Multifamily Ventilation 302

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Course Description

Central ventilation systems in multifamily buildings are a vital building system that often compromises overall building performance. Correcting ventilation problems can produce significant energy savings in multifamily buildings while also improving occupant comfort and health.

Central ventilation system restoration is an emerging energy retrofit that has had its bumps along the way.

This session explores the lessons learned from projects that encountered a variety of design and implementation problems along the way, but ultimately achieved good performance results.

Learning Objectives

At the end of the this course, participants will be able to:

1. Understand how to evaluate existing conditions and identify good candidates for this retrofit
2. Develop a reliable, flexible design approach to help control cost overruns and minimize change orders
3. Control implementation of the work to optimize system performance and minimize occupant inconvenience
4. Commission these systems to quantify the improvement benefits

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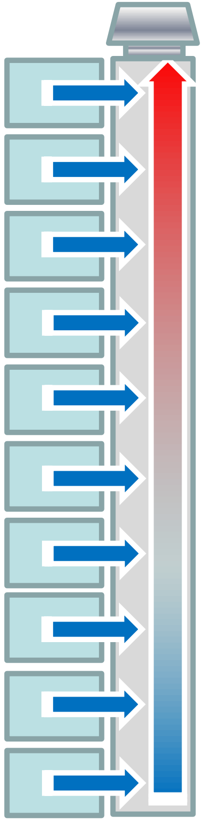
What We Expect

The central ventilation system takes stale air from the “apartment space” into the “duct space” and expels it from the building.

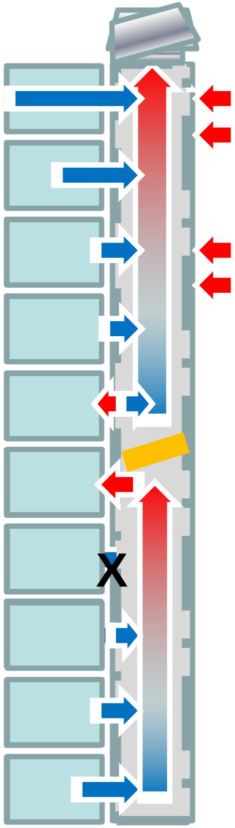
- Fan on the roof draws air from the riser
- Exhausted air is drawn up the risers to the fan
- Vents in the apartments pull air to the risers
- Fresh air replaces stale air

But…



What We Find

- The fan is switched off, broken, missing its belt or otherwise not functioning properly
- The riser has gaps and holes that compete with the vents or sometimes the “duct” is missing altogether
- Air flows at the vents vary wildly, sometimes flowing *into* the apartments or changing direction with the wind
- Shaft blockages or accumulated leaks prevent lower floors from removing any air at all or send it into apartments above
- Occupants block up their vents or neglect them to the point where no flow can get through.



Identify Good Candidates

- What is the PRIMARY goal of the project?
  - ✓ Reducing energy costs?
  - ✓ Constructing a system that *actually works effectively*?
- How is the system currently operating?
- What are the complaints & known problems?
- How will we repair the system's weaknesses?
  - ✓ What *can* we do from the roof or common areas?
  - ✓ What *must* we do from inside the apartments?
  - ✓ What *can't* we really expect to accomplish here?

Identify Good Candidates

- How committed is the building?
  - ✓ Who is driving this project?
    - Owner subsidizing building upgrades?
    - Resident complaints?
  - ✓ What does building management think?
- What else is happening in the building?
  - ✓ Lots of upgrades can breed “Project Fatigue”
  - ✓ How will the work be coordinated?

What Are the Opportunities?

- Improve Energy Performance
  - ✓ Reduce heating and cooling loads by reducing the volume of air expelled from the building
  - ✓ Reduce the total kWh to operate the roof fans
- Improve *Building* Performance
  - ✓ Provide ~~code-compliant~~ effective ventilation to occupants
  - ✓ Improve indoor air quality, reduce odors in apartments
  - ✓ Reduce odor transfer among apartments
  - ✓ Reduce risk of smoke transfer in the event of a fire

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  - ✓ Reduce risk of smoke transfer in the event of fire

Reducing Ventilation Rates

Buildings built before 2008 have higher ventilation rates

	Kitchens	Bathrooms
Pre-2008 NYC Building Code	100 CFM	50 CFM
2008 NYC Adopted IBC/ IMC	25 CFM	20 CFM

Net Reduction for *Continuous* Ventilation	(75 CFM)	(25 CFM)

Reducing Ventilation Rates

*Note – These savings estimates are for "post production" energy that **doesn't** include system losses (boiler/ chiller efficiency, condensate temps, etc.)*

Good Energy Candidates

- ✓ Building Heating System is…
  - Oil - $2.99/ gallon = *$3.25 **PER YEAR** / CFM reduced*
  - District Steam - $38.50/MLB = *$5.00 **PER YEAR** / CFM reduced*
  - Electricity - $0.26/ kWh = *$11.50 **PER YEAR** / CFM reduced*
  - ~ Natural Gas - $0.49/ Therm = *$0.80 **PER YEAR** / CFM reduced*
- ✓ Summer Cooling adds an extra 20% savings (by fuel type)
  - Buildings with chillers or with common area central AC
  - Buildings with PTAC units
  - Depending on fuels, cooling may offer the ***greater*** cost savings!

Reducing Ventilation Rates

ANNUAL Savings Opportunity *Per Apartment…*

	Kitchens	Bathrooms
Natural Gas @ $0.49/ Therm	$60	$24
#2 Heating Oil @ $2.99/ Gal.	$244	$98
District Steam @ $38.50/ MLB	$375	$150
Electricity @ $0.26/ kWh	$863	$338

What Are the Opportunities?

- Improve Energy Performance
  - ✓ Reduce heating and cooling loads by reducing the volume of air expelled from the building
  - ✓ Reduce the total kWh to operate the roof fans
- Improve *Building* Performance
  - ✓ Provide ~~code-compliant~~ effective ventilation to occupants
  - ✓ Better balance building pressures to reduce odor transfer among apartments
  - ✓ Reduce risk of smoke transfer in the event of fire

Improve Building Performance

TABLE 403.3-continued
MINIMUM VENTILATION RATES

OCCUPANCY CLASSIFICATION	PEOPLE OUTDOOR AIRFLOW RATE IN BREATHING ZONE CFM/PERSON	AREA OUTDOOR AIRFLOW RATE IN BREATHING ZONE R_a CFM/FT[2a]	DEFAULT OCCUPANT DENSITY #/1000 FT[2 a]	EXHAUST AIRFLOW RATE CFM/FT[2a]
Private dwellings, single and multiple				
Garages, common for multiple units[b]	-	-	-	0.75
h dwelling[b]	-	-	-	100 cfm per car
Kitchens[b]	-	-	-	25/100[f]
[illegible]	0.35 ACH but not less than 15 cfmlperson	-	Based upon numbe bedrooms. Firs bedroom, 2; each additional bedroom, 1	
Toilet rooms and bathrooms[g]			-	20/50 f

Note that these are ***minimums*** for ***continuous** ventilation* for *every apartment*, even the ones on the *lowest floors*…

Source: 2009 IMC

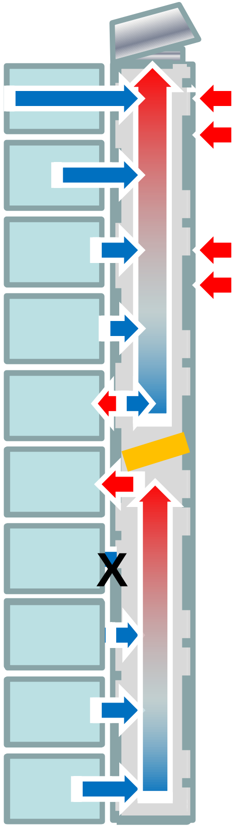
Improve Building Performance

- “Energy Performance” VS “Building Performance”
  - ✓ What costs are attributable to the EIM?
  - ✓ What costs are attributable to CODE COMPLIANCE?
- Design a ***necessary*** project that does BOTH
  - ✓ Start with what it will take to make the system ***work***
  - ✓ Refine to make it work ***efficiently***
- Making it ***efficient*** helps ***making it work*** affordable

Reducing Ventilation Rates

But WAIT - the vents ***already*** DON'T WORK!!

- Fixing the vents is a "good thing", but…
  - ✓ No vent flow means no energy lost, right?
  - ✓ What about what's *behind the walls?*
- When *is* the energy lost?
  - ✓ When it leaves ***the building***
- Fixing the *VENTS* means fixing the *SYSTEM*
- *Start with the FANS*



Reducing Ventilation Rates

VENTILATION RISER DIAGRAM.

ALL RISERS TO BE SHEETMETAL

EXHAUST FAN SCHEDULE.

E.F. No.	AREA SERVED	MODEL No	CFM.	S.P. "H_2O	H.P.	T.S.	RPM.	WHEEL DIA.	ELECTRIC DATA	R.O. SIZE.	CURB I. DIM.	REMARKS:
1	Toilet Exh.	Greenheck CBE-10-4	600	3/8"	1/4	3515	1310	—	120/1/60			6 Fans Required.
2	"	" "	650	"	"	"	"	—	"			4 Fans Required
3	"	" "	720	"	"	"	"	—	"			2 Fans Required
4	"	" "	760	"	"	"	"	—	"			1 Fan Required.
5	"	" "	650	"	"	"	"	"	"			1 Fan Required
6	Kitchen Exh.	" CBE-18-6	1440	1/2"	1/4	3250	670	—	120/1/60			10 Fans Required
7	Laundry	" SQB-14-4	1500	3/8"	1/4	4024	1060	—	120/1/60		—	1 Fan Required – 2 SPEED MOTOR
8	Laundry Dryers	" SQB-10-4	400	3/8	1/4	3087	1060	—	120/1/60	—	—	1 Fan Required
9	COMM. RM	" SQB-18-15	4550	1/8	1 1/2				208/3/60			1 " "

NOTES.

Roof Mounted Fans only.
1. Disconnect switches with thermal overloads under hoods
2. 'Greenheck' model ATE sound curb
3. Hinged hoods with padlock and key
4. No Backdraft dampers.

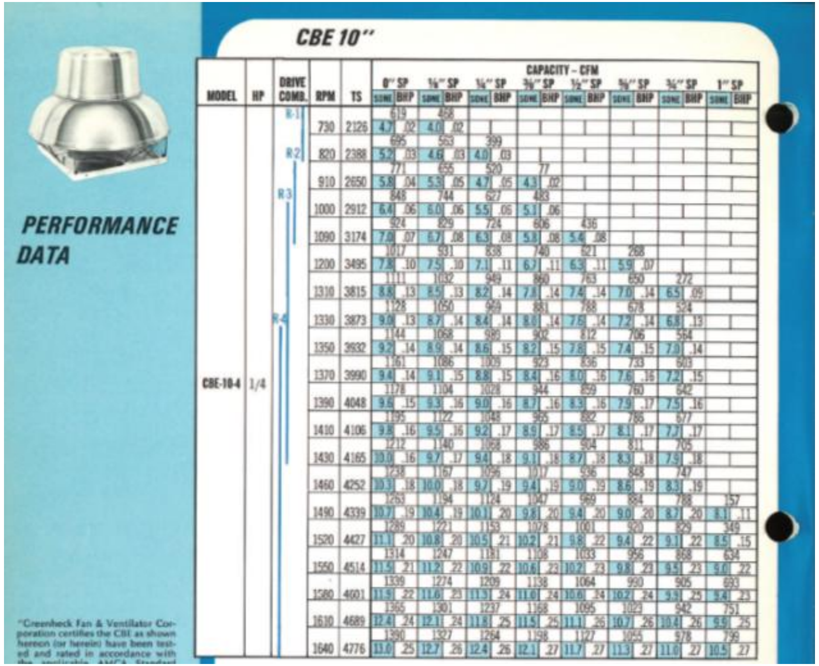
Reducing Ventilation Rates

EXHAUST FAN SCHEDULE.

E.F. No.	AREA SERVED	MODEL No		CFM.	S.P. "H_2O	H.P.	T.S.	R.P.M.	WHEEL DIA.	ELECTRIC DATA
1	Toilet Exh.	Greenheck	CSF-10-4	600	3/8"	1/4	3515	1310	—	120/1/60
2	"	"	"	650	"	"	"	"	—	"
3	"	"	"	720	"	"	"	"	—	"
4	"	"	"	760	"	"	"	"	—	"
5	"	"	"	650	"	"	"	"	—	"
6	Kitchen Exh.	"	CSF-18-4	1440	1/8"	1/4	3250	670	—	120/1/60

Reducing Ventilation Rates

- Fan Selection – Original
  - 1/4HP motor
  - 1310 Fan RPM/ 3815 TS
  - 5/8” wc SP (150pa)
  - 600CFM
- Check Source Specs
  - Obsolete Fan Specs are available from OEM
  - Compare to Field Conditions



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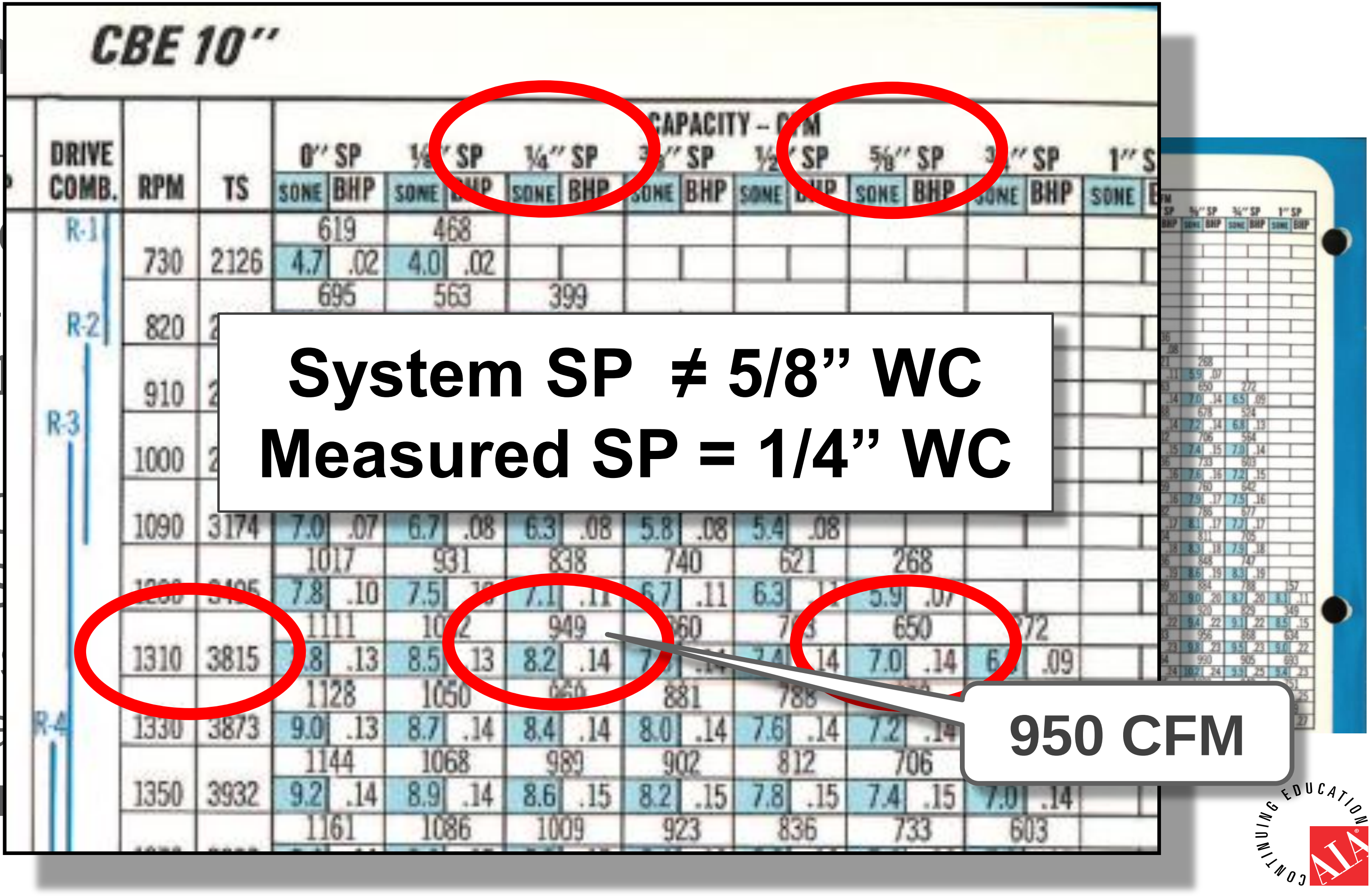


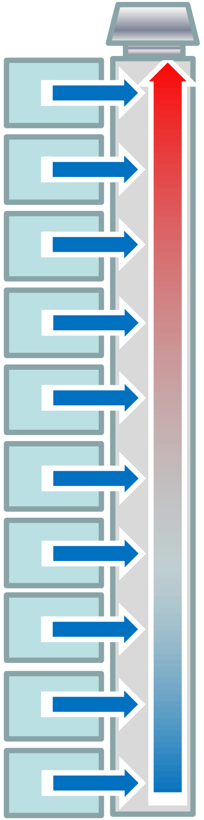
Reducing Ventilation Rates

	Cost/ CFM per Year	250 CFM per Riser	X 22 Risers
Natural Gas @ $0.49/ Therm	$0.80	$200	$4,400
#2 Heating Oil @ $2.99/ Gal.	$3.25	$813	$17,875
District Steam @ $38.50/ MLB	$5.00	$1,250	$27,500
Electricity @ $0.26/ kWh	$11.50	$2,875	$63,250

What We Expect

The central ventilation system takes stale air from the "apartment space" into the "duct space" and expels it from the building.

- Fan on the roof draws air from the riser
- Exhausted air is drawn up the risers to the fan
- Vents in the apartments pull air to the risers
- Fresh air replaces stale air



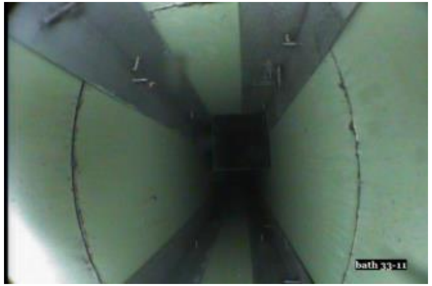
The Risers

Rooftop Curbs/ Tops of Risers

- ✓ Blockages, restrictions through the roof deck
- ✓ Failed joints or visible holes in risers
- ✓ Gaps inside the curb or between the deck and duct
- ✓ Are there even any ducts at all?

The Risers

- Risers generally come in three varieties
  - ✓ Masonry (tile) risers
  - ✓ Drywall risers
  - ✓ Sheet metal risers
- Many systems are "hybrid", using one type for certain portions and then transitioning to another
- Transitions are *always* key leakage points



The Risers

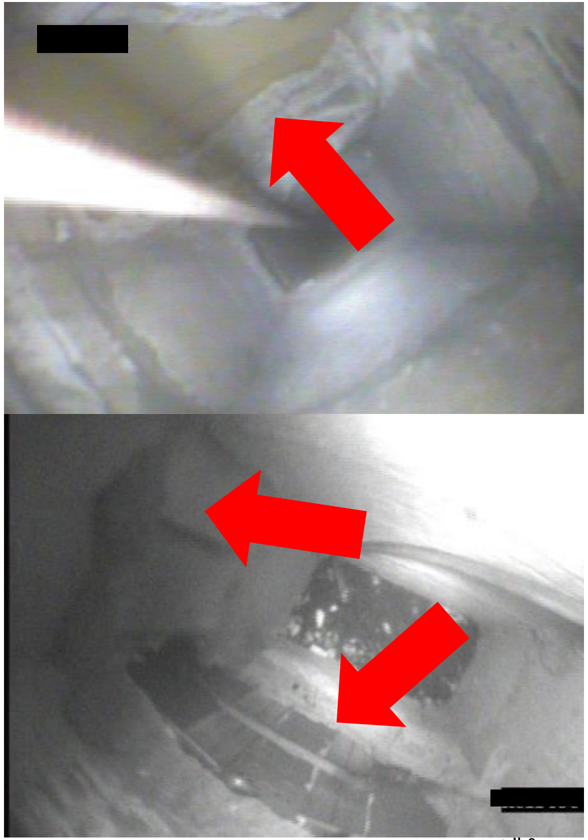
Duct Construction: Masonry

- Weaknesses
  - ✓ Mortar joints missing or failed (leaving large gaps)
  - ✓ Connections to sheet metal transitions are generally big leakers (often in ceilings, requiring manual access)

The Risers

Duct Construction: Masonry

- Weaknesses
  - ✓ Building mods can create big holes that need manual repair
  - ✓ Many buildings with masonry risers have plaster walls, making access to ducts more challenging



The Risers

Duct Construction: Drywall

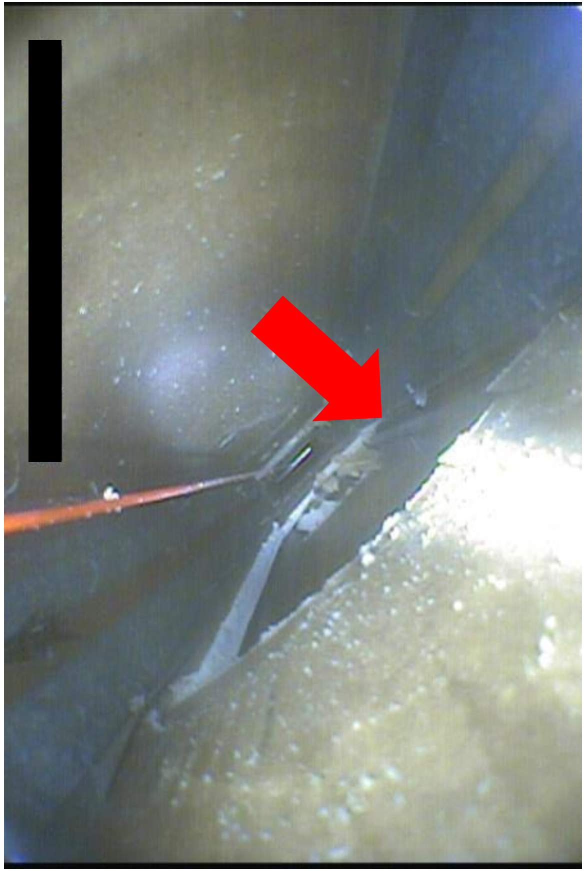
- Weaknesses
  - ✓ Often “discontinuous” (built floor to floor) with misalignments common
  - ✓ …or shoved up against a column

The Risers

Duct Construction: Drywall

This is a hole cut into a duct we *already sealed* a month before. The staff was hunting for leaky water pipe and thought it might be around here somewhere.

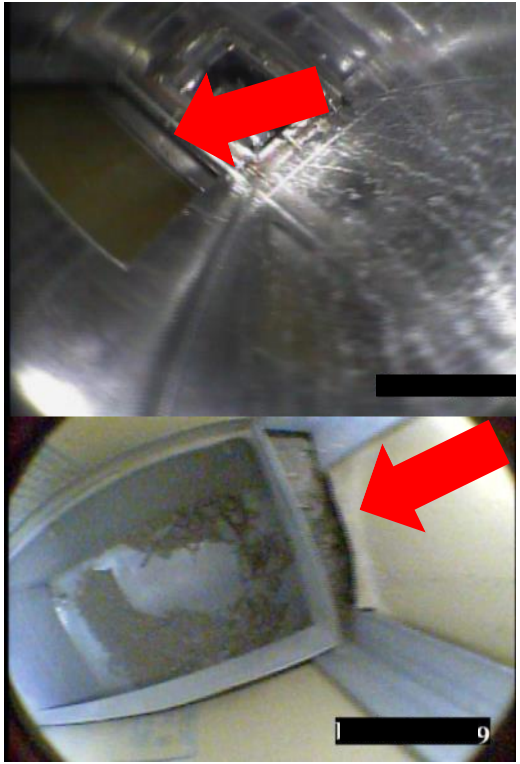
The orange line to the left is a pressure reference line for the variable speed fan 4 floors above. No wonder it wouldn't commission.



The Risers

Duct Construction: Sheet Metal

- Weaknesses
  - ✓ Pricy to install (“value engineered” out of final construction)
  - ✓ Careless work at seams can still leave large gaps
  - ✓ Frequently found at transitions that are key leakage points



CONTINUING EDUCATION AIA

The Risers

- Remote Mastic Application
  - ✓ Gaps around the connection need to be less than 1”
  - ✓ If the runout extends into the riser, getting a good seal on all four sides is challenging
  - ✓ Just a ¼” gap on the top & sides of a 6” X 6” runout will *equal* the opening size of the CAR regulator! (4.5si)

The Risers

- Aerosolized Sealant (Aeroseal®)
  - ✓ Gaps ***must be*** less than 1/4”
  - ✓ Pressurizes entire riser – sealant flows to every gap, sealing them as it passes through – *caution in occupied buildings!*
  - ✓ Best when used in conjunction with manual sealing and mastic
  - ✓ Possible to get leakage below 5% of total system flow

All Risers are NOT Created Equal

- ✓ Are they DUCTS or are they CHASES?
  - *Ducts* transport AIR, *Chases* transport stuff (including ducts)
- ✓ Where the holes are makes a BIG difference
  - A 2si hole at the top might be equal to a 12si hole at the bottom
- ✓ Design efficiencies need to consider what's ***practical*** for ***this building's systems***

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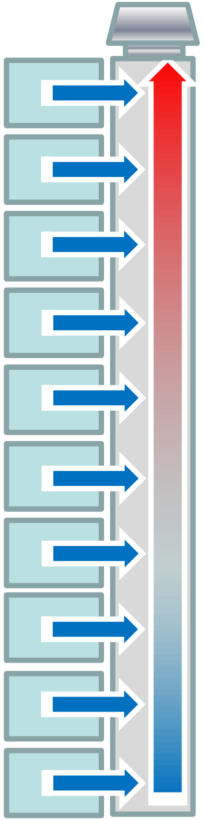


The Boots

- Boots are a big source of leakage
  - ✓ Gaps at the apartment side can draw air from wall cavities
  - ✓ Gaps where runouts meet the risers *really* leak – and can be hard to reach to seal
  - ✓ Can easily *triple* the opening over just the CAR regulator

The Boots

- It's often better to manually seal by reaching in from the apartments
  - ✓ Pack gaps with mineral wool
  - ✓ Apply intumescent caulk or similar
  - ✓ We sometimes fabricate metal clips that allow us make a seal to the riser
  - ✓ Spray foam is *not* approved for use inside ducts, unless it is covered with an approved fire barrier

The Boots

- Sometimes the duct is so degraded that no amount of mastic, caulk or anything else can save it.
  - ✓ This is generally from past water leaks in the wet walls where many ducts live
  - ✓ This condition is often *NOT* visible from video taken inside the ducts
  - ✓ Crews need to know to look for this
  - ✓ This is a legitimate "extra"

The Vents

Manual
Vent Damper

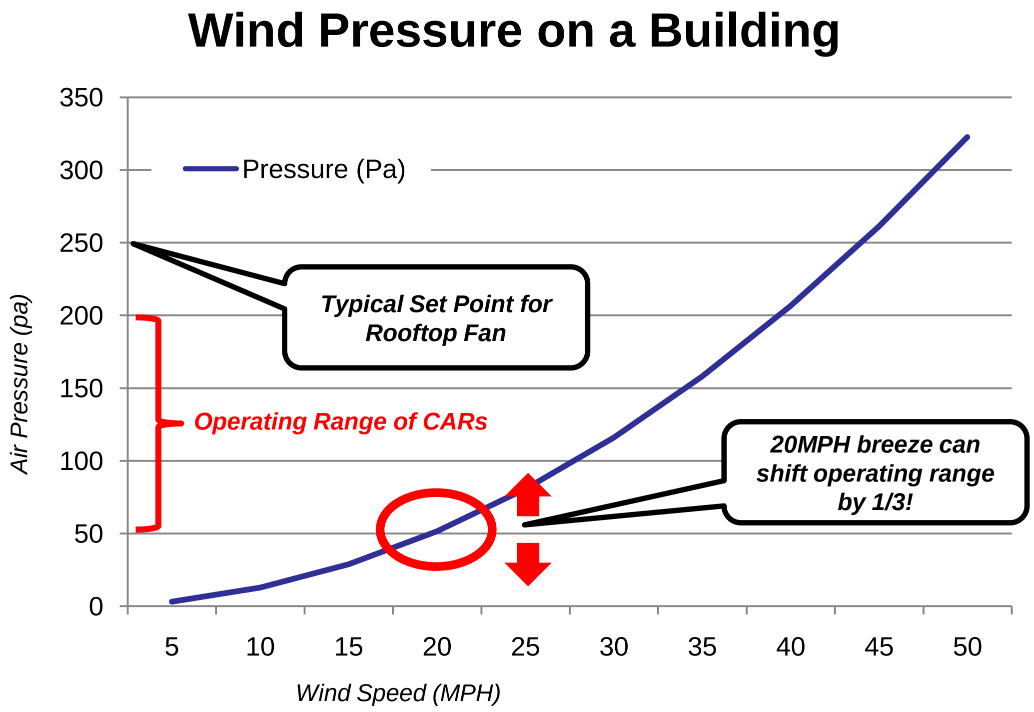
Self-Regulating
Vent Damper (CAR)

The Vents

CAR Regulators - Limitations

- ✓ Requires minimum 50pa (0.2” wc) to operate properly
- ✓ Smaller opening “competes” more with system leakage – ***requires tighter ducts***
- ✓ Relies on pressure difference between duct and apartment, which can change significantly

The Vents



Beaufort Wind Scale

Beaufort No.	Description of wind	Observation	Wind speed m/s	mph	knots	ft/min
0	Calm	Smoke rises vertically. The sea is mirror smooth.	0 - 0.15	0 - 0.3	0 - 0.5	0 - 25
1	Light Air	Direction of wind shown by smoke drift but not by vanes. Scale-like ripples on sea, no foam on wave crests.	0.15 - 2.7	0.3 - 6	0.5 - 3	25 - 525
2	Light Breeze	Wind felt on face, leaves rustle, ordinary vanes moved by wind. Short wavelets, glassy wave crests.	2.7 - 3.6	6 - 8	3 - 7	525 - 700
3	Gentle Breeze	Leaves and small twigs in constant motion, wind extends light flag	3.6 - 7.2	8 - 16	7 - 10	700 - 1400
4	Moderate Breeze	Raises dust and loose paper, small branches moved. Fairy frequent whitecaps occur.	7.2 - 8.9	16 - 20	10 - 15	1,400 - 1,800
5	Fresh Breeze	Small trees in leaf begin to sway. Moderate waves, many white foam crests.	8.9 - 12.5	20 - 28	15 - 21	1,800 - 2,500
6	Strong Breeze	Large branches in motion, whistling heard in telegraph wires. Some spray on the sea surface.	12.5 - 14.5	28 - 32	21 - 27	2,500 - 2,800
7	Moderate gale	Whole trees in motion, inconvenience felt when walking into wind. Foam on waves blows on streaks.	14.5 - 20	32 - 44	27 - 33	2,800 - 3,900
8	Gale	Twigs broken of trees, generally impeded progress. Long streaks on foam appear on sea.	20 - 22	44 - 50	33 - 40	3,900 - 4,400
9	Strong gale	Straight structural damage, e.g. slates and chimney pots removed from the roofs. High waves, crest start to roll over.	22 - 28	50 - 62	40 - 48	4,400 - 5,450
10	Storm	Trees uprooted, considerable structural damage. Exceptionally high waves, visibility affected.	28 - 31	62 - 70	48 - 55	5,450 - 6,150
11	Violent Storm	Widespread damage	31 - 37	70 - 82	55 - 63	6,150 - 7,200
12	Hurricane	Air is filled with spray and foam.	> 37	> 82	> 63	> 7,200

Lessons Learned

CAR Regulators – Will work well when…

- ✓ Overall duct systems are tight enough to hold negative pressures *along the entire riser*
- ✓ Fans have sufficient power to maintain static pressures *along entire riser*
- ✓ Regulators are not "competing" with large gaps, especially around the registers, themselves
- ✓ Open windows, windy conditions *will* influence performance of even very good systems!

Lessons Learned

Don’t “Swing for the Fences” with Minimum Flow Targets

- ✓ Designs with *minimum flows* as their baseline leave no room for field conditions that result in reduced flows at the lowest floors
- ✓ Allow for 10% - 15% “fade” in air flows top to bottom in tall buildings - 35CFM at the top will be 25CFM at the bottom
- ✓ Apply the *whole code* - larger apartments = higher flows (15CFM/ occupant)

Identify Good Candidates

- How “tight” is tight?
  5CFM per register? …per floor? … X% of total flow?
  Does it matter how the ducts were constructed?
- How tall is the building? Does that affect the targets?
- How do we address restrictions at the curb? Do they need to be opened up to reduce pressure drop?
- What *are* the acceptable flows at the bottom? How do we design the overall project to achieve them?

Learning Objectives

At the end of the this course, participants will be able to:

1. Understand how to evaluate existing conditions and identify good candidates for this retrofit
2. Develop a reliable, flexible design approach to help control cost overruns and minimize change orders
3. Control implementation of the work to optimize system performance and minimize occupant inconvenience
4. Commission these systems to quantify the improvement benefits

Lessons Learned

- Existing system hadn't worked in years.
- Designed with 2 large fans, 1 per wing
- Design flow of 8,900CFM per fan
  - 6,690 from 233 vents
  - 2,230 leakage allowance (10CFM per register)
  - 13 risers, 1,800 LF of discontinuous, drywall duct
  - 350 LF of unsealed sheet metal lateral above the top story

Lessons Learned

- Large gaps at runouts to registers
- Historical water damage
- Some areas were just plain “Busted Up”

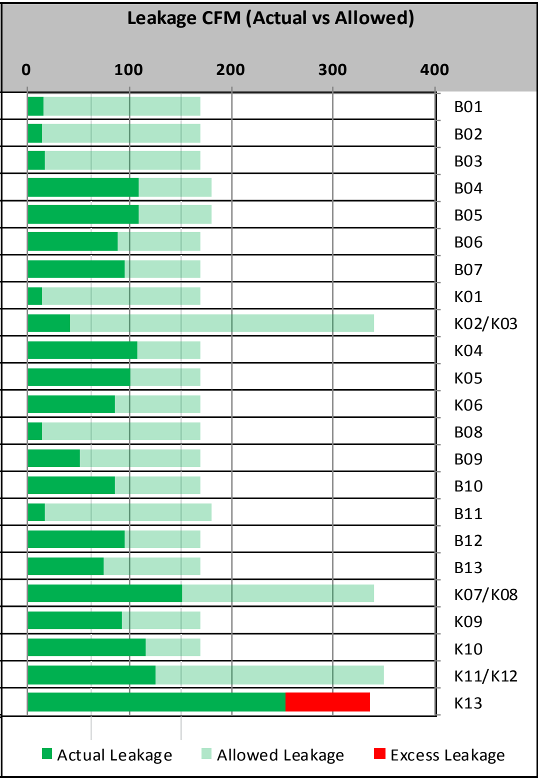
Lessons Learned

FAN	Project Design			
	Fan Flow	Vent Flow	Allowed Leakage	Leakage Percent
B01	10,000	510	170	22.3%
B02		510	170	22.3%
B03		510	170	22.3%
B04		540	180	22.3%
B05		540	180	22.3%
B06		510	170	22.3%
B07		510	170	22.3%
K01		510	170	22.3%
K02/K03		1,020	340	22.3%
K04		510	170	22.3%
K05		510	170	22.3%
K06		510	170	22.3%
B08	10,000	510	170	22.3%
B09		510	170	22.3%
B10		510	170	22.3%
B11		540	180	22.3%
B12		510	170	22.3%
B13		510	170	22.3%
K07/K08		1,020	340	22.3%
K09		510	170	22.3%
K10		510	170	22.3%
K11/K12		1,050	350	22.3%
K13		510	170	22.3%
Totals	**20,000**	**13,380**	**4,460**	**22.3%**

- ✓ Two "systems", each consisting of…
  - ✓ 220 vents
  - ✓ 11 drywall duct risers (140ft long)
  - ✓ 180ft of sheet metal ductwork above the top floor
  - ✓ One 10,000CFM roof fan
- ✓ 30CFM design flow per vent (sharp edged orifices, not CARs)
- ✓ 10CFM Leakage Allowed per vent

Lessons Learned

FAN	Project Design				Project Results			
	Fan Flow	Vent Flow	Allowed Leakage	Leakage Percent	Pre Seal Leakage	Percent of Flow	Post Seal Leakage	Percent of Flow
B01		510	170	22.3%	284	37.3%	15	2.0%
B02		510	170	22.3%	424	55.6%	14	1.8%
B03		510	170	22.3%	416	54.6%	17	2.2%
B04		540	180	22.3%	310	38.4%	109	13.5%
B05		540	180	22.3%	297	36.8%	109	13.5%
B06	10,000	510	170	22.3%	317	41.6%	88	11.5%
B07		510	170	22.3%	420	55.1%	95	12.5%
K01		510	170	22.3%	380	49.8%	14	1.8%
K02/K03		1,020	340	22.3%	406	26.6%	42	2.8%
K04		510	170	22.3%	380	49.8%	108	14.2%
K05		510	170	22.3%	456	59.8%	101	13.2%
K06		510	170	22.3%	415	54.4%	86	11.3%
B08		510	170	22.3%	299	39.2%	14	1.8%
B09		510	170	22.3%	283	37.1%	52	6.8%
B10		510	170	22.3%	418	54.8%	86	11.3%
B11		540	180	22.3%	404	50.1%	17	2.1%
B12		510	170	22.3%	240	31.5%	95	12.5%
B13	10,000	510	170	22.3%	368	48.3%	74	9.7%
K07/K08		1,020	340	22.3%	341	22.4%	151	9.9%
K09		510	170	22.3%	473	62.0%	92	12.1%
K10		510	170	22.3%	273	35.8%	116	15.2%
K11/K12		1,050	350	22.3%	310	19.8%	126	8.0%
K13		510	170	22.3%	520	68.2%	253	33.2%
Totals	**20,000**	**13,380**	**4,460**	**22.3%**	**8,434**	**42.2%**	**1,874**	**9.4%**



Lessons Learned

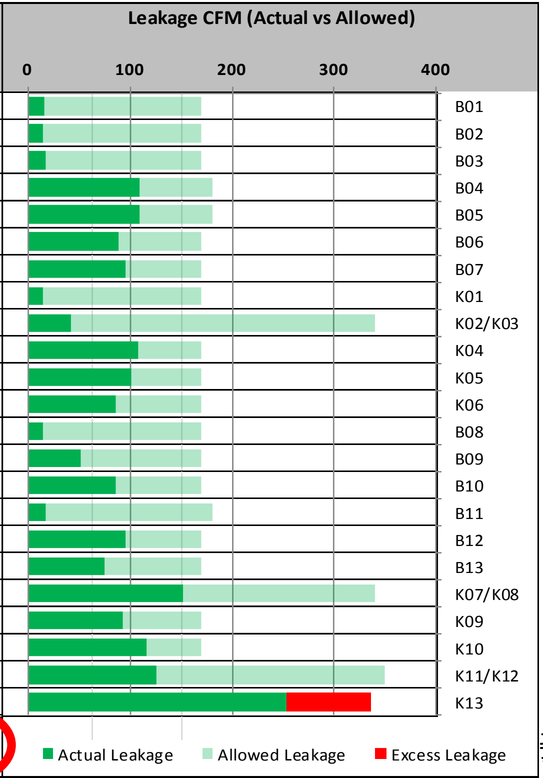
FAN	Project Design				Project I	
	Fan Flow	Vent Flow	Allowed Leakage	Leakage Percent	Pre Seal Leakage	Percent of Flow
B01	10,000	510	170	22.3%	284	37.3%
B02		510	170	22.3%	424	55.6%
B03		510	170	22.3%	416	54.6%
B04		540	180	22.3%	310	38.4%
B05		540	180	22.3%	297	36.8%
B06		510	170	22.3%	317	41.6%
B07		510	170	22.3%	420	55.1%
K01		510	170	22.3%	380	49.8%
K02/K03		1,020	340	22.3%	406	26.6%
K04		510	170	22.3%	380	49.8%
K05		510	170	22.3%	456	59.8%
K06		510	170	22.3%	415	54.4%
B08	10,000	510	170	22.3%	299	39.2%
B09		510	170	22.3%	283	37.1%
B10		510	170	22.3%	418	54.8%
B11		540	180	22.3%	404	50.1%
B12		510	170	22.3%	240	31.5%
B13		510	170	22.3%	368	48.3%
K07/K08		1,020	340	22.3%	341	22.4%
K09		510	170	22.3%	473	62.0%
K10		510	170	22.3%	273	35.8%
K11/K12		1,050	350	22.3%	310	19.8%
K13		510	170	22.3%	520	68.2%
Totals	**20,000**	**13,380**	**4,460**	**22.3%**	**8,434**	**42.2%**

- ✓ After in-unit sealing *and* remote mastic application, way too leaky
- ✓ We re-entered apartments and sprayed *directly into risers* eliminating all *visible* leaks…
- ✓ Better, but *still way too leaky*

Lessons Learned

- ✓ Each riser was treated with Aeroseal
- ✓ Significant leakage reductions across the board
  - (K05 and K13 were sealed along with the large metal laterals)
- ✓ Net system leakage less than 10%

Project Results			
Pre Seal Leakage	Percent of Flow	Post Seal Leakage	Percent of Flow
284	37.3%	15	2.0%
424	55.6%	14	1.8%
416	54.6%	17	2.2%
310	38.4%	109	13.5%
297	36.8%	109	13.5%
317	41.6%	88	11.5%
420	55.1%	95	12.5%
380	49.8%	14	1.8%
406	26.6%	42	2.8%
380	49.8%	108	14.2%
456	59.8%	101	13.2%
415	54.4%	86	11.3%
299	39.2%	14	1.8%
283	37.1%	52	6.8%
418	54.8%	86	11.3%
404	50.1%	17	2.1%
240	31.5%	95	12.5%
368	48.3%	74	9.7%
341	22.4%	151	9.9%
473	62.0%	92	12.1%
273	35.8%	116	15.2%
310	19.8%	126	8.0%
520	68.2%	253	33.2%
8,434	**42.2%**	**1,874**	**9.4%**



Lessons Learned

FAN	Project Design			
	Fan Flow	Vent Flow	Allowed Leakage	Allowed Percent
KEF10E	1,145	910	130	11%
ERV01	800	625	125	16%
ERV02	800	625	125	16%
TEF01E	953	700	140	15%
TEF02E	953	700	140	15%
TEF03E	953	700	140	15%
TEF04E	885	650	130	15%
TEF05E	885	650	130	15%
TEF06E	953	700	140	15%
TEF07E	953	700	140	15%
TEF08E	953	700	140	15%
TEF09E	885	650	130	15%
TEF10E	953	700	140	15%
TEF11E	953	700	140	15%
TEF12E	953	750	150	16%
TEF13E	953	700	140	15%
TEF14E	1,021	750	150	15%
Totals	**15,951**	**11,910**	**2,330**	**14.6%**

- ✓ 16 260ft long Drywall Ducts
  (KEF10E is sheet metal)
- ✓ 3,250 CFM Target Reduction
  (@ $12/CFM = $39,000/ year)
- ✓ 10%-15% “Head” Fan vs Vent
- ✓ 15% Leakage Allowance (5cfm/ vent)

Lessons Learned

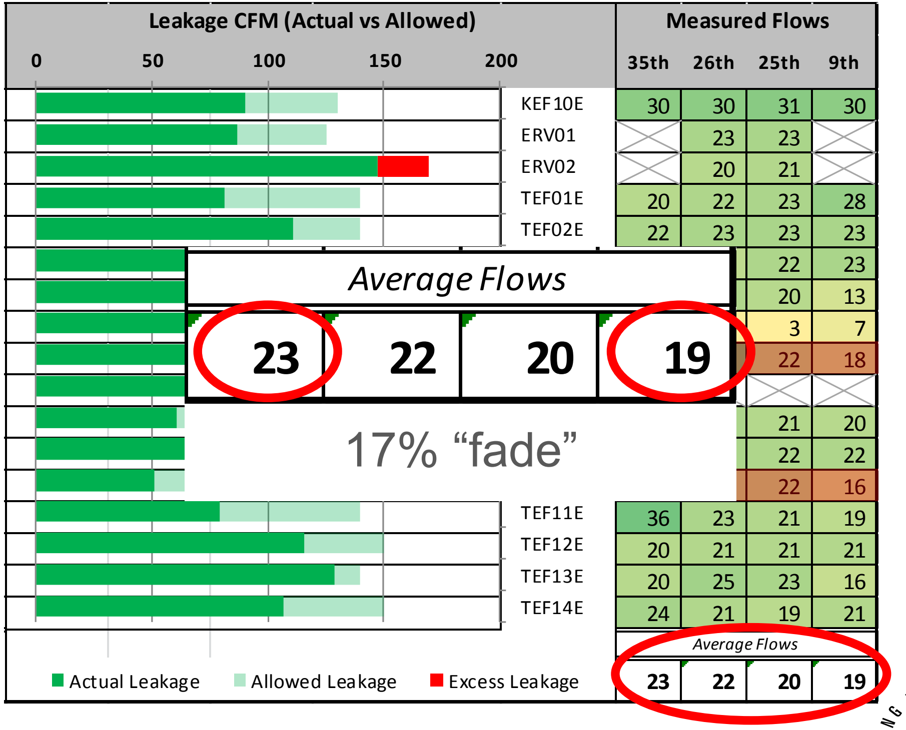
FAN	Project Design				Project Results		
	Fan Flow	Vent Flow	Allowed Leakage	Allowed Percent	Req'd Flow	Actual Leakage	Actual Percent
KEF10E	1,145	910	130	11%	1,000	90	7.9%
ERV01	800	625	125	16%	712	87	10.9%
ERV02	800	625	125	16%	772	147	18.4%
TEF01E	953	700	140	15%	781	81	8.5%
TEF02E	953	7[illegible]	[illegible]	[illegible]	[illegible]	111	11.6%
TEF03E	953	7[illegible]	[illegible]	[illegible]	[illegible]	109	11.4%
TEF04E	885	6[illegible]	[illegible]	[illegible]	[illegible]	103	11.6%
TEF05E	885	6[illegible]	[illegible]	[illegible]	[illegible]	69	7.8%
TEF06E	953	7[illegible]	[illegible]	[illegible]	[illegible]	137	14.4%
TEF07E	953	7[illegible]	[illegible]	[illegible]	[illegible]	111	11.6%
TEF08E	953	7[illegible]	[illegible]	[illegible]	[illegible]	61	6.4%
TEF09E	885	6[illegible]	[illegible]	[illegible]	[illegible]	83	9.4%
TEF10E	953	700	[illegible]	[illegible]	[illegible]	51	5.4%
TEF11E	953	700	140	15%	779	79	8.3%
TEF12E	953	750	150	16%	866	116	12.2%
TEF13E	953	700	140	15%	829	129	13.5%
TEF14E	1,021	750	150	15%	857	107	10.5%
Totals	**15,951**	**11,910**	**2,330**	**14.6%**	**13,581**	**1,671**	**10.5%**

129	13.5%
107	10.5%
1,671	**10.5%**

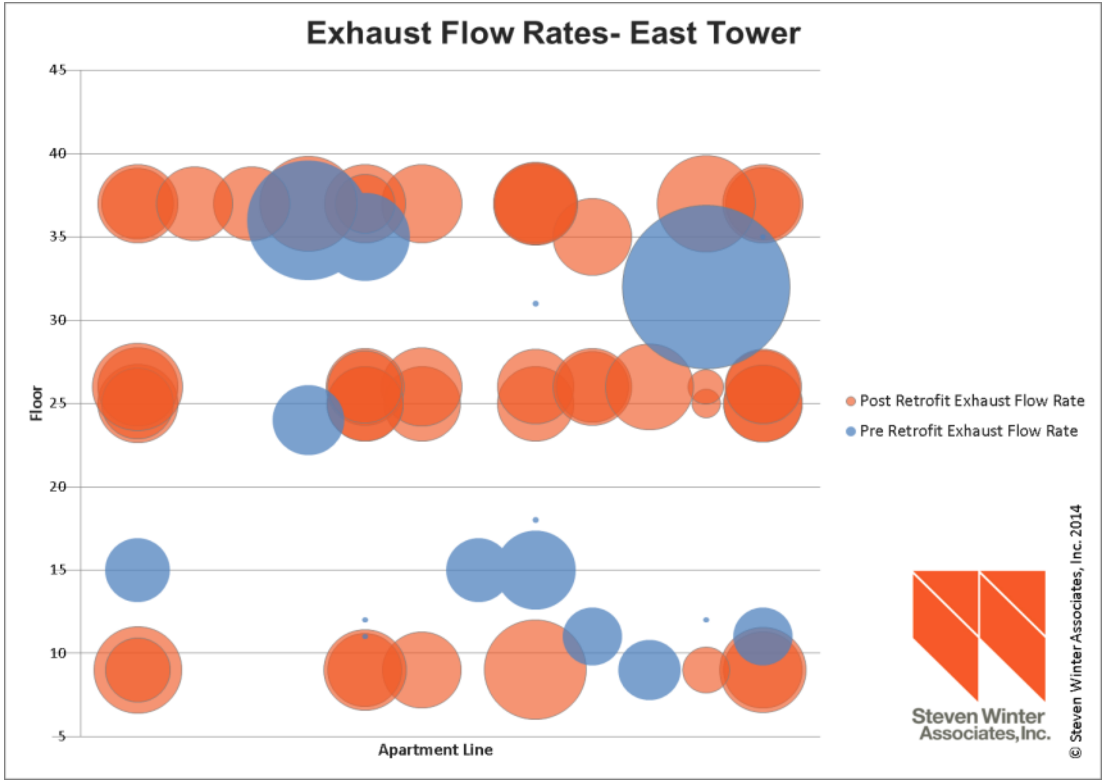
- ✓ Solid sealing results
- ✓ 660 CFM *additional* leakage reduction *($7,900/ year additional savings)*
- ✓ + 8-10% More “Fan Head”
- ✓ 10.5% Net System Leakage - *28% below target*

Lessons Learned

- ✓ System leakage may *not* predict actual vent flows
- ✓ Curb restrictions, small ducts or smoke snorkels can “rob” static pressure
- ✓ Plan for “Flow Fade” of 20% - 25%



Lessons Learned



Cluttered Ducts - Snorkels nearly fill this duct at the bottom, impeding flows

Learning Objectives

At the end of the this course, participants will be able to:

1. Understand how to evaluate existing conditions and identify good candidates for this retrofit
2. Develop a reliable, flexible design approach to help control cost overruns and minimize change orders
3. Control implementation of the work to optimize system performance and minimize occupant inconvenience
4. Commission these systems to quantify the improvement benefits

Commissioning: The Ducts

Leak Testing Vertical Risers

- ✓ Generally tested to 50pa with all "intentional openings" (registers) sealed
- ✓ *X*CFM per floor, register, or similar
- ✓ 50pa with reference to *where?*
  - Curb reference will give artificially low leakage (limited by any restriction through the deck)
  - At least measure to ½ way down the riser

Commissioning: The Fans

ECM fans allow “tuning” of the system.

- ✓ Our method:
  - Tachometer for fan speed
  - Manometer for SP reading
  - Plot on the fan curve
- ✓ Quick, easy, repeatable

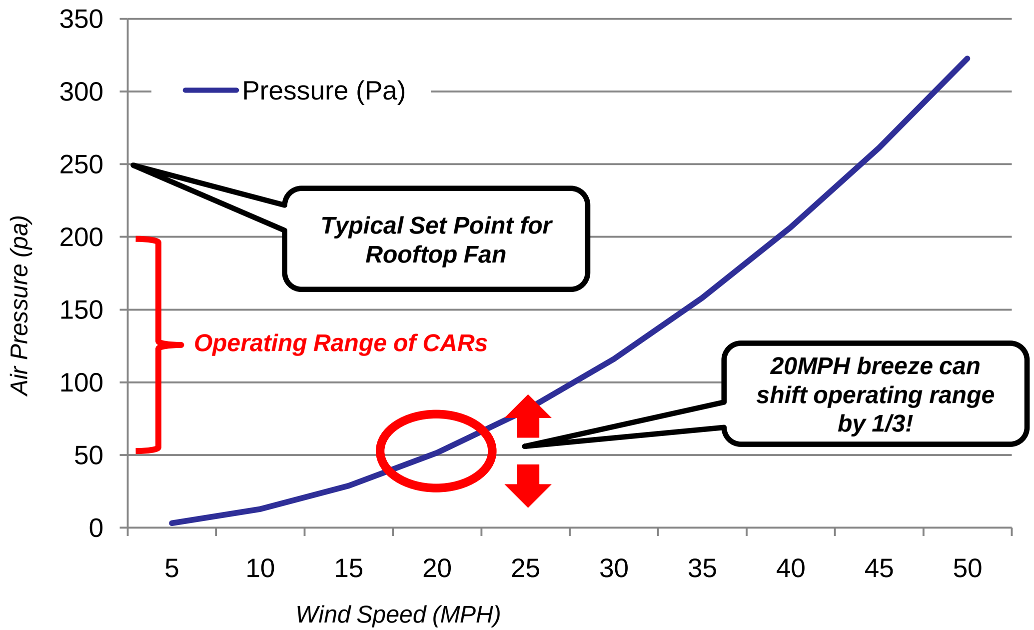
Commissioning: The Vents

Establish Performance Parameters

- ✓ Place unit under operating conditions
    - Close windows, doors
    - Note overall building conditions
    - Make sure the fans are operating properly
- ✓ Get a good seal/ get reliable readings
- ✓ YMMV, depending on…
    - Time of year – summer VS winter conditions
    - High winds – open windows, even in adjacent units!

Commissioning: The Vents

Wind Pressure on a Building



Beaufort Wind Scale

Beaufort No.	Description of wind	Observation	Wind speed m/s	Wind speed mph	Wind speed knots	Wind speed ft/min
0	Calm	Smoke rises vertically. The sea is mirror smooth.	0 - 0.15	0 - 0.3	0 - 0.5	0 - 25
1	Light Air	Direction of wind shown by smoke drift but not by vanes. Scale-like ripples on sea, no foam on wave crests.	0.15 - 2.7	0.3 - 6	0.5 - 3	25 - 525
2	Light Breeze	Wind felt on face, leaves rustle, ordinary vanes moved by wind. Short wavelets, glassy wave crests.	2.7 - 3.6	6 - 8	3 - 7	525 - 700
3	Gentle Breeze	Leaves and small twigs in constant motion, wind extends light flag	3.6 - 7.2	8 - 16	7 - 10	700 - 1400
4	Moderate Breeze	Raises dust and loose paper, small branches moved. Fairy frequent whitecaps occur.	7.2 - 8.9	16 - 20	10 - 15	1,400 - 1,800
5	Fresh Breeze	Small trees in leaf begin to sway. Moderate waves, many white foam crests.	8.9 - 12.5	20 - 28	15 - 21	1,800 - 2,500
6	Strong Breeze	Large branches in motion, whistling heard in telegraph wires. Some spray on the sea surface.	12.5 - 14.5	28 - 32	21 - 27	2,500 - 2,800
7	Moderate gale	Whole trees in motion, inconvenience felt when walking into wind. Foam on waves blows on streaks.	14.5 - 20	32 - 44	27 - 33	2,800 - 3,900
8	Gale	Twigs broken of trees, generally impeded progress. Long streaks on foam appear on sea.	20 - 22	44 - 50	33 - 40	3,900 - 4,400
9	Strong gale	Straight structural damage, e.g. slates and chimney pots removed from the roofs. High waves, crest start to roll over.	22 - 28	50 - 62	40 - 48	4,400 - 5,450
10	Storm	Trees uprooted, considerable structural damage. Exceptionally high waves, visibility affected.	28 - 31	62 - 70	48 - 55	5,450 - 6,150
11	Violent Storm	Widespread damage	31 - 37	70 - 82	55 - 63	6,150 - 7,200
12	Hurricane	Air is filled with spray and foam.	> 37	> 82	> 63	> 7,200

Learning Objectives
Wrap Up

At the end of the this course, participants will be able to:

1. Understand how to evaluate existing conditions and identify good candidates for this retrofit
2. Develop a reliable, flexible design approach to help control cost overruns and minimize change orders
3. Control implementation of the work to optimize system performance and minimize occupant inconvenience
4. Commission these systems to quantify the improvement benefits

This concludes The American Institute of Architects Continuing Education Systems Course

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