.8	69.3	30.7
AR	46.2	0.1	20.4	0.0	0.0	2.7	6.0	0.0	0.0	0.0	24.6	91.3	8.7	2.7	69.4	30.6
AZ	39.1	0.1	26.6	0.0	0.0	0.2	6.1	0.1	0.0	0.0	27.9	93.6	6.4	0.3	65.8	34.2
CA	1.0	1.2	52.7	0.2	0.3	3.0	16.3	3.0	0.4	6.2	15.8	71.3	28.7	12.5	58.4	41.6
CO	68.1	0.0	21.9	0.0	0.1	0.1	2.9	6.8	0.1	0.0	0.0	90.1	9.9	7.0	90.2	9.8
CT	7.8	1.2	35.2	2.2	0.0	2.1	1.2	0.0	0.0	0.0	50.2	96.7	3.3	2.1	48.6	51.4
DC	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	[illegible]	0.0	100.0	0.0
DE	45.6	1.0	50.9	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	97.5	[illegible]	2.5	100.0	0.0
FL	26.1	4.0	56.2	0.6	0.7	1.9	0.1	0.0	0.0	0.0	10.4	98.0	[illegible]	1.9	89.4	10.6
GA	53.3	0.5	17.4	0.0	0.0	2.3	2.2	0.0	0.0	0.0	24.4	95.5	4.5	2.3	73.4	26.6
HI	14.3	74.8	0.0	3.5	0.0	2.5	0.6	2.4	0.0	1.9	0.0	92.6	7.4	6.8	95.1	4.9
IA	71.8	0.3	2.3	0.0	0.0	0.3	1.6	15.9	0.0	0.0	7.7	82.1	17.9	16.2	74.7	25.3
ID	0.7	0.0	14.0	0.0	0.7	4.2	76.1	3.7	0.0	0.6	0.0	15.4	84.6	8.4	19.6	80.4
													2.6	2.6	50.0	50.0
													2.9	2.6	97.3	2.7
													7.2	7.2	72.9	27.1
													3.1	0.4	97.4	2.6
													3.4	2.4	81.0	19.0
													4.4	2.8	84.7	15.3
													5.1	1.3	64.1	35.9
													46.7	24.3	74.7	25.3
													2.7	2.5	72.9	27.1
													13.9	12.3	64.4	35.6
													3.7	1.1	86.6	13.4
													2.8	2.8	82.3	17.7
													34.8	3.1	65.2	34.8
													5.6	1.6	64.5	35.5
													17.6	11.7	82.4	17.6
													4.9	1.3	65.1	34.9
													12.2	5.5	43.8	56.2
													1.2	1.2	50.2	49.8
													5.7	5.1	94.3	5.7
													12.6	6.5	87.4	12.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21.7	3.4	49.3	50.7
OH	82.1	1.0	5.0	0.2	0.0	0.5	0.3	0.0	0.0	0.0	11.0	99.2	0.8	0.5	88.7	11.3
OK	43.5	0.0	47.0	0.0	0.0	0.5	3.7	[illegible]	0.0	0.0	0.0	90.6	9.4	5.8	91.1	8.9
OR	7.5	0.0	28.4	0.1	0.0	1.5	55.4	[illegible]	0.0	0.0	0.0	36.0	64.0	8.6	37.5	62.5
PA	48.0	0.3	14.7	0.6	0.0	1.0	0.7	0.8	0.0	0.0	33.9	97.4	2.6	1.8	64.6	35.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0	0.0	98.1	[illegible]	1.8	99.9	0.1
SC	36.2	0.2	10.5	0.1	0.0	1.8	1.4	0.0	0.0	0.0	49.9	96.8	[illegible]	1.8	48.7	51.3
[illegible]	[illegible]	0.1	1.3	0.0	0.0	0.0	52.1	13.6	0.0	0.0	0.0	34.2	[illegible]	13.6	34.2	65.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	33.9	90.2	9.8	1.2	57.5	42.5
TX	36.5	0.8	45.3	0.2	0.1	0.4	0.3	6.4	0.0	0.0	10.1	93.0	7.0	6.7	83.3	16.7
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.6	1.1	0.0	0.7	0.0	96.5	3.5	1.8	96.6	3.4
VA	34.9	1.8	23.3	0.6	0.0	3.0	0.0	0.0	0.0	0.0	36.4	97.0	3.0	3.0	63.6	36.4
[illegible]	[illegible]	0.1	0.1	0.0	0.0	7.1	20.3	0.2	0.0	0.0	72.2	72.4	27.6	7.3	7.2	92.8
[illegible]	[illegible]	0.3	9.9	0.1	0.0	1.8	66.2	4.5	0.0	0.0	8.9	27.5	72.5	6.3	20.4	79.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.7	0.0	0.0	20.7	92.9	7.1	3.8	74.4	25.6
WV	96.7	0.2	0.2	0.1	0.0	0.0	1.7	1.2	0.0	0.0	0.0	97.1	2.9	[illegible]	97.1	2.9
WY	89.3	0.1	1.0	0.6	0.1	0.0	2.1	6.7	0.0	0.0	0.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.4	0.0	0.0	7.2	0.0
Maximum	96.7	100.0	98.0	3.5	0.9	21.4	76.1	15.9	0.6	6.2	72.2	100.0	84.6	24.3	100.0	92.8
Average	41.9	4.3	22.5	0.4	0.1	1.8	9.2	2.5	0.0	0.3	17.0	86.1	13.9	4.7	71.0	29.0

State	Non-renewable Percent of Total	Renewable Percent of Total	Non-hydro Renewable Percent of Total	Combustion Process Generated Percent of Total	Non-combustion Process Generated Percent of Total
Minimum	15.4	0.0	0.0	7.2	0.0
Maximum	100.0	84.6	24.3	100.0	92.8
Average	86.1	13.9	4.7	71.0	29.0

Based on egrid 2010 data, about 71% of the electricity generated in the USA is generated by burning something

My Logic Based Conclusion;
We Have to be Having Some Sort of Impact




You Also
are Here

We Don’t Inherit the World from our Ancestors,
We Borrow it From Our Children

Unknown

A Few Bottom Lines

- Operate Filters Based on Life Cycle Cost
- Purchase Clean Air, not Filters
- Accumulate Multiple Benefits
  - Save fan energy
    - Fan Power
    - Fan heat
    - Related ripple Effects
  - Reduce filter consumption
  - Reduce filter maintenance labor
  - Reduce waste stream

We Don't Inherit the World from our Ancestors,
We Borrow it From Our Children

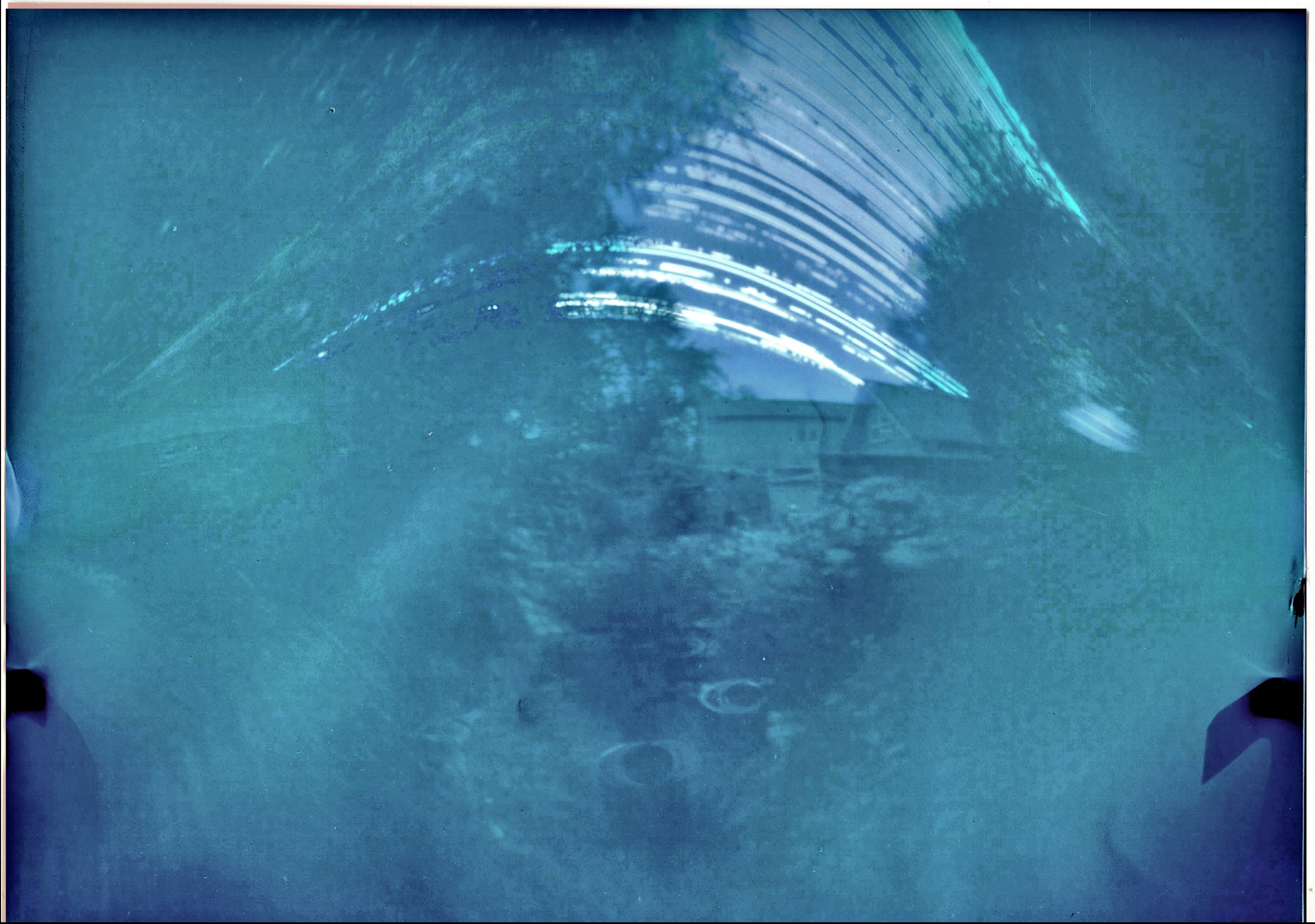
Unknown

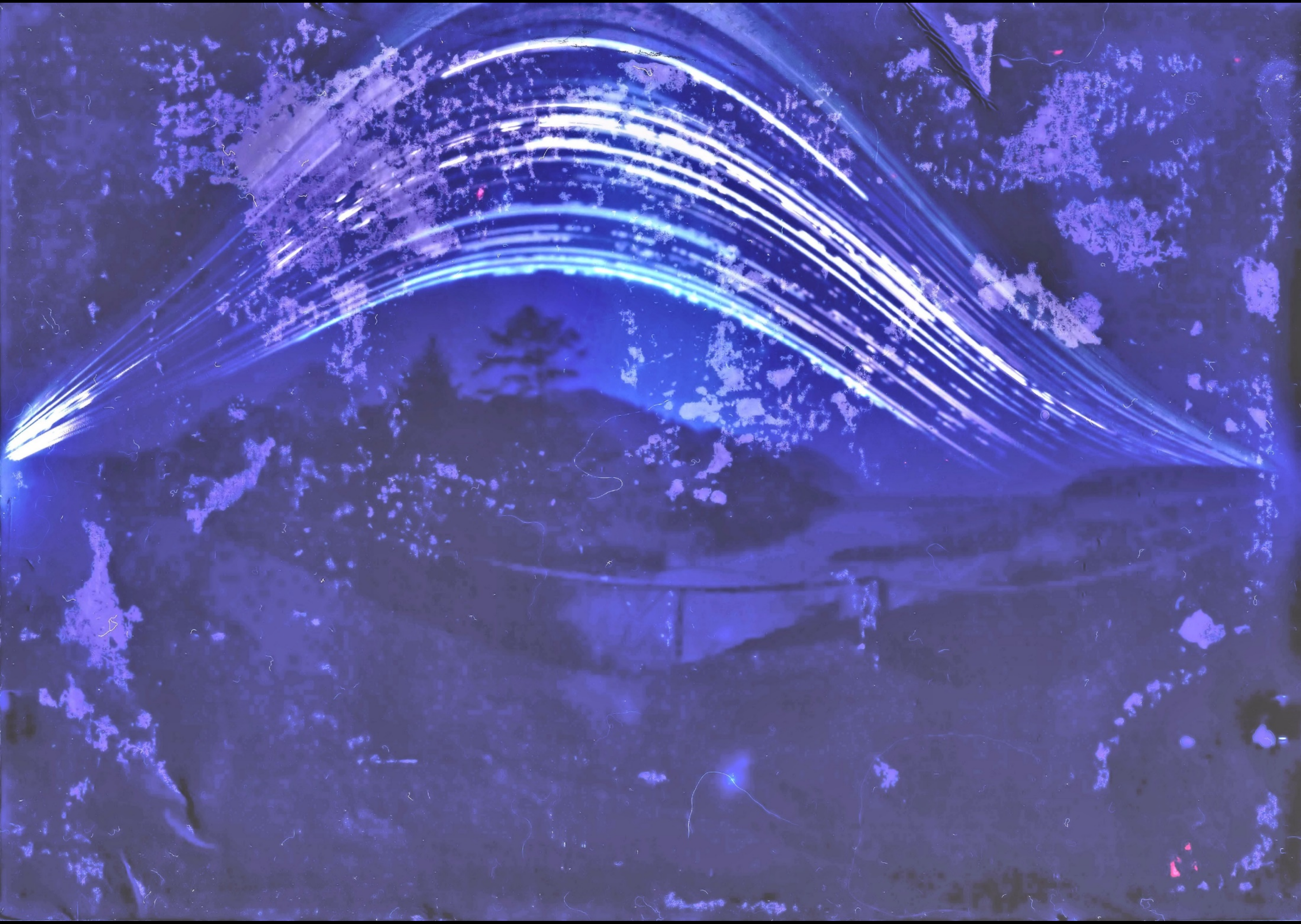
Resources on Filtration

- Follow the field trial at www.Av8rdas.Wordpress.com (starts in a September 2009 post)
- 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

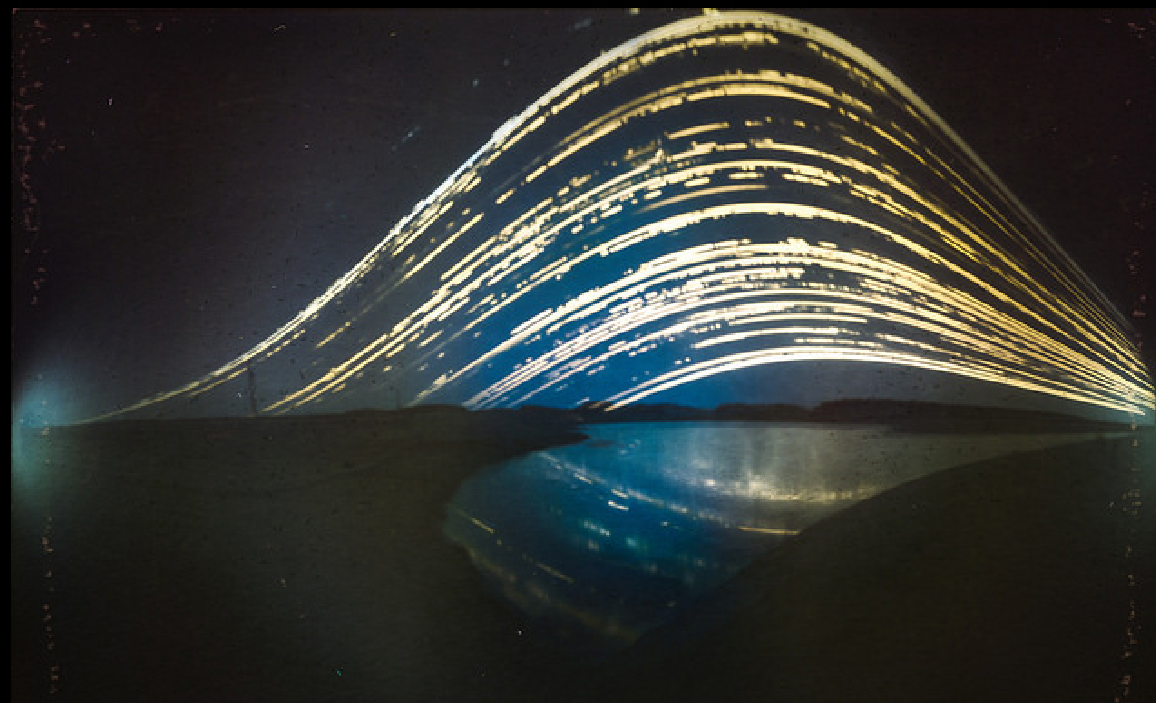
Resources on Filtration

- ASHRAE Research Project Report 1360-RP; *How do Pressure Drop, Efficiency, Weight Gain, and Loaded Dust Composition Change throughout Filter Lifetime; March 2013*
- *ASHRAE Journal, Filters and Filtration, April 1999, Timothy J Robinson and Alan E Quellet*
- ASHRAE Research Project Report RP-675; *Determination of Air Filter Performance Under Variable Air Volume (VAV) Conditions Final Report; January 1999*





https://solarcan.co.uk/



A four month Solarcan exposure of Williestruther Loch, Scotland.

Questions?

David Sellers, Senior Engineer

Facility Dynamics Engineering

Dsellers@FacilityDynamics.com

www.FacilityDynamics.com

https://av8rdas.wordpress.com/ (blog)

https://www.av8rdas.com/ (Cx Resources website)