Facility Dynamics Engineering

Controlling Variable Air Volume Systems

Supply and Return Fan Flow Management and Tracking (Supplemental)

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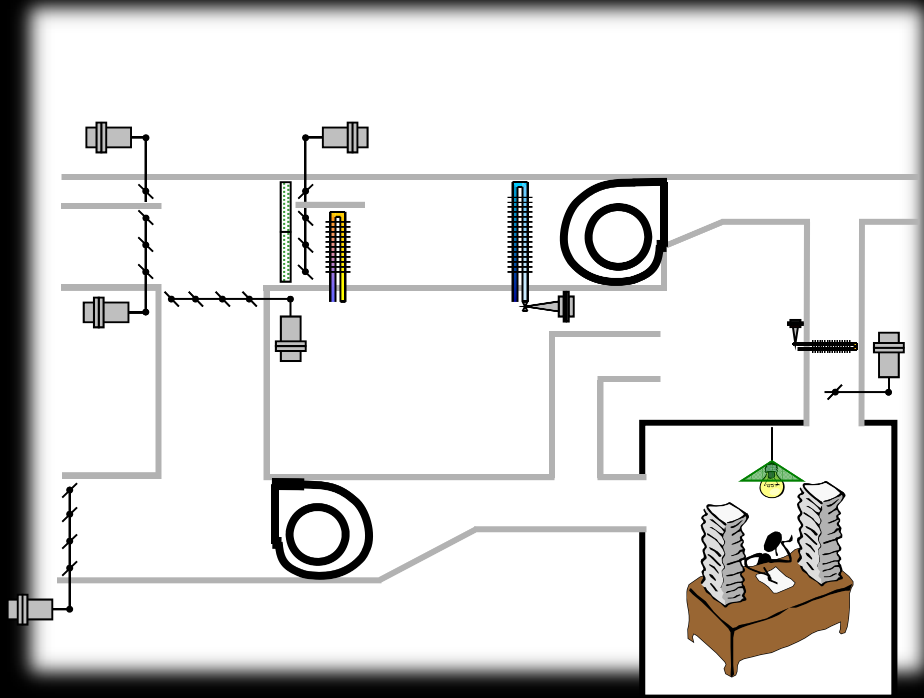
A Word about Return and Relief Fans

Return Fans

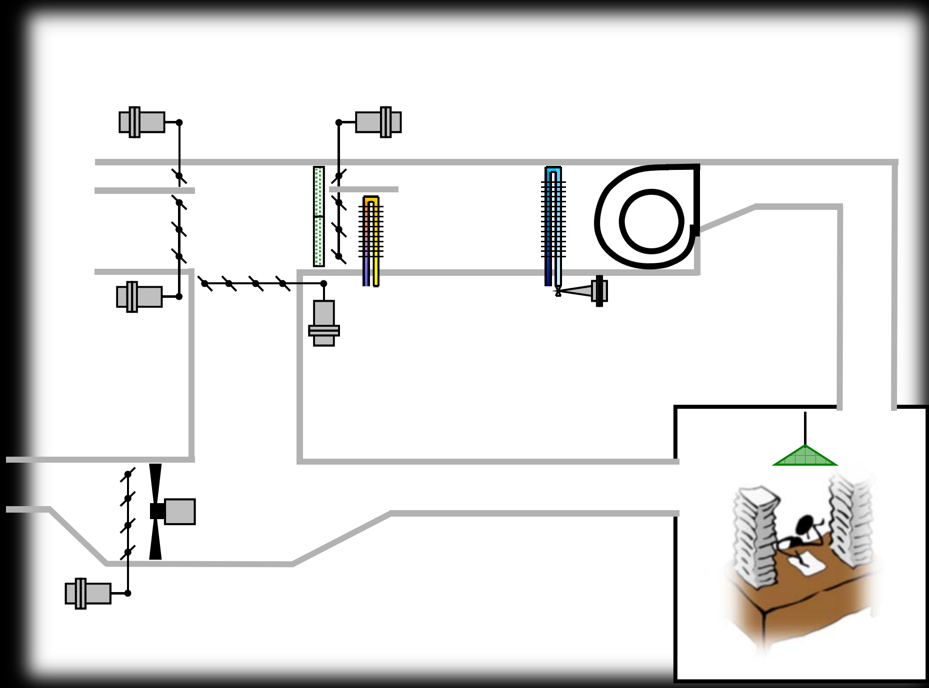
- Overcome the static pressure loss *between the zone and the air handling system*
- Operate any time the supply fan runs
  - Return air for recirculation
  - Frequently, deliver air to the relief louver for discharge to the exterior when operating on an economizer cycle
- Coordinating with VAV supply operation is tricky



A Word about Return and Relief Fans

Relief Fans

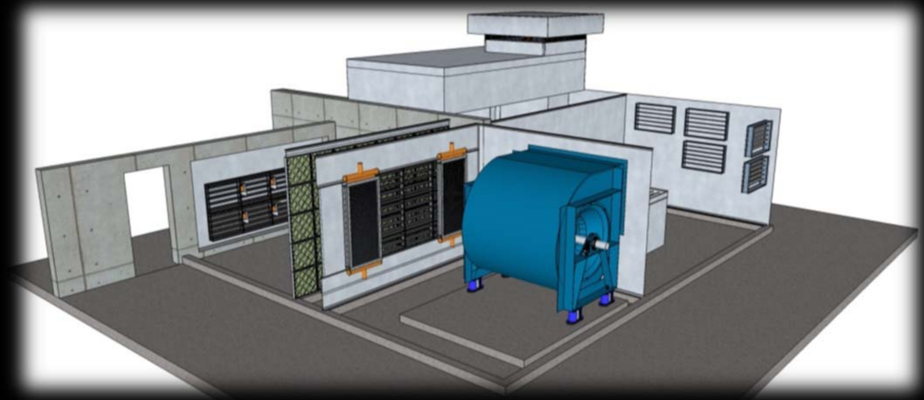
- Overcome the static pressure loss *between the air handling unit location and the relief louver*
- Only operate during an economizer cycle
- VFD operation often coordinated with building pressure



Large, Slow Speed Fan Considerations

Because of their moment of inertia, large, slow speed fans can required a larger motor to start them than they need to run them

- Large = heavy fan wheels with a high moment of inertia
- Slow speed = Not doing a lot of work, relatively speaking



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Motor starting torque capabilities can vary radically from manufacturer to manufacturer

WR^2 Values For Open Drip-Proof Motors

HP	Baldor	General Electric	Gould Century	Lincoln Electric	Marathon Electric	Reliance Motors	U.S. Motors	Leeson Electric
1750 rpm								
1	11	14	15	13	NA	20	53	14
1-1/2	20	20	21	18	NA	30	47	21
2	25	27	27	25	NA	40	43	27
3	35	41	37	26	NA	50	30	38
5	55	68	52	44	NA	70	70	60
7-1/2	80	59	64	55	NA	100	143	85
10	100	53	82	71	NA	124	208	110
15	150	103	152	93	135	185	579	140
20	200	118	236	121	190	260	139	NA
25	240	135	265	185	190	300	266	NA
30	290	166	367	244	230	305	362	NA
40	370	228	447	394	305	450	202	NA
50	400	277	572	546	320	490	222	NA
60	450	400	637	502	375	580	550	NA
75	500	380	683	691	555	950	739	NA
100	NA	876	954	1,111	610	1,000	1,254	NA
125	NA	912	1,136	1,284	765	1,270	2,019	NA
1150 rpm								
HP	**Baldor**	**General Electric**	**Gould Century**	**Lincoln Electric**	**Marathon Electric**	**Reliance Motors**	**U.S. Motors**	**Leeson Electric**
1	30	38	45	24	NA	34	153	NA
1-1/2	45	56	50	25	NA	73	59	NA
2	60	75	72	32	NA	84	77	NA
3	90	69	85	48	NA	86	161	NA
5	145	88	117	79	NA	150	517	NA
7-1/2	210	142	290	104	320	210	612	NA
10	270	164	385	137	370	270	250	NA
15	400	201	573	206	430	430	380	NA
20	500	282	865	274	585	480	574	NA
25	650	342	944	390	645	750	738	NA
30	750	457	1,145	454	855	870	1,037	NA
40	1,000	725	1,350	764	770	930	1,004	NA
50	1,200	826	1,547	942	1,035	1,080	1,562	NA
60	NA	865	1,732	1,003	1,710	1,400	4,953	NA
75	NA	1,121	1,864	1,237	2,140	1,600	6,815	NA
100	NA	1,945	1,987	2,003	1,875	2,100	NA	NA
125	NA	2,153	2,342	2,994	2,505	2,600	NA	NA

Notes:

1. Values are for T-frame motors.
2. WR^2 is at motor shaft as measured in LB - Ft2.
3. NA = Not Available.
4. WR^2 is the same as WK^2 which is used by many manufacturers.
5. Data from Penn Barry Engineering Data 16000 - *Fan Starting Requirements and WR_2 Values for Motors*.

Large, Slow Speed Fan Considerations

Because of their moment of inertia, large, slow speed fans can required a larger motor to start them than they need to run them

- Large = heavy fan wheels with a high moment of inertia
- Slow speed = Not doing a lot of work, relatively speaking

Motor starting torque capabilities can vary radically from manufacturer to manufacturer

WR^2 Values For Totally Enclosed Fan Cooled Motors

HP	Baldor	General Electric	Gould Century	Lincoln Electric	Marathon Electric	Reliance Motors	U.S. Motors	Leeson Electric
1750 rpm								
1	11	14	16	13	NA	20	43	14
1-1/2	20	20	22	18	NA	30	34	21
2	25	27	27	25	NA	40	83	27
3	34	41	37	26	NA	50	34	38
5	54	68	52	44	NA	70	73	58
7-1/2	80	55	64	55	NA	100	154	80
10	100	57	82	71	NA	124	336	90
15	150	110	213	93	215	185	184	NA
20	200	152	293	121	290	270	271	NA
25	240	267	397	185	265	300	315	NA
30	290	325	492	244	315	390	590	NA
40	370	396	622	394	475	530	561	NA
50	440	496	736	546	610	640	637	NA
60	490	609	933	502	580	770	1,037	NA
75	530	837	1,134	691	710	1,000	1,103	NA
100	NA	1,073	1,525	1,111	1,075	1,540	NA	NA
125	NA	1,389	2,132	1,284	1,340	1,820	NA	NA
1150 rpm								
HP	Baldor	General Electric	Gould Century	Lincoln Electric	Marathon Electric	Reliance Motors	U.S. Motors	Leeson Electric
1	30	38	45	24	NA	34	235	NA
1-1/2	45	56	50	25	NA	73	51	NA
2	65	75	72	32	NA	84	65	NA
3	95	69	85	48	NA	86	142	NA
5	150	88	117	79	NA	150	450	NA
7-1/2	215	142	382	104	345	220	539	NA
10	280	164	513	137	315	300	224	NA
15	410	398	738	206	495	430	767	NA
20	510	443	916	274	645	660	1,662	NA
25	620	694	1,049	390	750	750	1,077	NA
30	700	854	1,293	454	875	870	1,506	NA
40	950	785	1,745	764	1,230	980	2,848	NA
50	1,150	1,152	2,268	942	1,455	1,570	4,624	NA
60	NA	1,442	3,764	1,003	2,785	2,000	NA	NA
75	NA	1,713	4,660	1,237	3,280	2,100	NA	NA
100	NA	2,448	5,534	2,003	3,595	3,700	NA	NA
125	NA	2,781	6,820	2,994	4,485	4,300	NA	NA

Notes:
1. Values are for T-frame motors.
2. WR^2 is at motor shaft as measured in LB - Ft2.
3. NA = Not Available.
4. WR^2 is the same as WK^2 which is used by many manufacturers.
5. Data from Penn Barry Engineering Data 16000 - *Fan Starting Requirements and WR_2 Values for Motors*.

A Few Rules of Thumb

From Twin City Engineering Bulletin ED-1800

1. Remember, the motor has to accelerate the motor armature and the drive system in addition to the fan wheel itself.
2. Acceleration time can be estimated as follows:

$$Time_{Acceleration} = \left(\frac{WR^2{}_{MotorSpeedReference} \times MotorSpeed}{308 \times \left(1.5 \times MotorFullLoadTorque\right)} \right)$$

Where:

$Time_{Acceleration}$ = Acceleration time in seconds

$WR^2{}_{MotorSpeedReference}$ = Moment of inertia of the load, referenced to the motor speed

$MotorFullLoadTorque$ = Motor rating in lb-ft

Taken from Twin City Fan Engineering Letter ED-1800 "Application Guide for Selecting AC Motors Capaboe of Overcoming Fan Inertia"

3. Totally enclosed fan cooled motor WK^2 capabilities can be estimated as follows:
   - 3600 rpm motor WK^2 = 2.25 x motor hp
   - 1800 rpm motor WK^2 = 13.5 x motor hp
   - 1200 rpm motor WK^2 = 37.5 x motor hp
   - 900 rpm motor WK^2 = 80.0 x motor hp

Matching VAV Supply and Return Fan Performance

A Number of Options

- Speed tracking
- Flow tracking
- Building static pressure based
- Return fan discharge static pressure based
- Mixed air plenum static pressure based

A Number of Issues

- Minimum outdoor air flow control
- Building make-up/exhaust balance
- Zone pressure control
- Building pressurization
- Economizer performance

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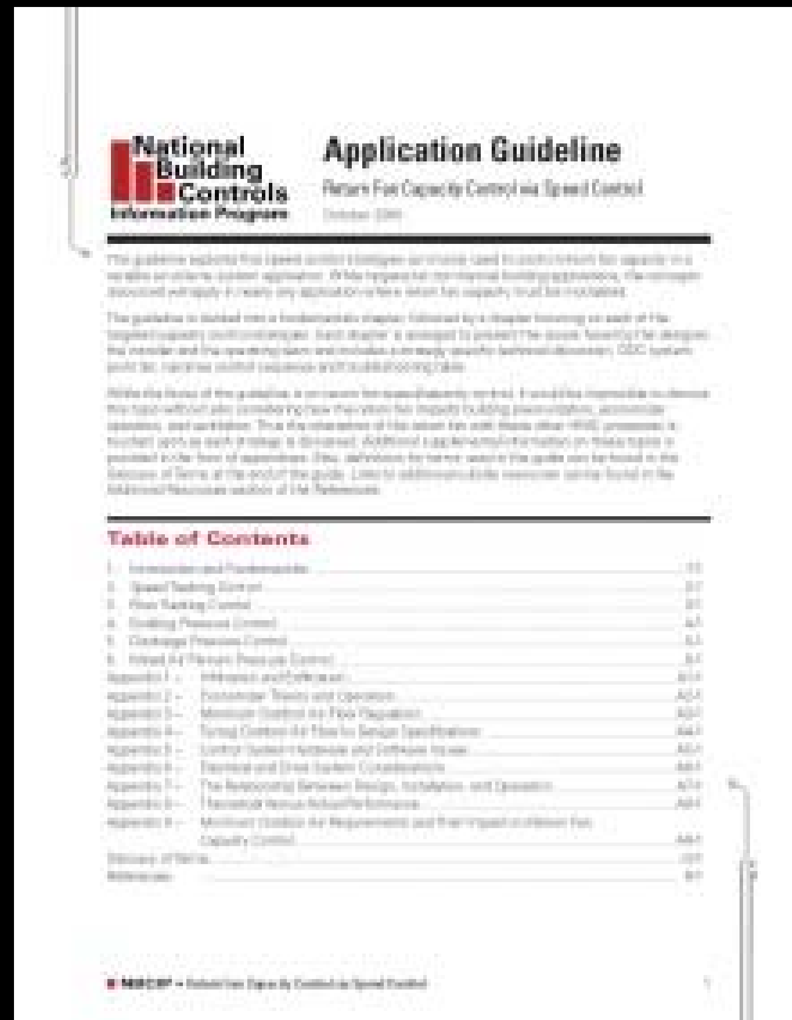
National Building Controls Information Program

Application Guideline

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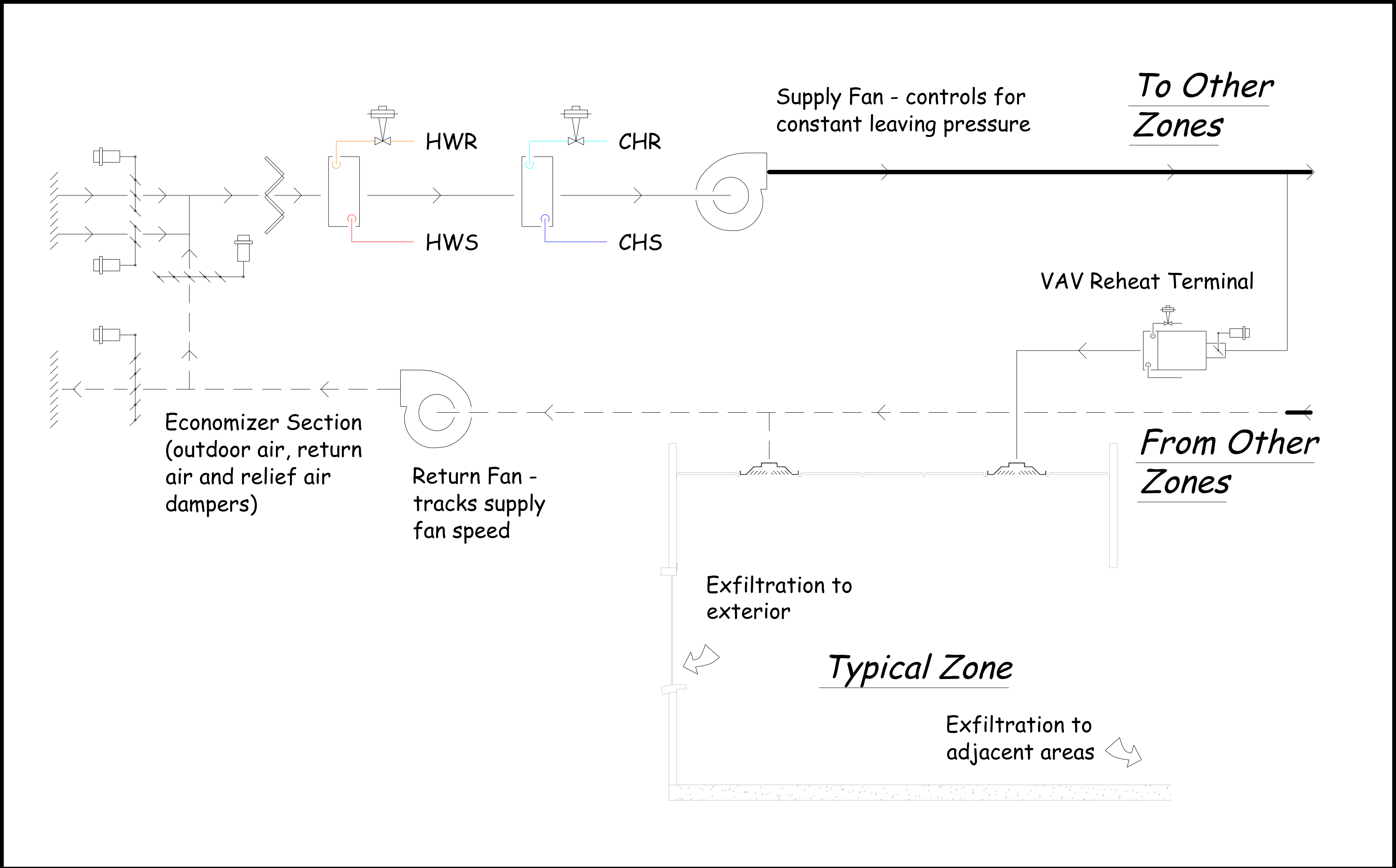
Matching VAV Supply and Return Fan Performance

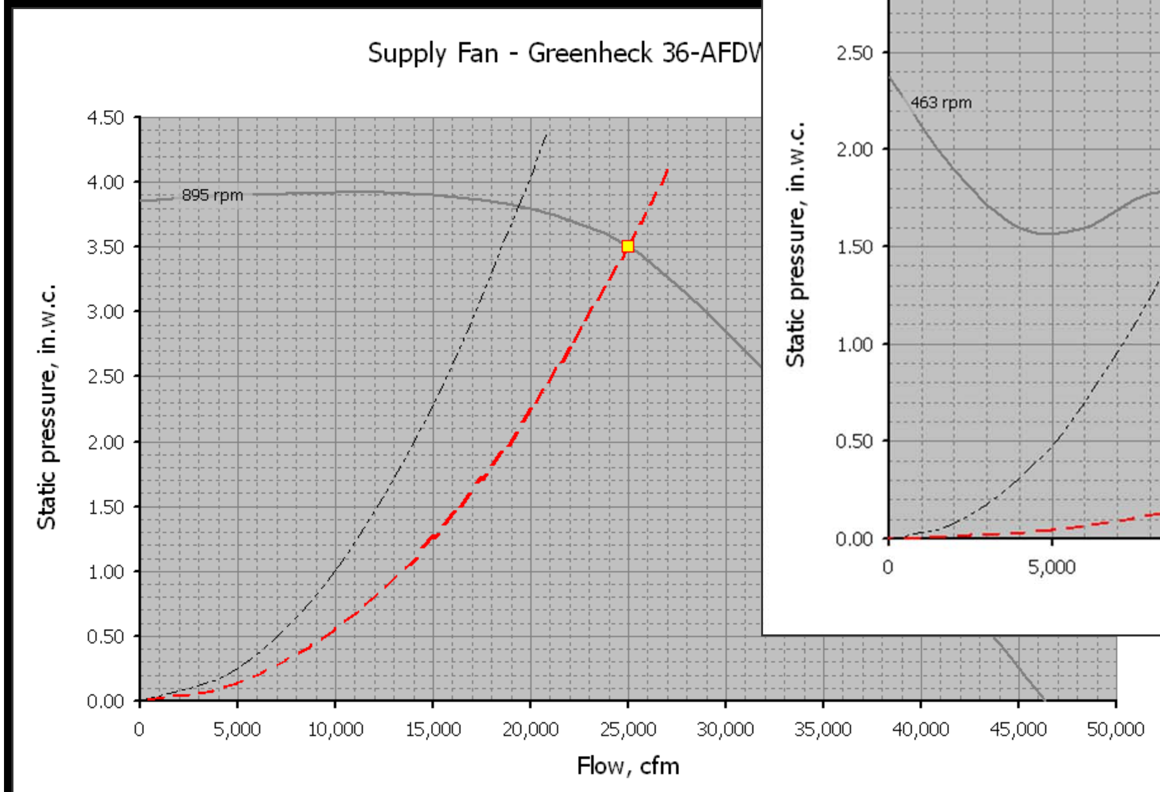
Theory vs. Reality: Applying a VFD to a VAV System Return Fan:

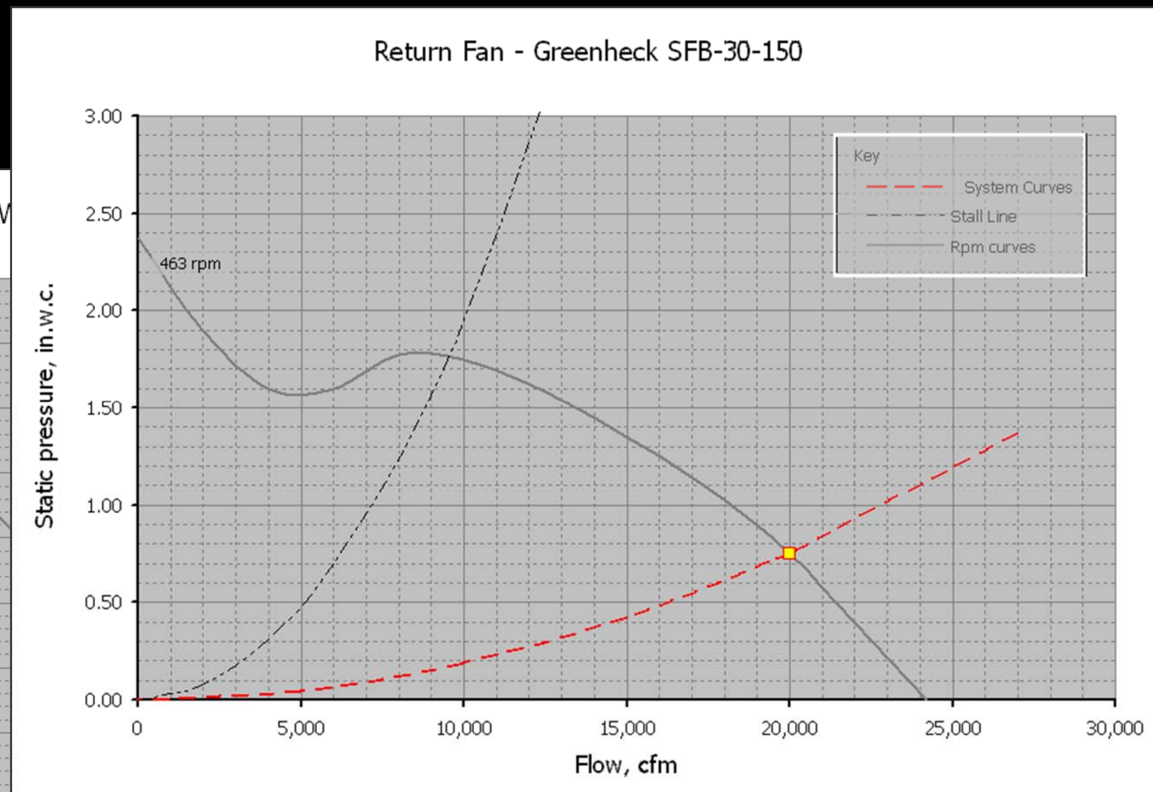
- 25,000 cfm fan system
- Serves an average low-rise office building
- Design intent – provide a constant 5,000 cfm minimum outdoor air flow
- Supply fan controlled to maintain a fixed discharge static pressure
- Supply fan static = 3.5 inches w.c.
  - 1.5 inches w.c. internal
  - 2.0 inches w.c. external
- Return fan controlled by signal tracking technique

The System Diagram



The Design Selection Points

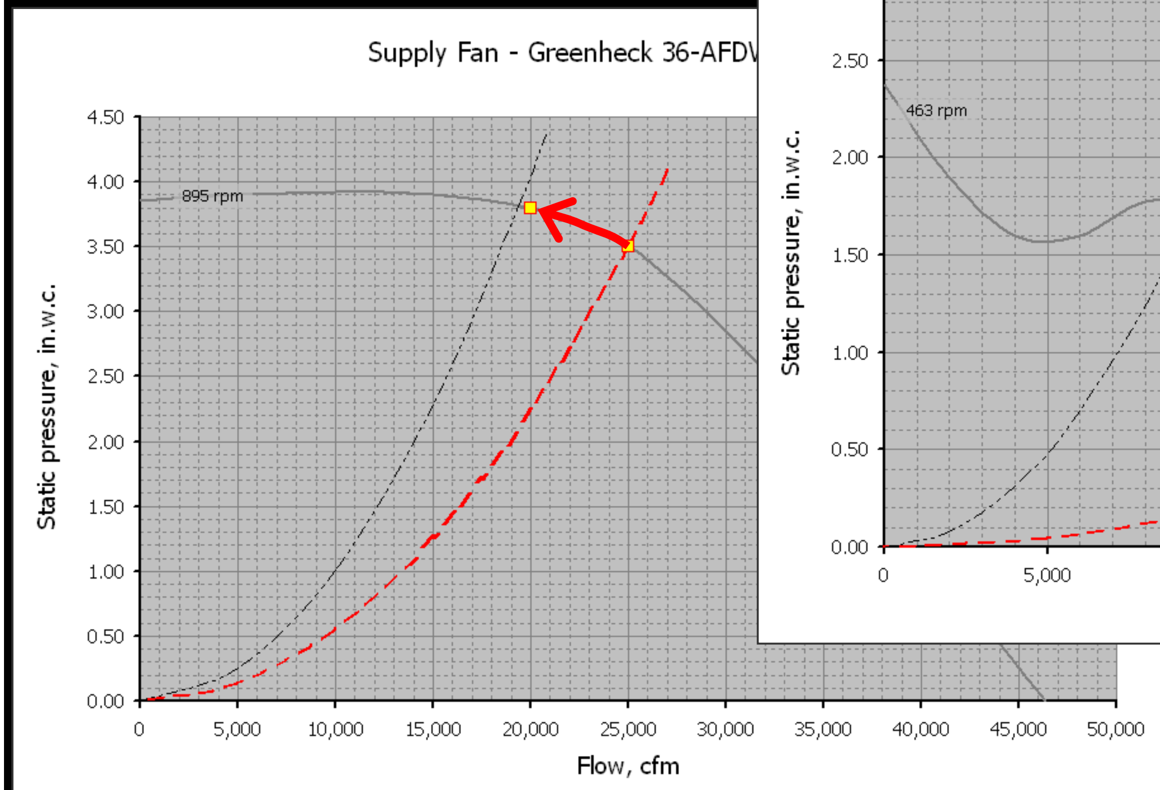


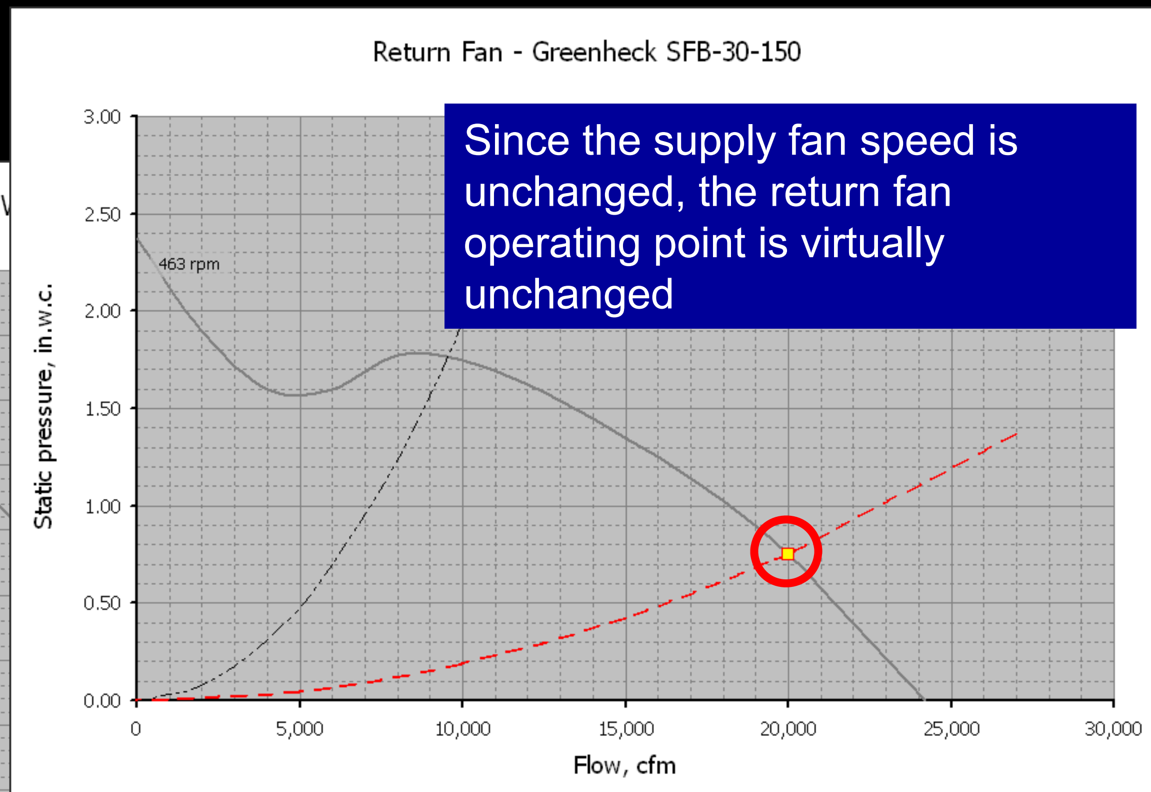


Flow differential = 5,000 cfm

Step 1:
The VAV Terminal Unit Throttles from 5,000 to 0 cfm

The VAV box throttling forces the supply fan up its curve





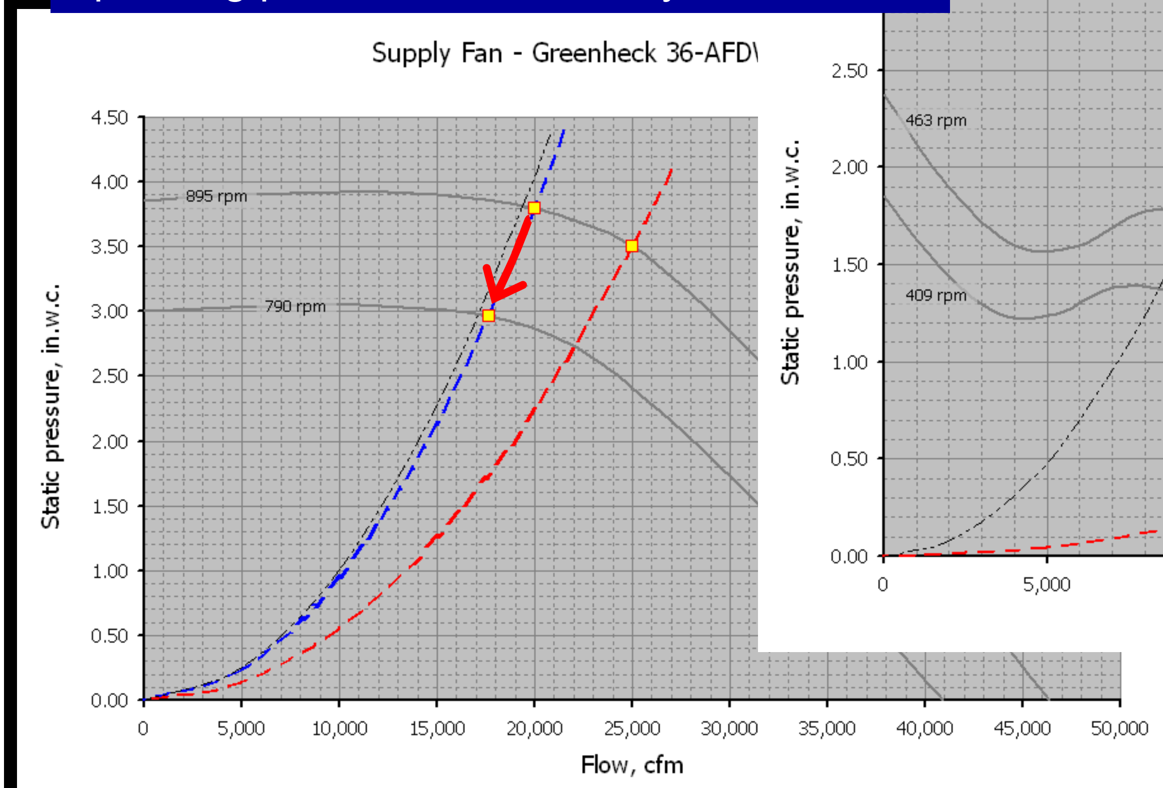
Since the supply fan speed is unchanged, the return fan operating point is virtually unchanged

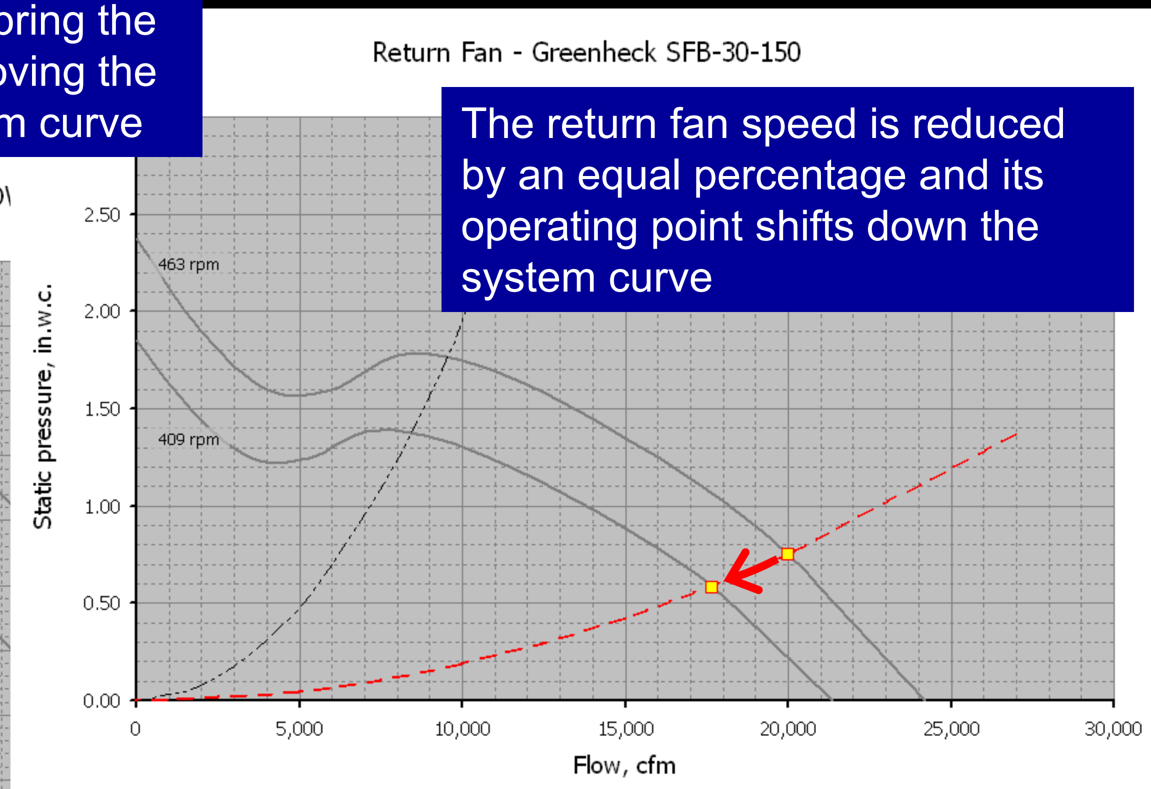
Flow differential = 0 cfm

Step 2:

The Supply Fan and Return Fan Operating Points Shift

The supply fan VFD slows down to bring the discharge static under control by moving the operating point down the new system curve





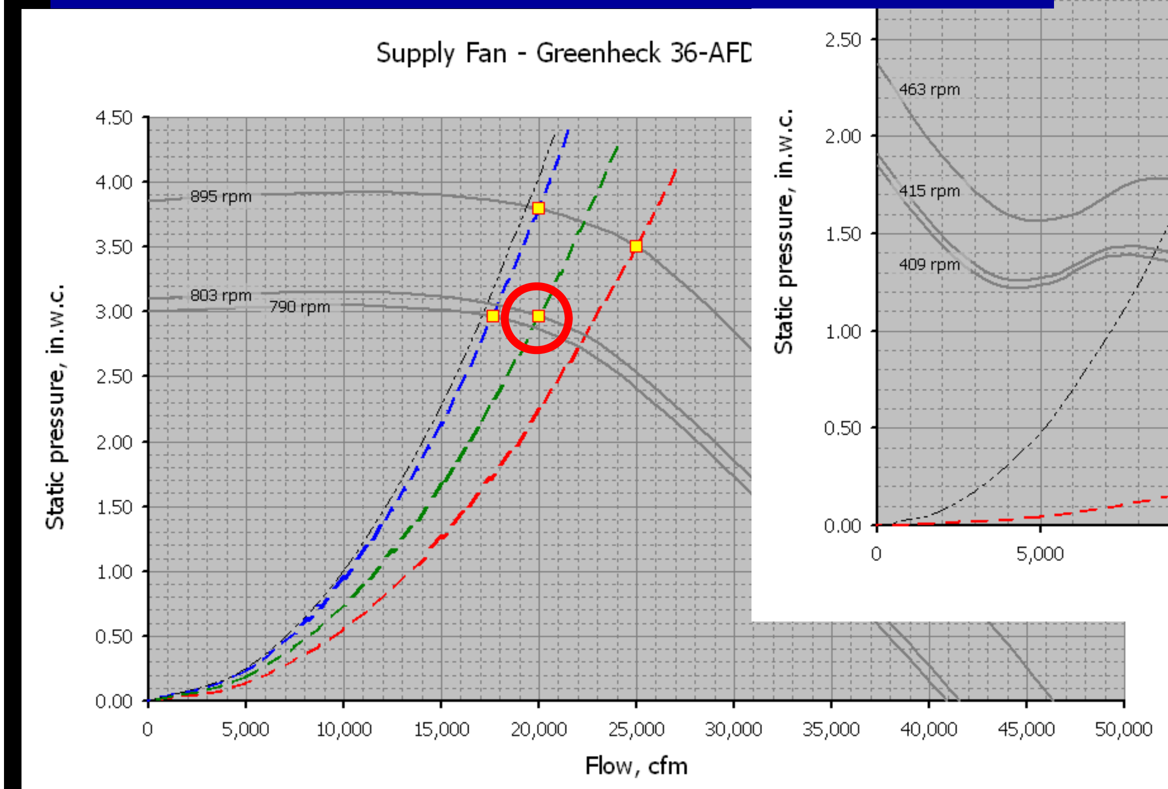
The return fan speed is reduced by an equal percentage and its operating point shifts down the system curve

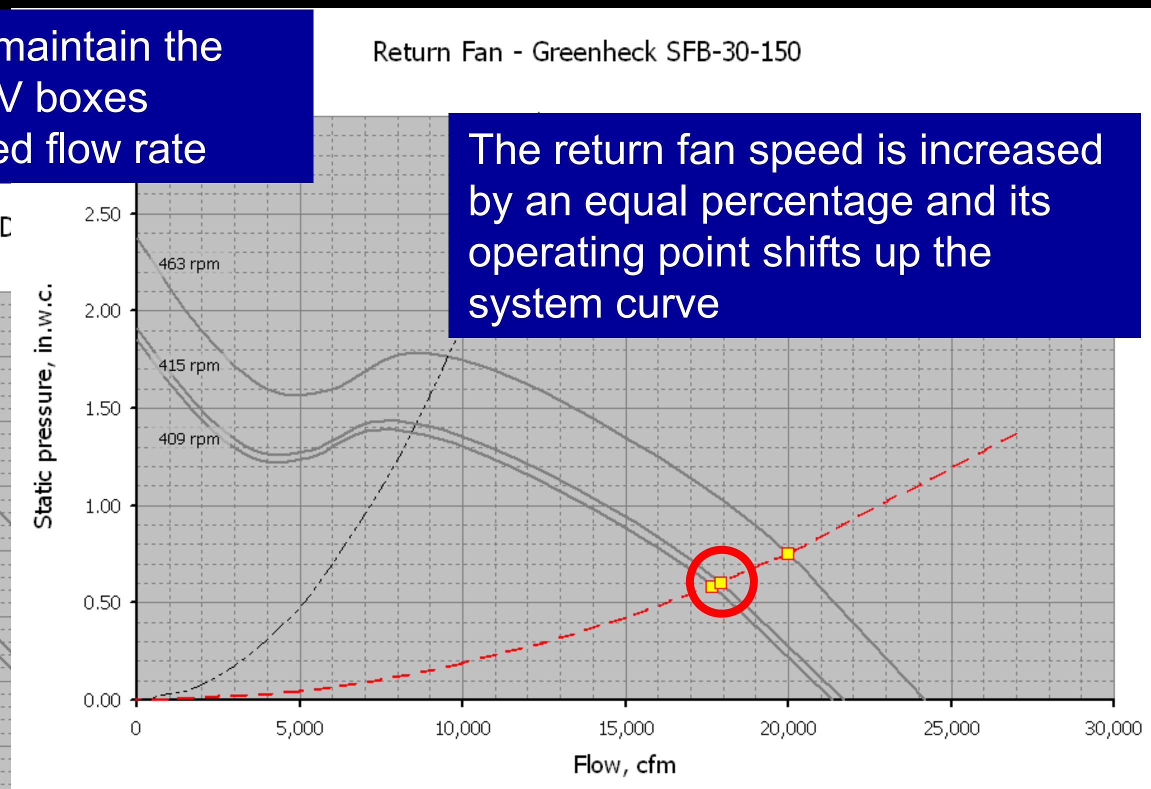
Flow differential = 0 cfm

Step 3:

The Supply Fan and Return Fan Operating Points Shift

The supply fan speed increases to maintain the discharge static pressure as the VAV boxes reposition to re-establish the required flow rate





The return fan speed is increased by an equal percentage and its operating point shifts up the system curve

Flow differential = 2,067 cfm

Summary

Step	Flow							
	Supply		Return		Outdoor Air		OA Deviation from Design	
	cfm	% Change	cfm	% Change	cfm	% of Supply	cfm	% of Supply
Desgin	25,000	Base case	20,000	Base case	5,000	20%	Base case	Base case
1	20,000	20%	20,000	0%	0	0%	-5,000	-20%
2	17,650	29%	17,650	12%	0	0%	-5,000	-20%
3	20,000	20%	17,933	10%	2,067	10%	-2,933	-10%

Step	Speed					
	Supply	Return	Change from Base Case			
			Supply		Return	
	rpm	rpm	rpm	%	rpm	%
Desgin	895	463	Base case	Base case	Base case	Base case
1	895	463	0	0%	0	0%
2	790	409	-105	-12%	-54	-12%
3	803	415	-92	-10%	-48	-10%