Odor Control
Oxidation and Activated Carbon

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ENGINEERED AIR®

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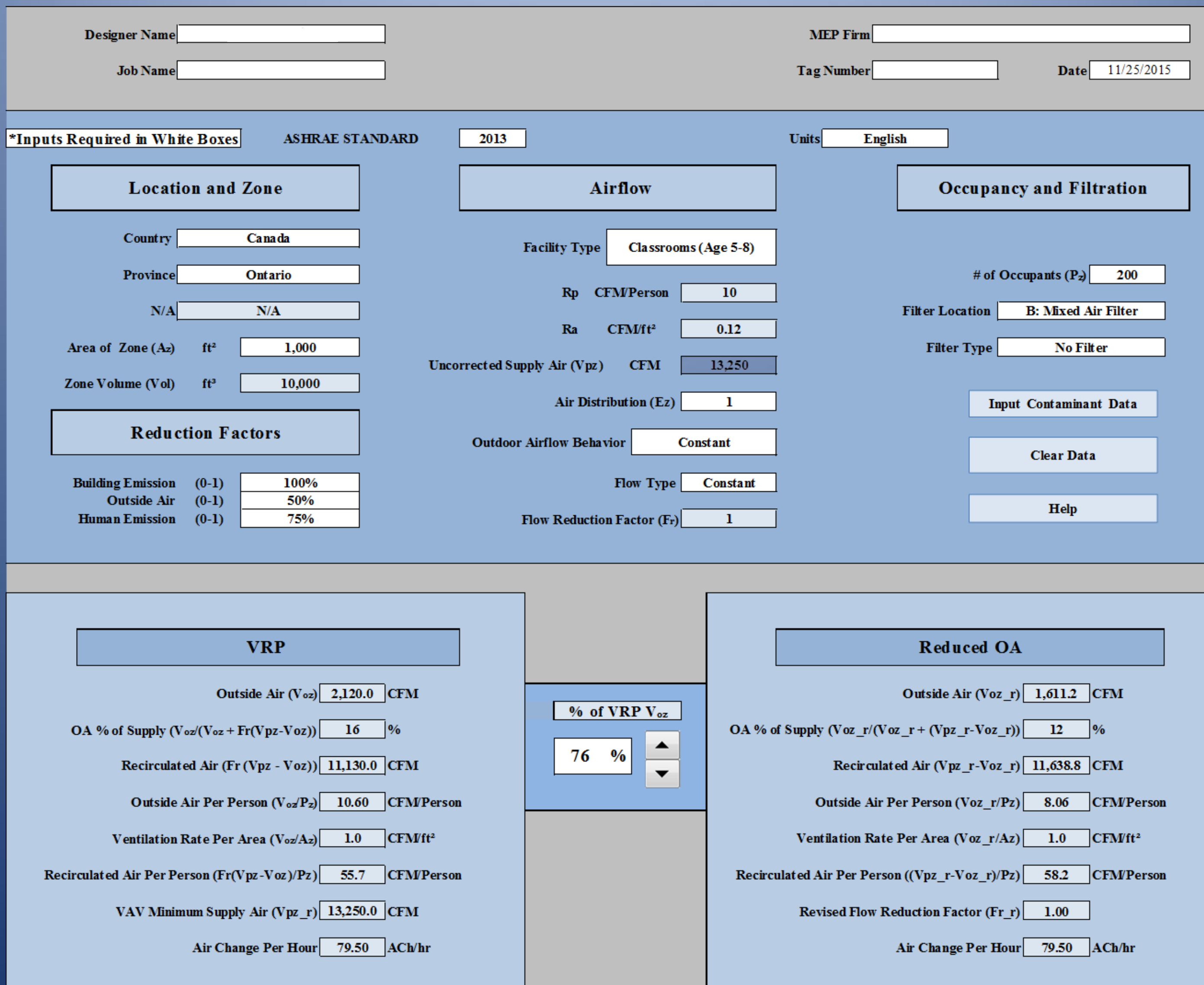
Contaminant Calculator

- The University of Kansas Mechanical Engineering Department has developed a calculator using ASHRAE 62.1 standards and guidelines



Designer Name:
MEP Firm:
Job Name:
Tag Number:
Date: 11/25/2015

*Inputs Required in White Boxes | ASHRAE STANDARD: 2013 | Units: English

Location and Zone

Country		Canada
Province		Ontario
N/A		N/A
Area of Zone (A_z)	ft²	1,000
Zone Volume (Vol)	ft³	10,000

Reduction Factors

Building Emission	(0-1)	100%
Outside Air	(0-1)	50%
Human Emission	(0-1)	75%

Airflow

Facility Type		Classrooms (Age 5-8)
Rp	CFM/Person	10
Ra	CFM/ft²	0.12
Uncorrected Supply Air (Vpz)	CFM	13,250
Air Distribution (Ez)		1
Outdoor Airflow Behavior		Constant
Flow Type		Constant
Flow Reduction Factor (F_r)		1

Occupancy and Filtration

# of Occupants (P_z)	200
Filter Location	B: Mixed Air Filter
Filter Type	No Filter

Input Contaminant Data

Clear Data

Help

VRP

Outside Air (V_{oz})	2,120.0	CFM
OA % of Supply (V_{oz}/(V_{oz} + Fr(Vpz-Voz))	16	%
Recirculated Air (Fr (Vpz - Voz))	11,130.0	CFM
Outside Air Per Person (V_{oz}/P_z)	10.60	CFM/Person
Ventilation Rate Per Area (V_{oz}/A_z)	1.0	CFM/ft²
Recirculated Air Per Person (Fr(Vpz-Voz)/Pz)	55.7	CFM/Person
VAV Minimum Supply Air (Vpz_r)	13,250.0	CFM
Air Change Per Hour	79.50	ACh/hr

% of VRP V_{oz}: 76 %

Reduced OA

Outside Air (Voz_r)	1,611.2	CFM
OA % of Supply (Voz_r/(Voz_r + (Vpz_r-Voz_r))	12	%
Recirculated Air (Vpz_r-Voz_r)	11,638.8	CFM
Outside Air Per Person (Voz_r/Pz)	8.06	CFM/Person
Ventilation Rate Per Area (Voz_r/Az)	1.0	CFM/ft²
Recirculated Air Per Person ((Vpz_r-Voz_r)/Pz)	58.2	CFM/Person
Revised Flow Reduction Factor (Fr_r)	1.00	
Air Change Per Hour	79.50	ACh/hr

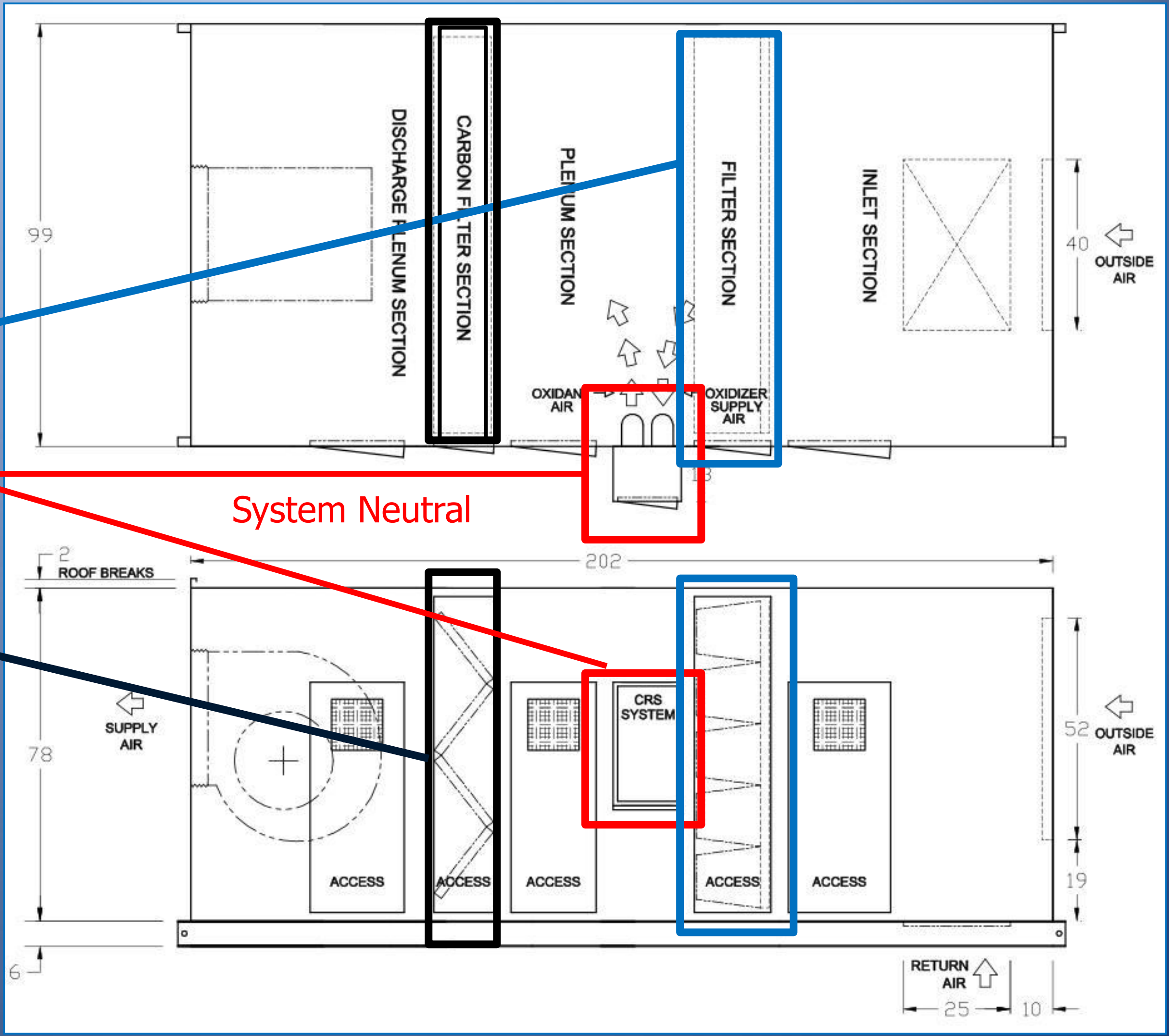
Contaminant	Building Emission	Outdoor Air Concentration	Human Emission	OSHA PEL	NIOSH REL	ACGIH TLV	Health Canada	Conc. Using VRP	Conc. Using Reduced OA
	ppm	ppm	ppm	ppm Off	ppm Off	ppm Off	ppm On	ppm	ppm
1,1,1 - Trichloroethane	0	0	6.7008E-05	100		50		0.0004188	0.0005511
1,1,2,2 Tetrachloroethane	0	0.00016	1.77517E-06	5	1	1		0.0001711	0.0001746
1,2 Dichloroethlene	0.0000206	0	0	50	1	10		0.0000206	2.711E-05
1,3,5 Trimethylbenzene	0	0.000083	0	25	25	25		0.000083	0.000083
1,4 Dichlorobenzene	0.076	0	0	75	150	10		0.076	0.1
2-Propanol			0	N/E	100	100		0	0
4-ethyltoluene		0.00011	0					0.00011	0.00011
2-Butanone (MEK)	0	0.00048	0.028629217	200	200	200		0.1794126	0.2359176
Acetaldehyde	0.044	0.0019	0.000169105	200	200	200		0.0469569	0.0611854
Acrolein			0	0.1	0.1			0	0
Acrylonitrile			0	40	40	20	20	0	0
Acetone (propane)	0	0.0036	0.001740605	1000	1000	500	500	0.0144788	0.0179142
Ammonia	0	0	0.194947504	50	25	25	50	1.2184219	1.6031867
Benzene	0.0056	0.00094	4.3596E-05	1	0.1	0.5	0.5	0.0068125	0.0086669
Carbon Dioxide	0	500	154.7504212	5000	5000	5000	3500	1467.1901	1772.6186
Carbon Disulfide	0.114	0	0	20	1	10		0.114	0.15
Carbon Monoxide	0	2	0.075983645	50	35	25	11	2.4748978	2.6248655
Carbon Tetrachloride	0.0036	0	0	10	2	5	5	0.0036	0.0047368
Chloroform	0.035	0	5.34839E-06	50	50	10	10	0.0350334	0.0460966
Chorobenzene	0.113	0	0	75	75			0.113	0.1486842
Dichloromethane	0	0.0014	0	25		50	50	0.0014	0.0014
Dioxane	0.23	0	9.66202E-07	100	100			0.230006	0.3026395
Ethanol	0	0.017	0	1000	1000	1000	1000	0.017	0.017
Ethyl acetate	0	0	0	400	400			0	0
Ethyl benzene	0.26	0.00021	0	100	100			0.26021	0.3423153
Formaldehyde	0	0.0032	0	0.5	0.5	0.3	0.3	0.0032	0.0032
Hexane	0.57	0.00048	0	500	500	50	50	0.57048	0.75048
Hexanol	0	0.00016	0	50	50	50		0.00016	0.00016
Hydrogen sulfide	0	0	9.36753E-05	20	10	1		0.0005855	0.0007704
Methane	0	0	0.022689503			1000		0.1418094	0.1865913
Methanol	0	0	3.98558E-05	200	200	200		0.0002491	0.0003278
Methylene Chloride	0.065	0	0.000220523	25		50		0.0663783	0.0873398
Naphthalene	0.000936	0	0	10	10			0.000936	0.0012316
Nitrogen dioxide	0	0.015	0	5	1	3	0.05	0.015	0.015
Nonane	0	0.00011	0		200	200		0.00011	0.00011
Octane	0	0.000094	0	500	75	300	300	0.000094	0.000094

CRS Installation

MERV 11 Filter section

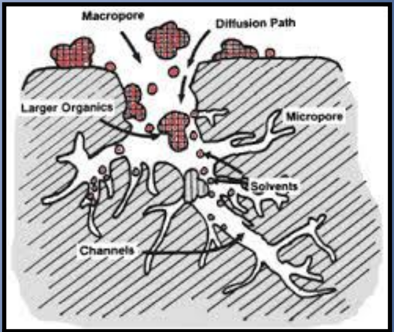
Carbon Regeneration System (CRS)

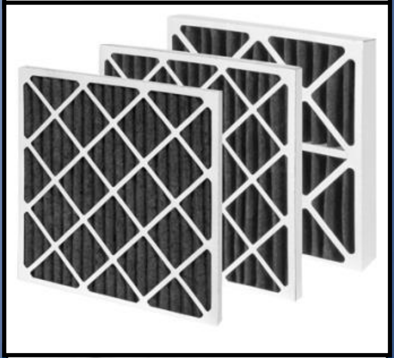
Carbon filter section



Activated Carbon

- *Adsorption properties collect molecular size contaminant*
- *holding capacity and removal efficiency*
- *Activated carbon vs. impregnated carbon*
- *Common types and configuration of activated carbon*



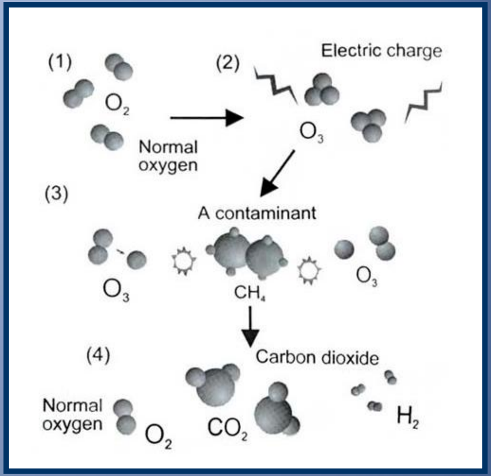


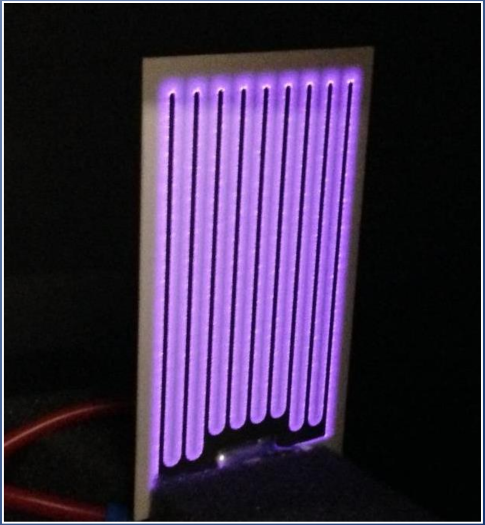
The Oxidation Process

- Energized air molecules are highly reactive.
- Reactive Oxygen Species (ROS) or oxidants are commonly known as:

Mono oxygen	O+ O-
Ozone	O_3
Hydroxyl radicals	•OH

- ROS quickly react with odorous compounds by breaking apart their molecular bonds
- ROS / oxidants are created using corona discharge from our oxidizer generator head

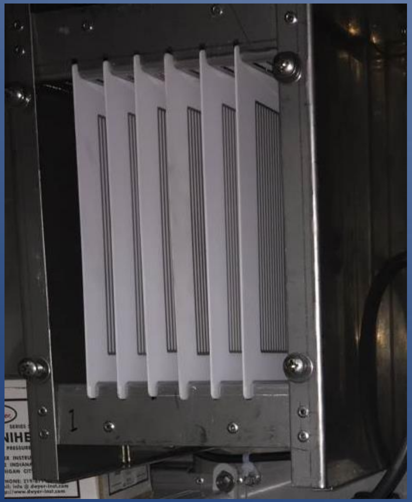


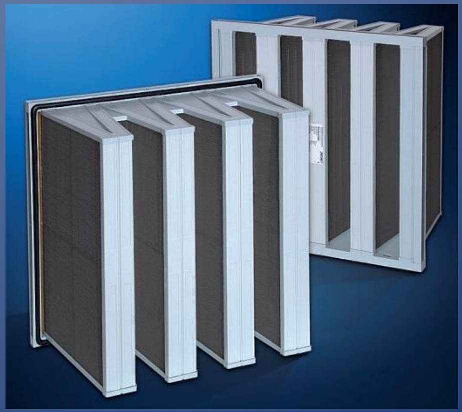


Combining Technologies: Oxidation and Activated Carbon

- *Oxidation: clean, efficient, low energy consumption, effective on a wide range of contaminants and very low maintenance. BUT oxidation reacts slowly to surges in contaminant levels and some engineers are reluctant to use oxidation.*

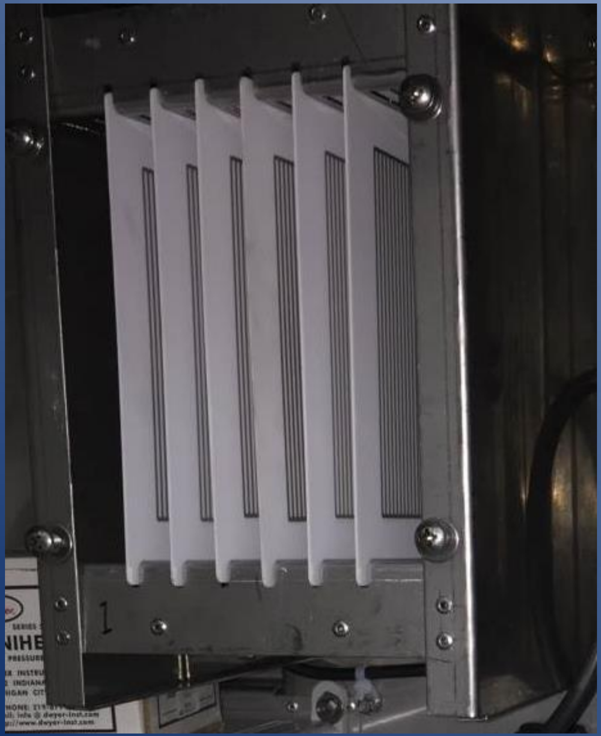
- *Activated Carbon: deals with variable levels of contaminants and flexible in terms of knowing the exact amount of contaminant. BUT it is messy, expensive to install and maintain, hard to dispose of and may require up to 1.5 " w.g.*





Combining Technologies

- *Extend the Activated Carbon change frequency*
- *Reduce the amount of AC required*
- *Reducing static pressure and energy consumption*
- *Remove broader range of Contaminant Doesn’t require Doesn’t require additional space.*

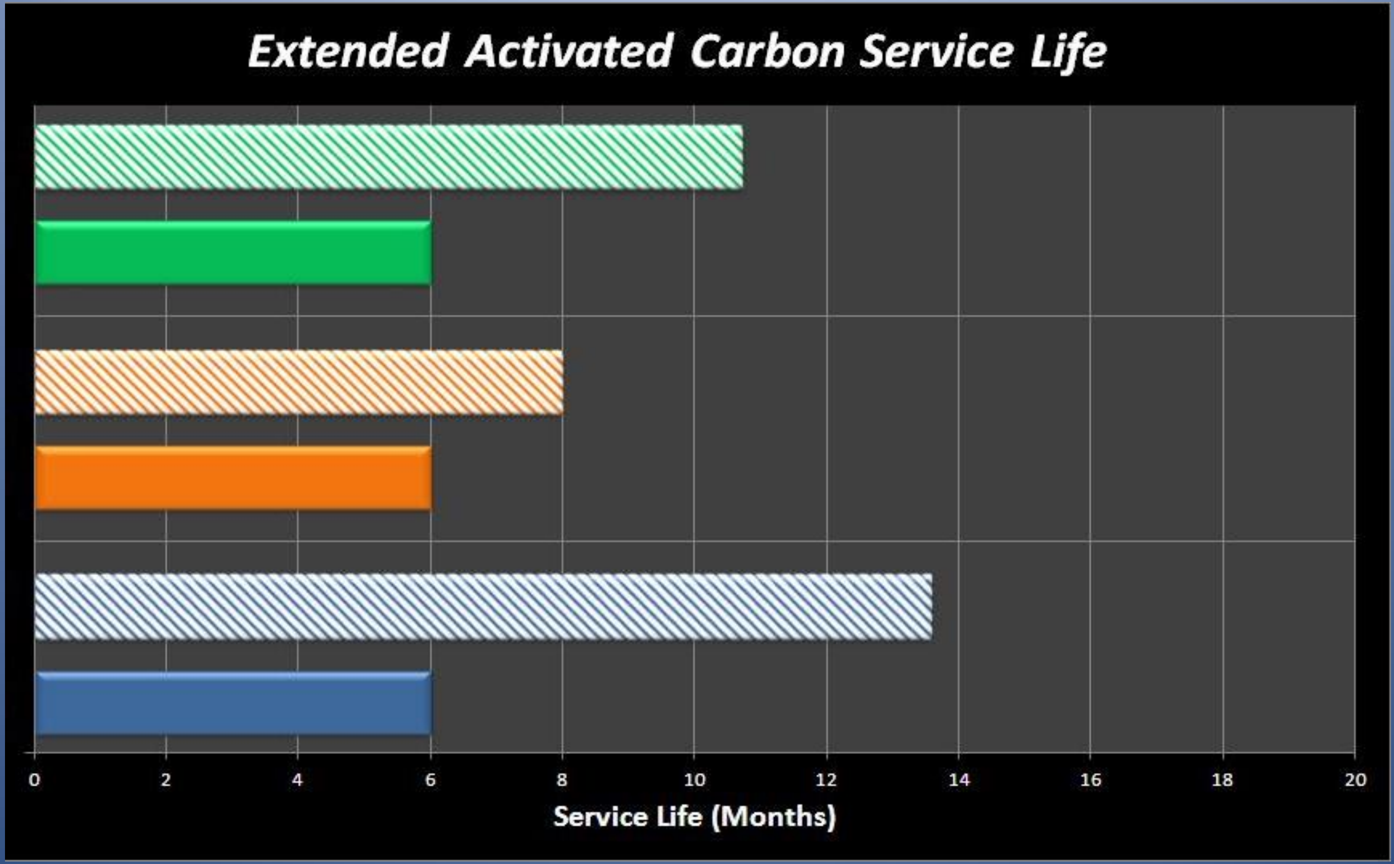


Test Results

Acetone

Diesel Exhaust

Isopropyl Alcohol



Note: test results from 3rd party laboratory.
striped bars with oxidant, solid bars without oxidant

The Carbon Calculator

"A tool to accurately calculate the life cycle and cost benefits associated to using activated carbon with oxidation when removing Gas-phase contaminant"

Design calculations

Activated Carbon Regeneration Calculator

Designer Name	MEP Firm
Matt Pfeiffer	EXP.

Project Name	Tag Number
O'Hare Airport	Existing units (31)

Activated Carbon Input

Total Air Volume (CFM)	837000
Total Number of Units	31
Carbon Volume (lbs./1000cfm)	50
Change Frequency (months)	4
Carbon Efficiency	0.16
Load Factor	0.95

Contamination Calculations

Contaminant from Building Emissions, people, O/A (grams/period)	1,300,442
Airport Application Contaminant (gram/period)	1,584,948
Total Contaminant (gram/period)	2,885,389

Input information

How many cfm per AHU?

How many AHU?

How many pounds are they using per 1000 cfm?

Number of carbon filter changes

What Carbon is specified or currently being used? Efficiency by weight

% of Activated Carbon spent at change out

Contaminant calculations

Sources of Contamination

Contaminant volumes calculated from each source

Carbon life calculations

Contaminant Concentrations Table

	Building Emissions/People/Outside Air			Airport Application Contribution			
Contaminant	ppm	g/hr.	g/period	ppm	g/hr.	g/period	Total Contaminant
1,1,1 - Trichloroethane	0.0003	0.26	755.29	0	0.00	0.00	755.29
1,1,2,2 Tetrachloroethane	0.0002	0.16	474.76	0	0.00	0.00	474.76
1,2 Dichloroethlene	0.0000	0.01	34.13	0	0.00	0.00	34.13
1,3 Butadiene	0.0000	0.00	0.00	0.014703025	46.23	133,135.61	133,135.61
1,3,5 Trimethylbenzene	0.0001	0.06	167.00	0	0.00	0.00	167.00
1,4 Dichlorobenzene	0.0760	64.94	187,025.77	0	0.00	0.00	187,025.77
2-Butanone (MEK)	0.1450	60.77	175,014.73	0	0.00	0.00	175,014.73
Acetaldehyde	0.0468	11.97	34,477.10	0.00601806	15.41	44,378.54	78,855.64
Acrolein	0.0000	0.00	0.00	0.002702161	8.81	25,359.16	25,359.16
Acetone (propane)	0.0124	4.18	12,042.19	0	0.00	0.00	12,042.19
Ammonia	0.9840	97.41	280,535.11	0	0.00	0.00	280,535.11
Benzene	0.0068	3.07	8,839.48	0.013575499	61.64	177,514.14	186,353.62
Carbon Disulfide	0.1140	50.45	145,307.58	0	0.00	0.00	145,307.58
Carbon Tetrachloride	0.0036	3.22	9,270.13	0	0.00	0.00	9,270.13
Chloroform	0.0350	24.31	70,001.12	0	0.00	0.00	70,001.12
Chlorobenzene	0.1130	73.93	212,928.14	0	0.00	0.00	212,928.14
Dichloromethane	0.0014	0.69	1,990.49	0	0.00	0.00	1,990.49
Dioxane	0.2300	117.80	339,260.09	0	0.00	0.00	339,260.09
Ethanol	0.0170	4.55	13,111.06	0	0.00	0.00	13,111.06
Ethyl benzene	0.2602	160.58	462,483.60	0	0.00	0.00	462,483.60
Formaldehyde	0.0032	0.56	1,608.76	0.212172784	370.37	1,066,669.81	1,068,278.56
Hexane	0.5705	285.78	823,033.38	0	0.00	0.00	823,033.38
Hydrogen sulfide	0.0005	0.09	269.75	0	0.00	0.00	269.75
Methane	0.1145	10.68	30,750.96	0	0.00	0.00	30,750.96
Methanol	0.0002	0.04	107.90	0	0.00	0.00	107.90
Methylene Chloride	0.0661	32.64	93,998.05	0	0.00	0.00	93,998.05
Naphthalene	0.0009	0.70	2,008.32	0	0.00	0.00	2,008.32
Nitrogen dioxide	0.0150	4.01	11,551.00	0	0.00	0.00	11,551.00
Nonane	0.0001	0.08	236.08	0	0.00	0.00	236.08
Octane	0.0001	0.06	179.75	0	0.00	0.00	179.75
Phenol	0.0304	16.64	47,925.37	0	0.00	0.00	47,925.37
Propane	0.0000	0.01	23.38	0	0.00	0.00	23.38
Styrene	0.1201	72.70	209,384.19	0.001545376	9.36	26,944.11	236,328.30
Tetrachloroethylene	0.0030	2.90	8,346.25	0	0.00	0.00	8,346.25
Toluene	0.0467	24.99	71,984.55	0.004315643	23.11	66,567.80	138,552.35
Trichloroethylene	0.0640	48.88	140,781.59	0	0.00	0.00	140,781.59
Vinyl Chloride Monomer	0.0000	0.00	7.19	0	0.00	0.00	7.19
Xylene	0.0003	0.17	497.66	0.002497132	15.41	44,378.54	44,876.20
Total	2.9673	1,128.86	1,300,442	0.26	550.33	1,584,948	2,885,389

Current Replacement 4.0 months | Proposed Replacement 7.1 months

Cost Calculations

Cost Calculations			
Current Activated Carbon Replacement	837,000 cfm (31 units)	Cost per Change	Annual Cost
	Activated Carbon	$167,400.00	$502,200.00
	Labor	$27,900.00	$83,700.00
	Freight	$12,555.00	$37,665.00
	Disposal	$5,022.00	$15,066.00
		$212,877.00	$638,631.00

Note:
41,850 lbs at $4.00/ lbs
41,850 lbs of AC based on 50lbs/1000cfm
transport to and from site 42,000 pounds @ .30 cents/lbs
landfill cost @ .12/lbs

Proposed Oxidation System		(Cost/Change x 1.7)	New Annual Cost
Oxidation equipment	$267,950.00	Activated Carbon	$284,580.00
Monitoring equipment	$119,350.00	Labor	$47,430.00
Installation	$93,000.00	Freight	$21,343.00
		Power Consumption	$18,144.00
		Disposal	$8,537.00
Total Cost	$480,300.00		$380,034.00

Annual Savings $258,597 Payback 1.85 years

CRS Applications

- *Airports*
- *Data centers*
- *Micro electronic manufacturing*
- *Veterinarian facilities*
- *Live stock barns*
- *Restaurants*
- *Hospitals*
- *Laboratories*
- *Long term health care*
- *Food processing*
- *Casinos*
- *RMGO's*
- *Museums*

Summary

- *ROS Oxidizes contaminant in activated carbon media.*
- *Potentially reduce the amount of activated carbon required thus reduces energy cost by lowering static pressure.*
- *ROS/Oxidant (ozone)is eliminated by the activated Carbon media*

Supporting Technical Papers

Alvarez, P.M., Beltran F.J., Gomez-Serrano, V., Jaramillo, J., Rodriguez, E.M. "Comparison between thermal and ozone renenerations of spent activated carbon exhausted with phenol." *Water Research*. Volume 38, Issue 8, April 2004, Pages 2155-2165. http://www.sciencedirect.com/science/article/pii/S00431354040.

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Cannon, Fred S., Dusenbury, James S., Paulsen, Paul D., Singh, Jyoti, Mazyck, David W., Maurer, David J. "Advanced oxidant regeneration of granular activated carbon for controlling air-phase VOCs." *Ozone: Science & Engineering: The Journal of the International Ozone Association.* Volume 18, Issue 5, 1996. http://www.tandfonline.com/doi/abs/10.1080/01919512.1996.1.

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