UVC IN THE BUILDING ENVIRONMENT:

Perspectives on Building Codes, Energy Consumption & Cost Benefits

IUVA WORKSHOP
NIST, MD

January 14, 2020

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PATHOGEN TRANSMISSION MODES

Air handler/cooling coil

- aspergillus, pseudomonas aeruginosa…

Airborne transmission through HVAC ducts

- TB, MRSA, Influenza, Klebsiellapneumoniae, aspergillus, Acinetobacter baumanni, aspergillus…

Water-borne transmission

- Legionella, pseudomonas aeruginosa; mycobacteria; aspergillus, fusarium, cryptosporium, giardia, acanthamoebia…

Surface cross-contamination

- MRSA, C-Diff, VRE, Candida auris, Ebola…

Hand cross-contamination

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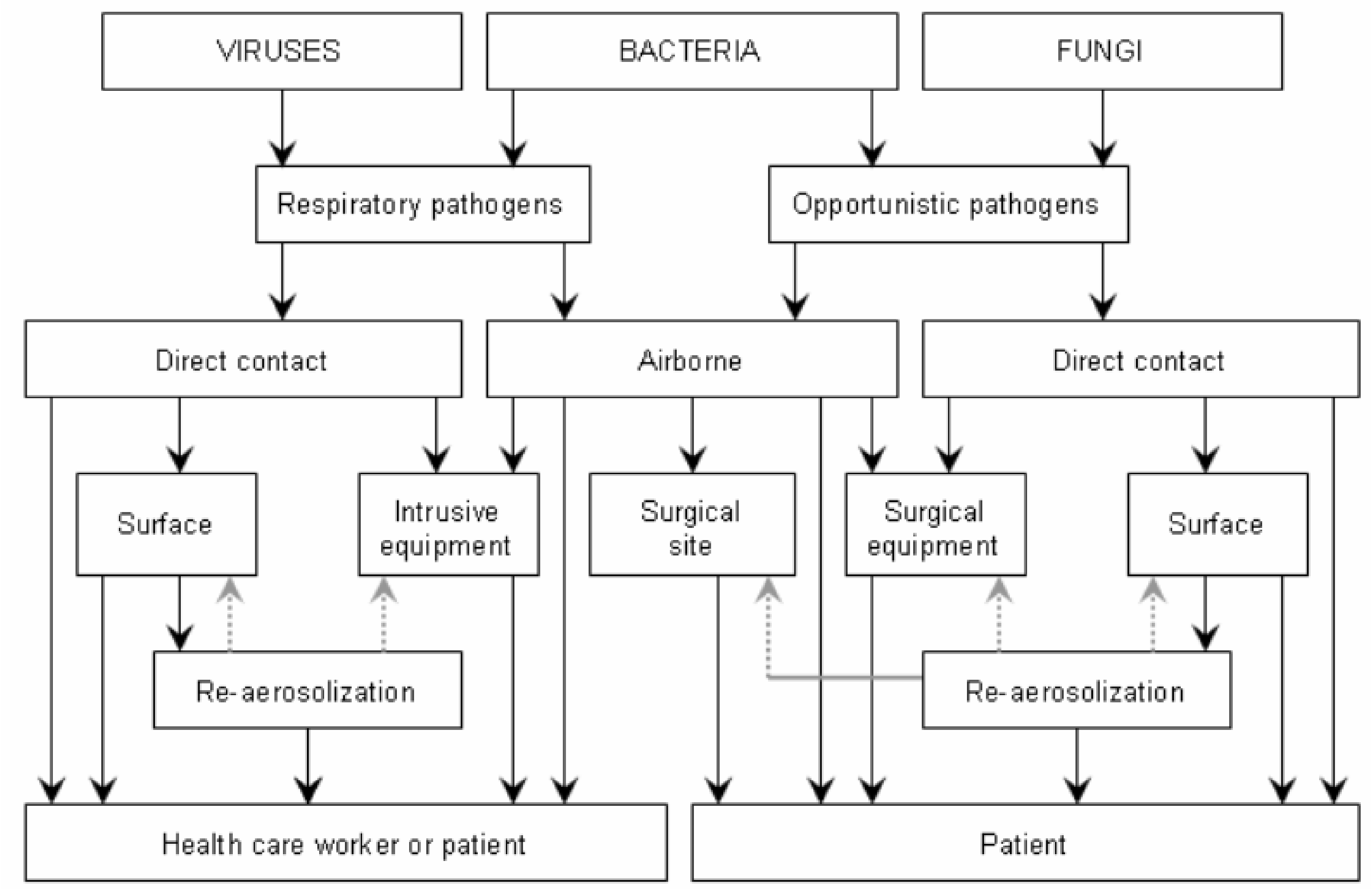
PATHOGEN TRANSMISSION ROUTES



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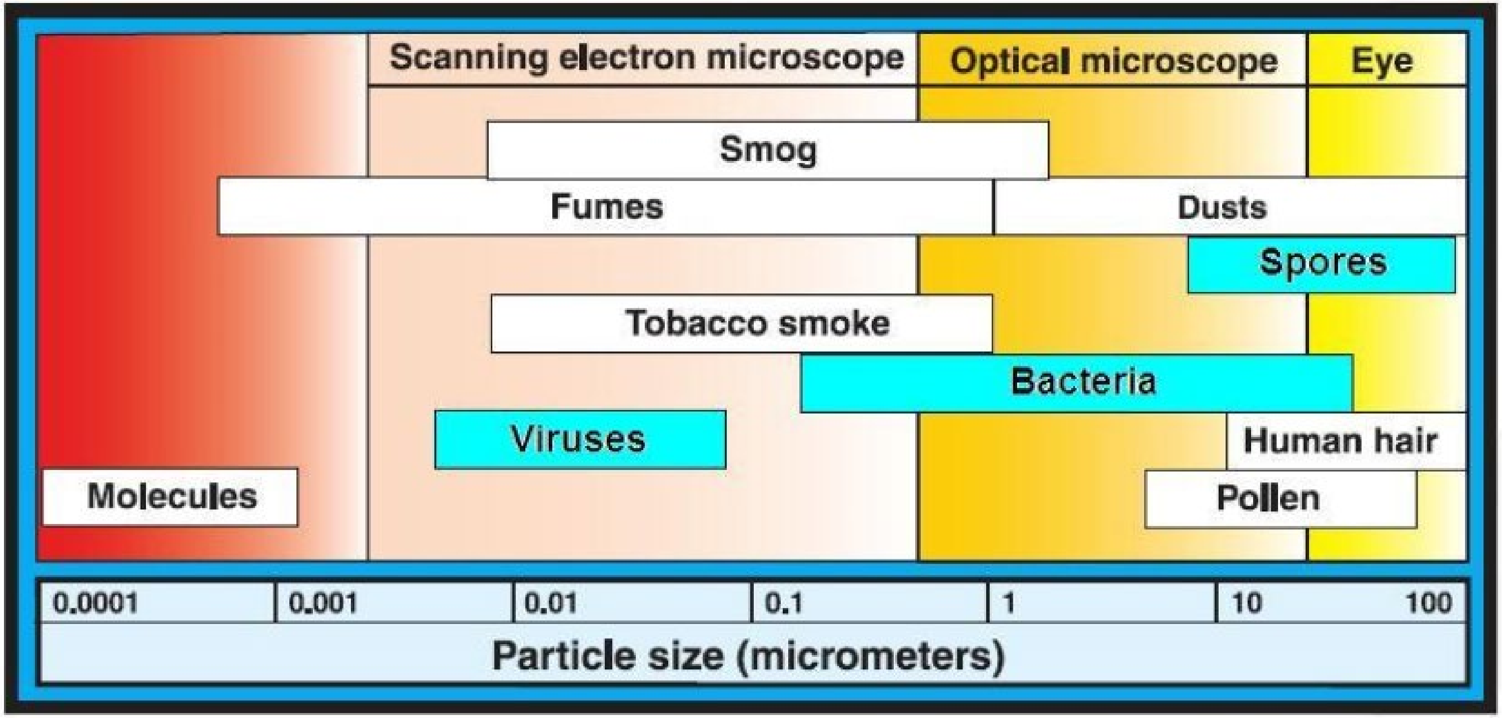
AIR CONTAMINANTS



CONTROL STRATEGIES

- Ventilation and Dilution
- Purging with Outside air
  - Increase Air changes per hour
- Pressurization control; isolation rooms
- Filtration
- Ultraviolet Germicidal Irradiation (UVGI)

RELEVANT INDUSTRY GUIDELINES

GUIDELINES	AGENCY
Guidelines for Environmental Infection Control in Healthcare Facilities	HICPAC
Guidelines for Construction and Equipment of Hospital and Medical Facilities	AIA
HVAC Design Manual for Hospitals and Clinics	ASHRAE
General Requirements: Purpose of the Facilities Standard for Public Buildings Service	GSA
Guidelines for Preventing the Transmission of Mycobacterium Tuberculosis in Health Care Settings	CDC
Environmental Control for Tuberculosis: Upper-Room Ultraviolet Germicidal Irradaition Guidelines for Health Care	NIOSH
Guidelines on the Design and Operation of HVAC Systems in Disease Isolation Areas	CHPPM
Unified Facilities Criterai UFC 4-510-01 design: Medical Military Facilities	UFC 2001

ASHRAE UVGI GUIDELINES AND STDS.

Position Document on Airborne Infectious Diseases
Position Document on Filtration and Air Cleaning
ASHRAE/ASHE Standard 170.1: Ventilation of Health Care Facilities
SYSTEMS and EQUIPMENT HANDBOOK *Chapter 12: Ultraviolet Lamp Systems*
APPLICATIONS HANDBOOK *Chapter 60: Ultraviolet Air and Surface Treatment*
ASHRAE Standard 185.1: Method of Testing UV-C Lights for use in Air Handling Units or Air Ducts to Inactivate Airborne Microorganisms
ASHRAE Standard 185.2: Method of Testing UV-C Lights for use in Air Handling Units or Air Ducts to Inactivate Microorganisms on Irradiated Surfaces
ASHRAE GPC 37: Guideline for the Application of Upper Air (Upper Room) Ultraviolet Germicidal (UV-C) Devices to Control the Transmission of Airborne Microorganisms

APPLICATION OF UVC IN AIR HANDLERS

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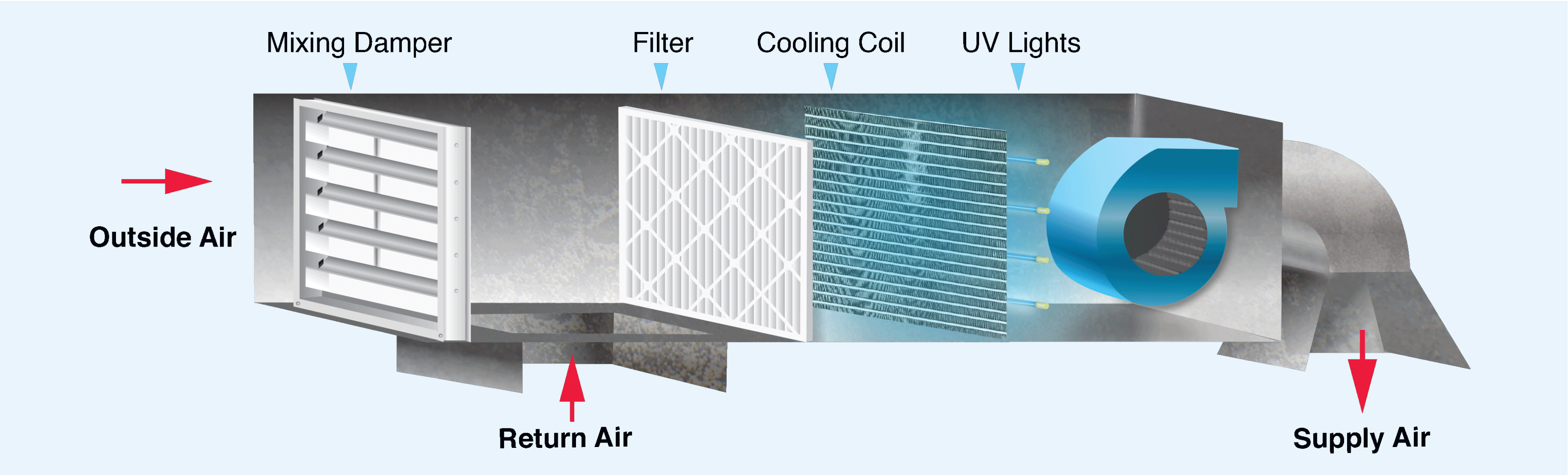
UVGI COIL CLEANING

Coil Cleaning Systems Save Energy and Money!

UV Destroys the Microbiological Biofilm that Thrives in the Moist Coil Environment



UV coil systems are typically installed downstream of the evaporator coil to destroy bacteria, mold and organic matter that grows and collects on cooling coils and surrounding areas.

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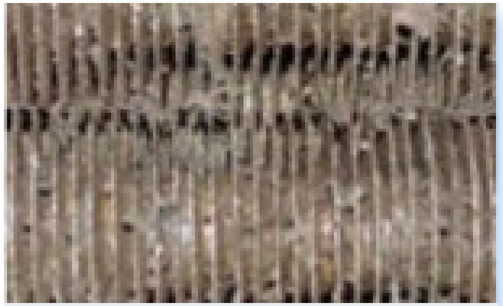
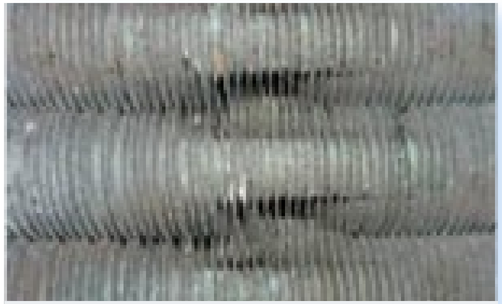
UVGI COIL CLEANING

- UV systems destroy bacteria, mold and organic matter that grows and collects on cooling coils
- **The resulting increase in HVAC cooling capacity and decreased pressure drop results in energy savings of up to 15% in some systems**
- UV is a 24/7 maintenance system that **eliminates** the need for periodic mechanical coil cleaning

Clogged Coil



UV destroys biofilm



Clean Coil after 3 months

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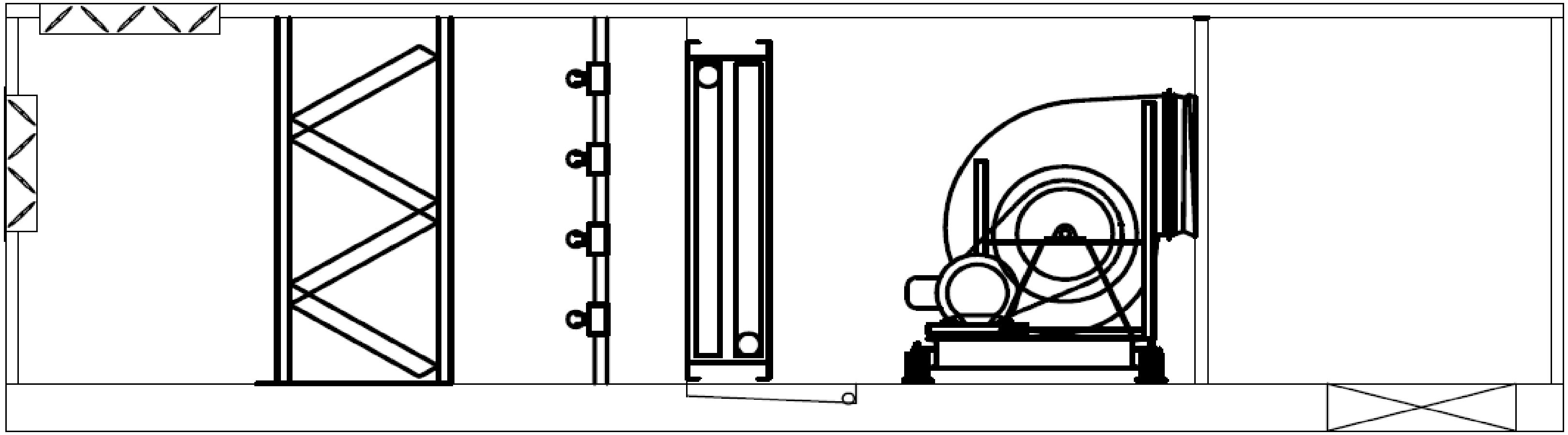
UVGI AIR STREAM DISINFECTION

"Kill on the Fly"

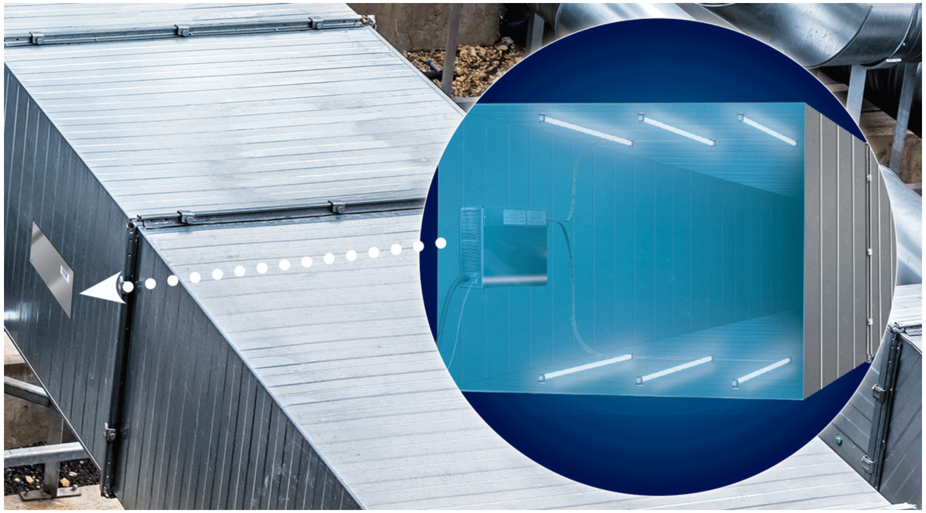
COMMON AIRBORNE MICROORGANISMS

INFLUENZA (COMMON COLD)	TUBERCULOSIS
SARS, HIN1	MEASLES
MERS	CHICKEN POX
MOLD SPORES	LEGIONELLA

UVGI AIR DISINFECTION



AHU Mounted



Duct Mounted

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UVGI UPPER AIR ROOM DISINFECTION

Courtesy: Dr. Richard Vincent Mt. Sinai School of Medicine, NY

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UVGI WHOLE ROOM SURFACE DISINFECTION

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CORRECT APPLICATION OF UVC DOSE

Bacteria

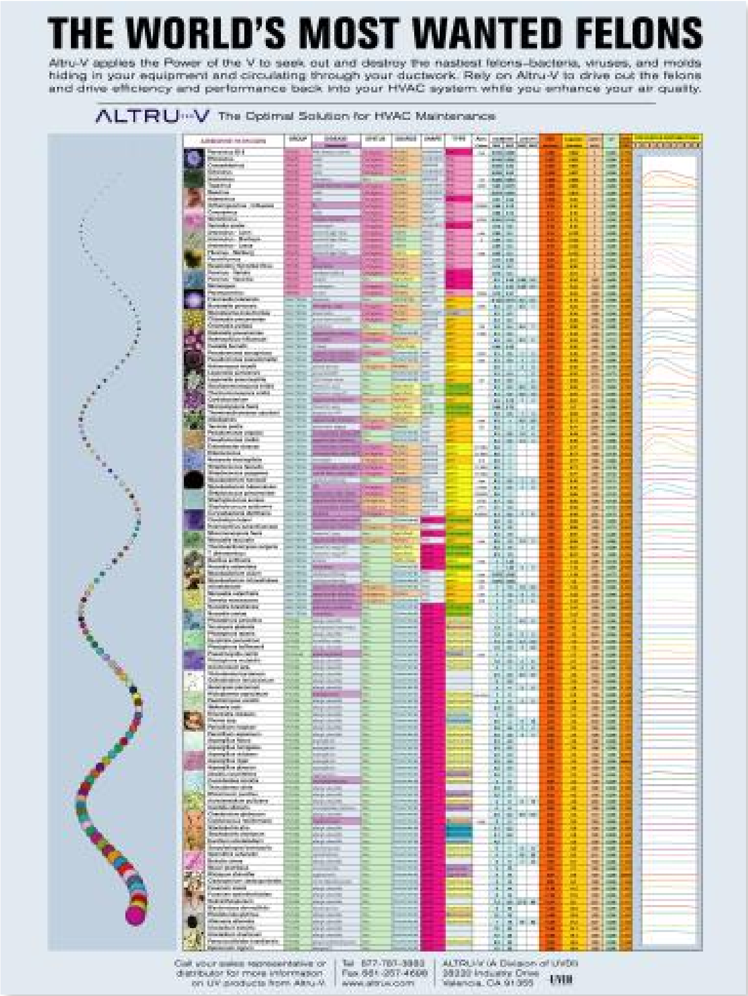
Bacillus anthracis	8,700
Bacillus anthracis spores	46,200
Escherichia coli	6,600
Legionella pneumophila	12,300
Mycobacterium tuberculosis	10,000
Salmonella typhi - Typhoid Fever	7,000
Staphylococus aureus	6,458
Vibrio comma – Cholerae	6,500
Clostridium difficile – C-diff	38,500
Vancomycin-Resistant Enterococci - VRE	12,600

Virus

Infectious Hepatitis	8,000
Influenza A	4,558

Mold

Aspergillus flavus	99,000
Aspergillus niger	330,000



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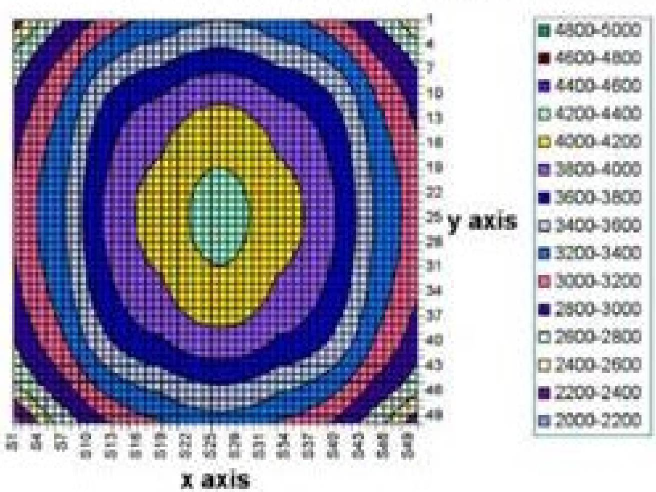
UV DOSE CRITICAL TO SYSTEM EFFICACY

Application Specific! Correct Intensity = Dose per Solution

Coil Disinfection:

- Surface fixed
- Unlimited Time
- **Low UV dose**

Coil Surface Intensity Distribution (μW/cm²)

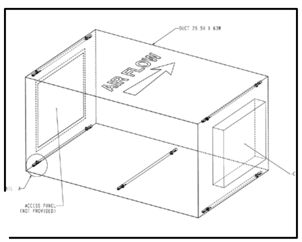


Air Disinfection: High Dose

- Fast moving microbes
- Fractions of seconds
- **High UV Dose**

Target Microbe and Dose for 90% Inactivation		
Microbe	*Influenza A virus*	
Microbe Rate Constant	0.0011870	cm²/μJ
Dose for 90% Kill (D90)	1940	μW/cm²

UV Exposure Dose =	1589	μW/cm²
URV =	12	



Lamp model	V-MAX-33	
Lamp UV power, W	27.00	
Lamp arc length, cm	76.2	
Lamp Diameter, cm	1.58	
Number of Lamps	5	
Total UV Power, W	135	
Duct Width	167.64	cm
	66.00	in
Duct Height	53.340	cm
	21.00	in
Duct Length	101.6	cm
	40.00	in
Airflow	339.802	m³/min
	11999.9	cfm
Velocity	6.3	m/s
	1246.7	fpm
Exposure Time	0.160	sec
Air Temperature	55	F
Reflectivity	57	%

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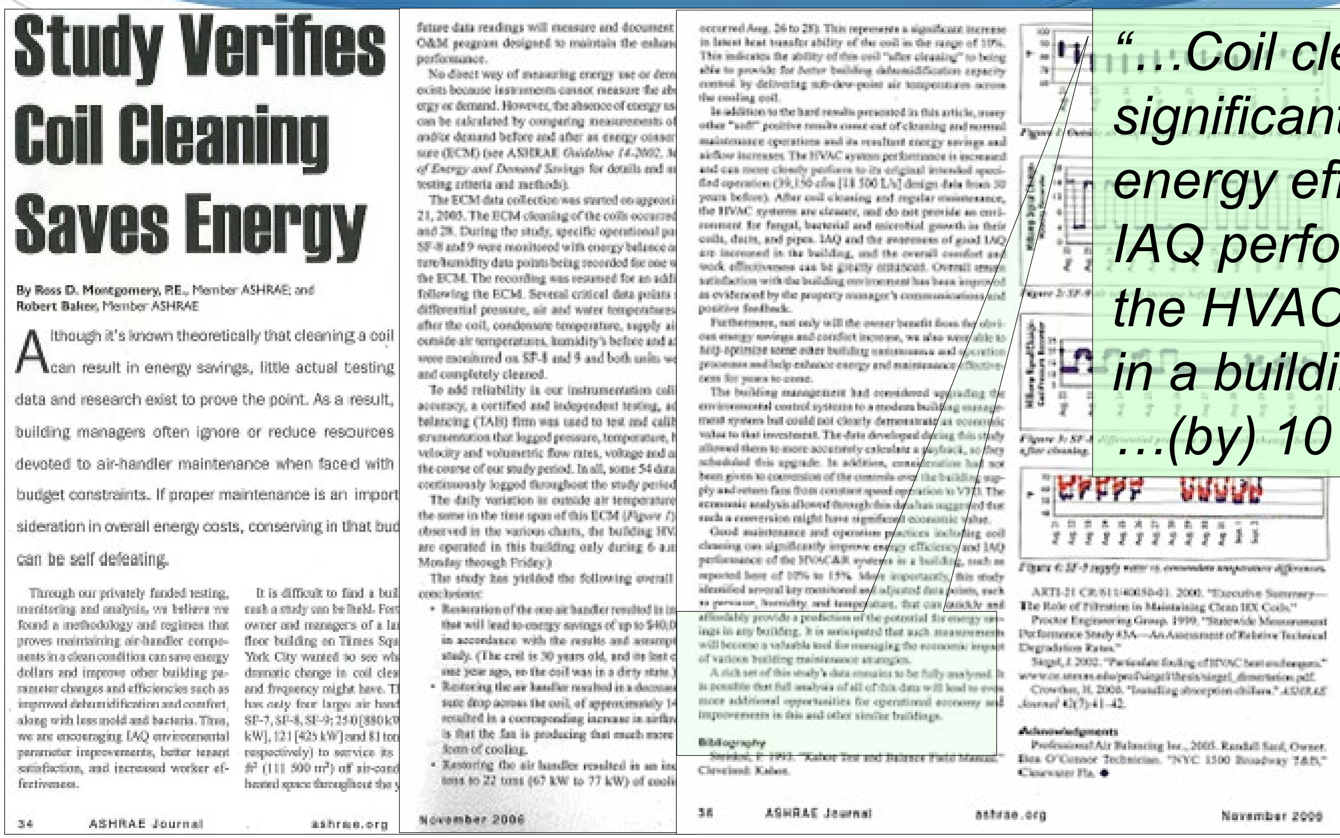
Cooling Coil's Impact On Energy Use

- ASHRAE Journal



Study Verifies Coil Cleaning Saves Energy

By Ross D. Montgomery, P.E., Member ASHRAE; and Robert Baker, Member ASHRAE

Although it's known theoretically that cleaning a coil can result in energy savings, little actual testing data and research exist to prove the point. As a result, building managers often ignore or reduce resources devoted to air-handler maintenance when faced with budget constraints. If proper maintenance is an import[...] sideration in overall energy costs, conserving in that bud[...] can be self defeating.

34 ASHRAE Journal ashrae.org November 2006

36 ASHRAE Journal ashrae.org November 2006

"…Coil cleaning can significantly improve energy efficiency and IAQ performance of the HVAC&R systems in a building …(by) 10 – 15%."

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UVGI COSTS and ENERGY CONSUMPTION

HVAC Systems

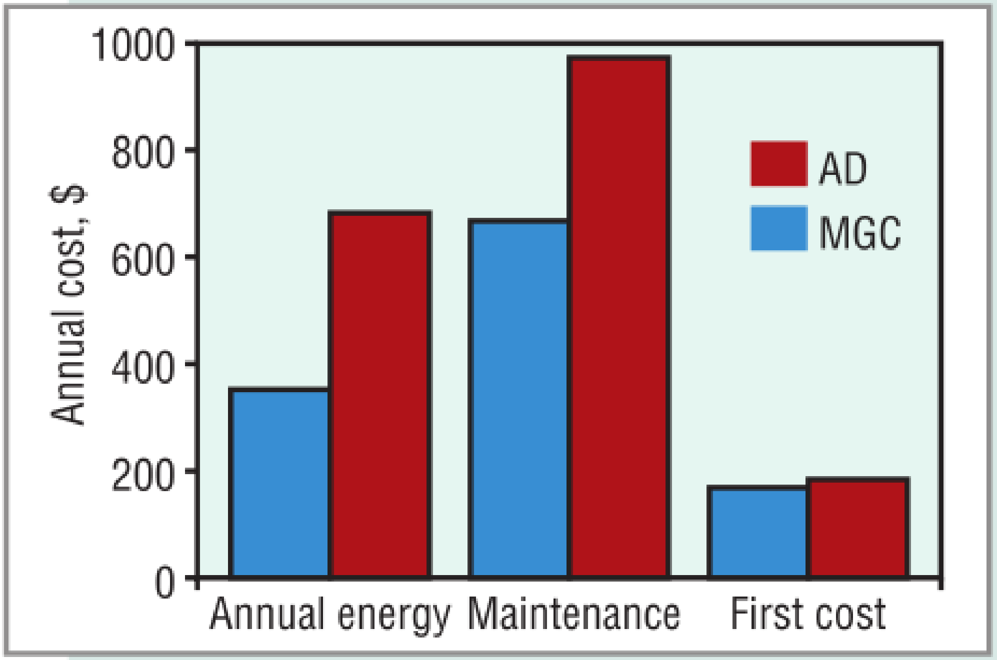

FIGURE 7. A comparison of UVGI air-stream-disinfection (AD) and microbial-growth-control (MGC) systems for a 20-year life cycle.

Economic evaluation of typical UVGI systems

Type of Application	Air-stream disinfection	Microbial-growth control
Design airflow	10,000 cfm	10,000 cfm
Velocity	413 fpm	413 fpm
Predicted disinfection	90 percent *Serratia*	99.99 percent *Aspergillus*
UVGI lamp model	GPH436T5	TUV18W
Number of lamps	2	1
Height	150 cm	150 cm
Width	150 cm	150 cm
Length	150 cm	150 cm
Lamp total power (each)	36 W	18 W
Hours of operation	3744 hr	8760 hr
Energy costs		
Heat generated	0.072 KW	0.018 KW
Cooling load	189 KWH	110 KWH
Total dP (lamps, fixtures, filters)	0.560 in. WG	0.290 in. WG
Total fan energy (80 percent eff.)	8016 KWH	4151 KWH
Electrical energy	270 KWH	158 KWH
Cooling load energy	189 KWH	110 KWH
Total energy	8475 KWH	4419 KWH
Rate	8 cents per KWH	8 cents per KWH
Annual energy cost	$678	$354
Maintenance costs		
Average tube life	9000 hr	9000 hr
Tube hours per year	7488 hr	8760 hr
Replacements per year	0.83	0.97
Cost per tube	$85	$85
Annual cost	$71	$89
Annual filter-replacement cost	$33	$6
Maintenance (assumed)	$200	$200
Annual maintenance cost	$949	$642
First costs		
UVGI system (AU prices)	$765	$550
Labor (estimated)	$1000	$1000
Total installation cost	$1765	$1550
Life cycle	20 years	20 years
Interest rate	8 percent	8 percent
Life cycle cost	$180	$158
Total annual cost	**$1806**	**$1154**

By W.J. KOWALSKI, PE, and
WILLIAM P. BAHNFLETH, PhD, PE,*
Department of Architectural Engineering,
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HPAC ENGINEERING January 2000 • Heating/Piping/AirConditioning

UVGI COSTS and ENERGY CONSUMPTION

HVAC Systems

Annual costs of employing UVGI systems for air stream disinfection is significantly lower than the cost associated with mechanical ventilation controls, such as increasing air changes or purging with more outside air.

Baseline	Upper Air UV	Increased Air Changes (9.2ACH)	UVGI in AHU
$6792	$10847	$10,900	$6675

SYSTEM DESIGN	Baseline System	Upper-Room UVGI	HVAC System with Increased 9.2 ACH	UVGI in AHU
System	AHU - 1	AHU - 1	AHU - 2	AHU - 1
Design Airflow (CFM)	3,900	3,900	8,240	3,900
Velocity (FPM)	520	520	495	520
ACH (Exam & Treatment Rooms)	6	15.2 (Equivalent)	15.2	6
Predicted disinfection in room	99%	99%	99%	99%
Predicted time required for room disinfection	46	18	18	46
Predicted coil disinfection	0%	0%	0%	99.99%
UVGI Fixture Model	-	#WM-136	-	#EXTV-60-1R4
Number of UVGI Fixtures per space	-	2	-	-
Number of Lamps per fixture	-	1	-	4
Nominal Power per Lamp (W)	-	36	-	60
Number of spaces with UVGI fixtures	-	14	-	-
UVGI hours of operation	-	8,760	-	8,760
FIRST COSTS (Installed costs)				
AHU	$11,548	$11,548	$24,867	$11,548
Ductwork	$23,509	$23,509	$35,727	$23,509
Exhaust Fan	$734	$734	$764	$734
UVGI system	$0	$25,018	$0	$1,567
Life cycle	20 years	20 years	20 years	20 years
Interest rate	8%	8%	8%	8%
Annualized first cost[1]	*$3,645*	*$6,193*	*$6,249*	*$3,805*
ENERGY COSTS				
AHU hours of operation	8,760	8,760	8,760	8,760
Total fan energy (KWH)	37,446	37,446	57,888	33,102
Electrical energy - UVGI lamps (KWH)	0	8,830	0	2,102
Total energy (KWH)	37,446	46,276	57,888	35,204
Energy rate ($/KWH)	0.078	0.078	0.078	0.078
Annual energy cost	*$2,921*	*$3,610*	*$4,515*	*$2,746*
MAINTENANCE COSTS				
UVGI replacement lamp cost	-	$25	-	$25
Total UVGI replacement lamp costs	-	$700	-	$100
Lamp replacements per year	-	1	-	1
Labor hours per UVGI lamp replacement	-	0.31	-	0.25
Total labor hours for UVGI lamp replacement	-	8.68	-	1
Labor rate ($/Hr)	-	$23.95	-	$23.95
Total maintenance cost for UVGI	-	$908	-	$124
Chemical costs	$40	$40	$40	-
Chemical cleanings per year	1	1	1	-
Labor hours for chemical cleaning	4	4	4	-
Labor rate ($/Hr)	$23.95	$23.95	$23.95	-
Total maintenance cost for chemical cleaning	$136	$136	$136	-
Annual maintenance cost	*$136*	*$1,044*	*$136*	*$124*
COMPARATIVE ANNUAL COST	**$6,702**	**$10,847**	**$10,900**	**$6,675**

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UVGI Value Proposition versus Mechanical Air Cleaning

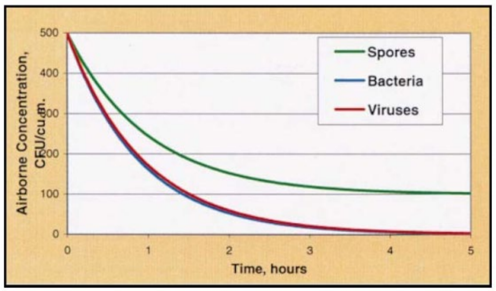

Figure 4.6 Outside Air Effectiveness

(W. J. Kowalski, 1997)

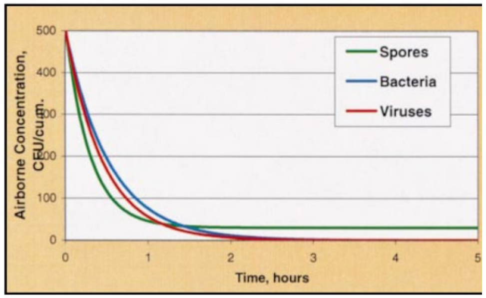

Figure 4.7 MERV 13 Filter Effectiveness

(W. J. Kowalski, 1997)

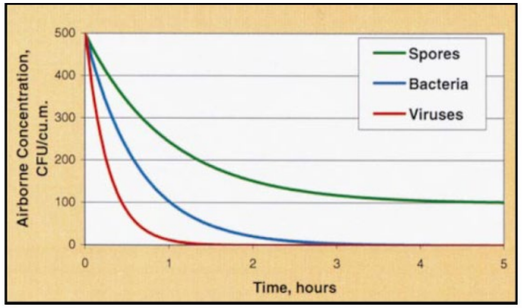

Figure 4.8 UVGI Effectiveness

(W. J. Kowalski, 1997)

The combination of UV and Merv 13-15 filters may be able to provide a performance equivalent to HEPA filtration thus reducing energy costs. Energy savings are due to the fact that the fan energy required to overcome static pressure loss of the HEPA filters is far greater than the energy consumed by UVGI lamps.

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ENERGY CONSUMPTION: WHOLE ROOM DISINFECTION DEVICES

- Limited by current availability in room
    - 15 Amp typical
- Not continuously on

Low Energy consumption, relatively

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HEALTHCARE ASSOCIATED INFECTIONS COST IMPACT

- CDC estimates 1.7 million HAI infections per year
  - Almost 100,000 deaths annually caused by HAIs
  - Estimated cost of $30+ billion
- HAI hospital length of stay is increased 5 + days
- Range of cost for a single HAI:

C. diff:	$6,408 - $9,124
SSI (often MRSA):	$11,874 - $34,670

Source: CDC

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Thank You

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