SUPPLY AIR CO_2

energy & IAQ

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HVAC Design since 1964
ASHRAE Standard 62 Committee 1996-2003

1 INTRODUCTION

About

- minimum outdoor air for ventilation
- outdoor air flow / person target
- systems that serve multiple spaces

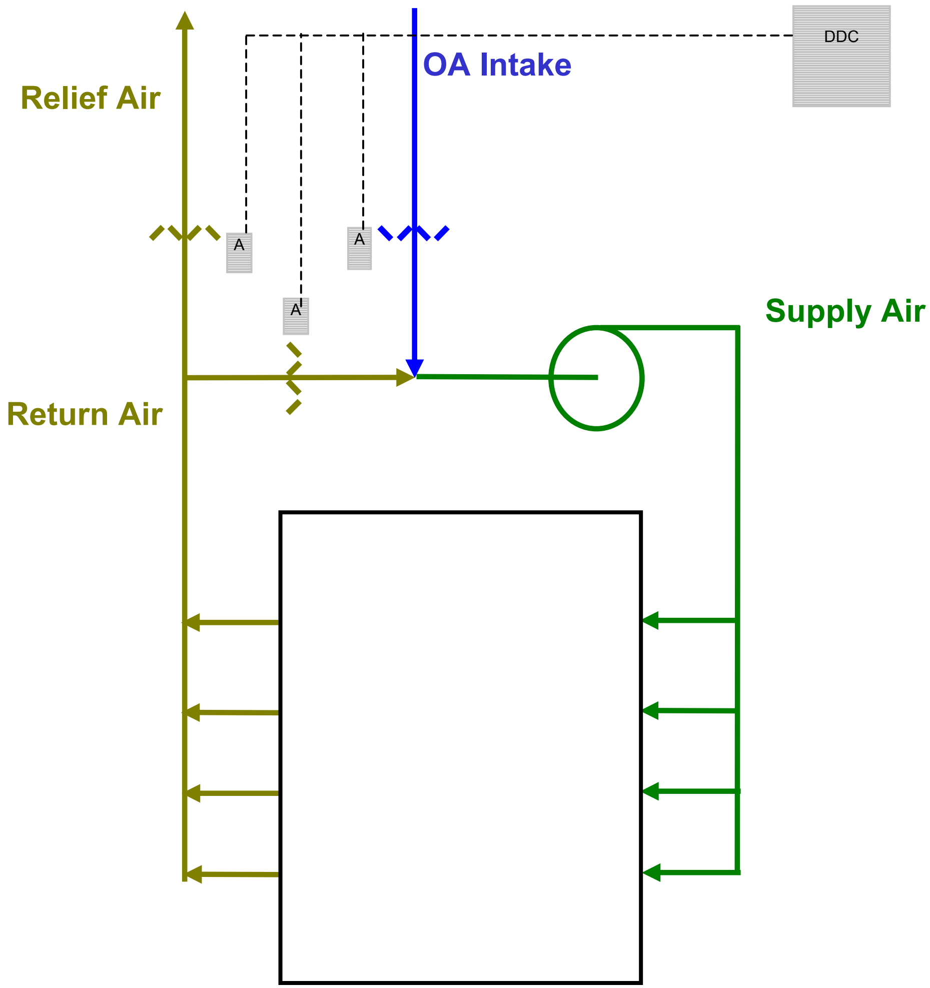
1.1 Goals for Minimum OA Control

Function:	Can ensure delivery of min. OA to the occupants
Setup:	Easy to set accurately whenever needed
Reliability:	Long term stability & fault alarms
Verifiability:	Easy to check setup & to record performance
Cost:	Low initial and long term costs
Energy:	Maximize efficiency under all conditions – DCV
Applicability:	to many systems, specially problem systems

1.2 General approaches

- fixed minimum intake (passive or active)
- control OA/person in space
- control OA fraction in supply air

1.2.1a fixed minimum position intake

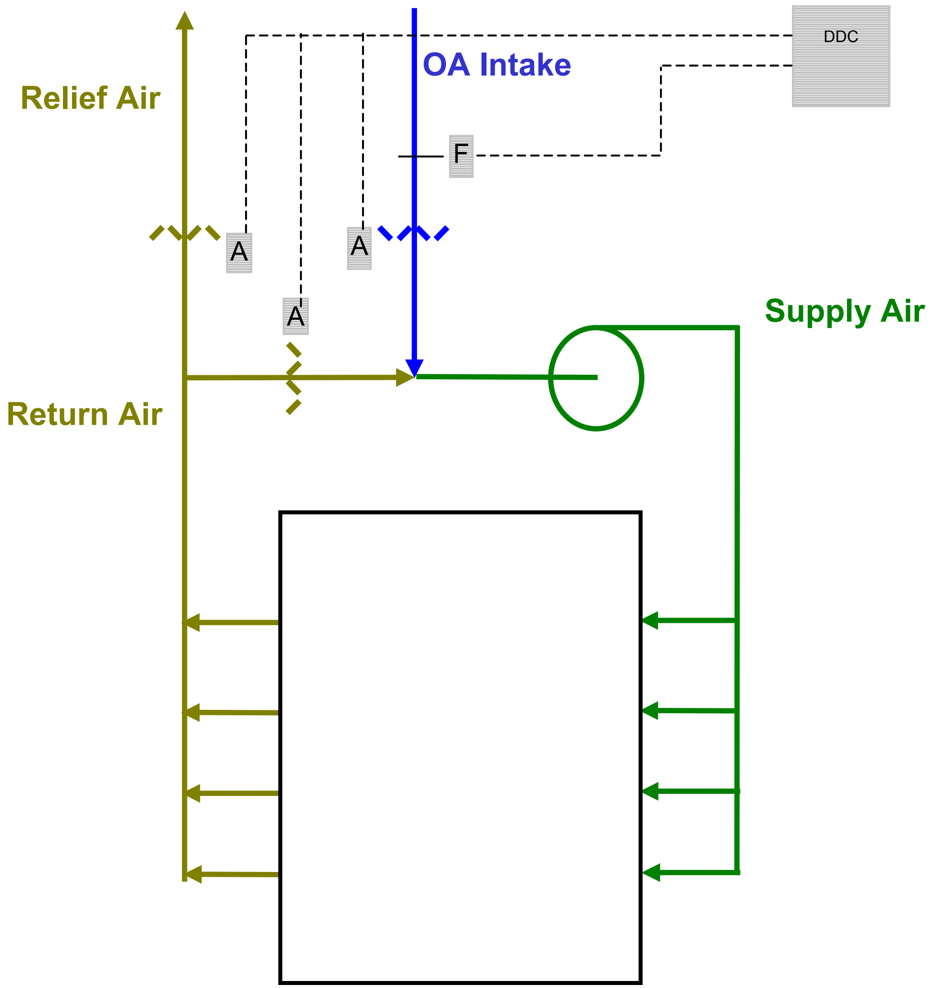


One example

Control system sends a fixed minimum signal to the dampers (Say 20%).

Intent is to provide a set minimum damper position.

1.2.1b fixed minimum flow intake

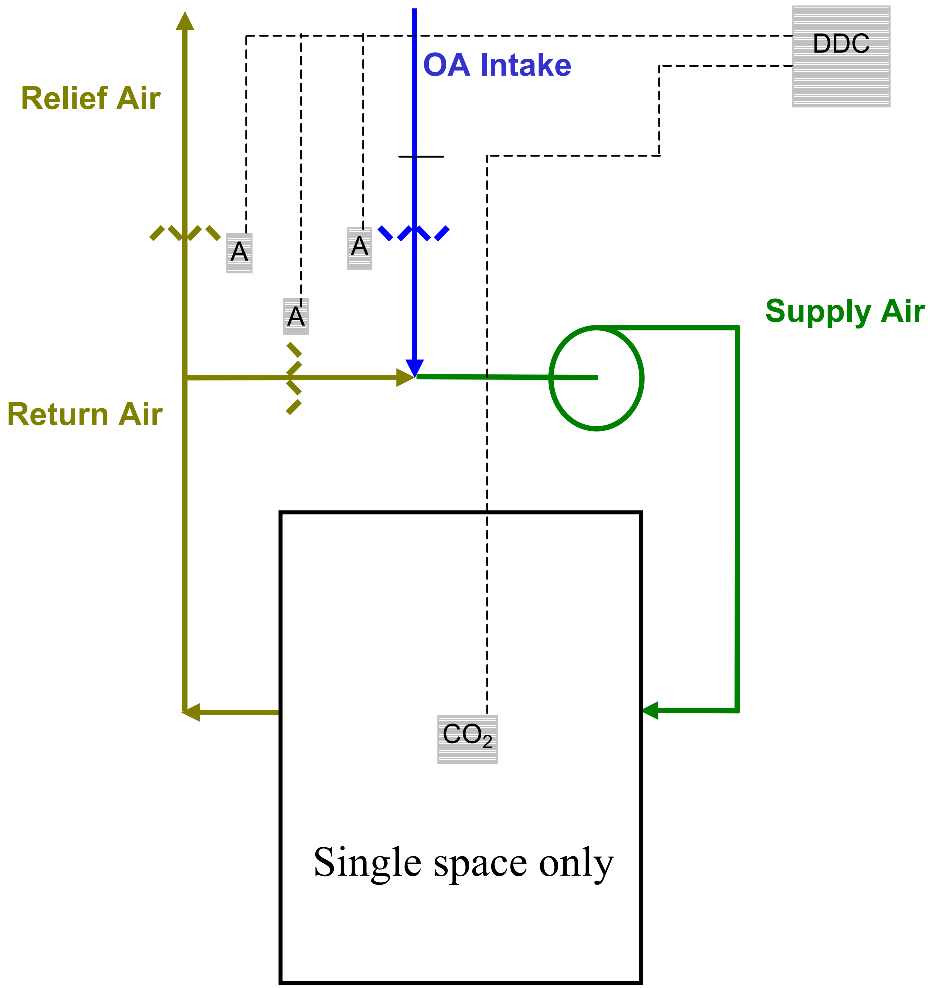


One example

Control system senses flow and controls dampers.

Intent is to maintain a fixed minimum outdoor air flow.

1.2.2 fixed min. OA / P in space

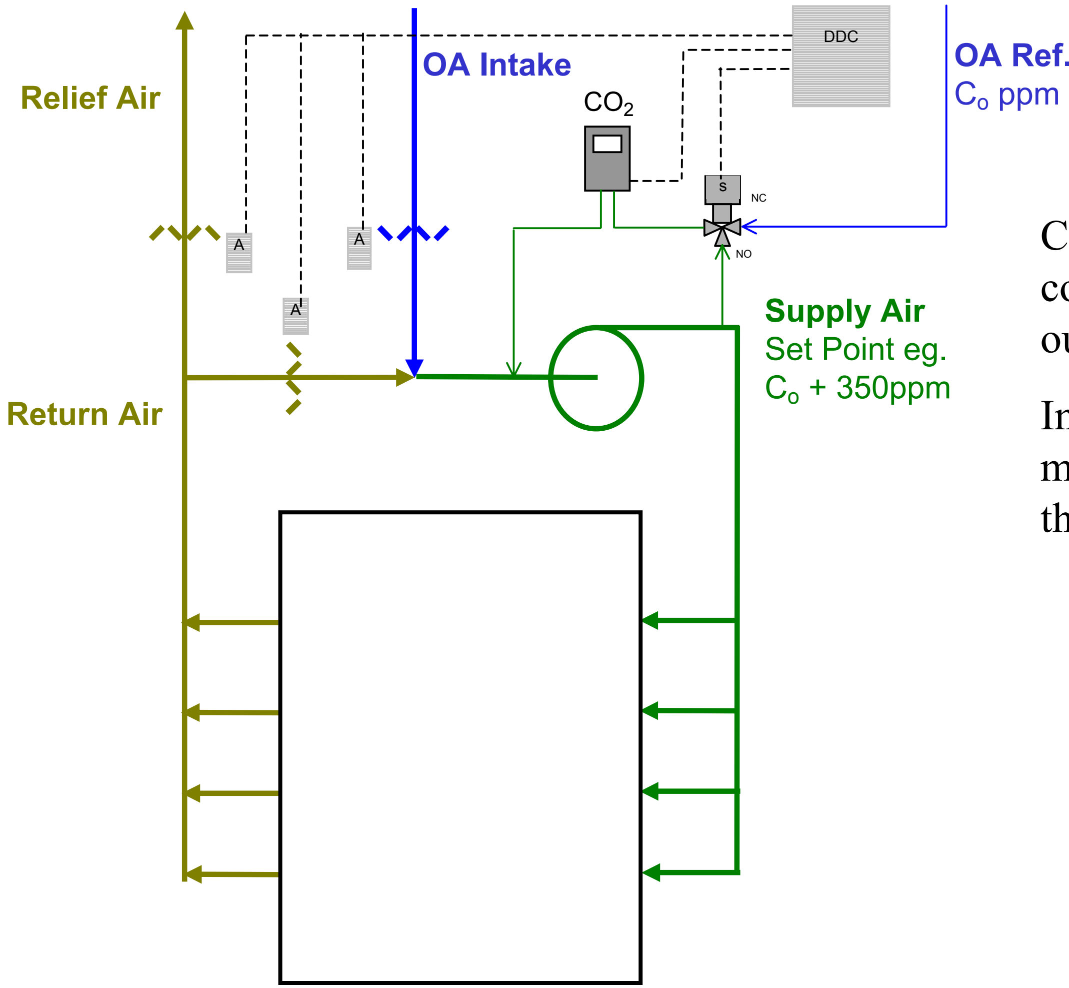


Control system senses CO_2 concentration in space.

Intent is to maintain a fixed minimum OA flow per person to space.

NOTE: Practical for single space systems. Multiple space issues discussed later.

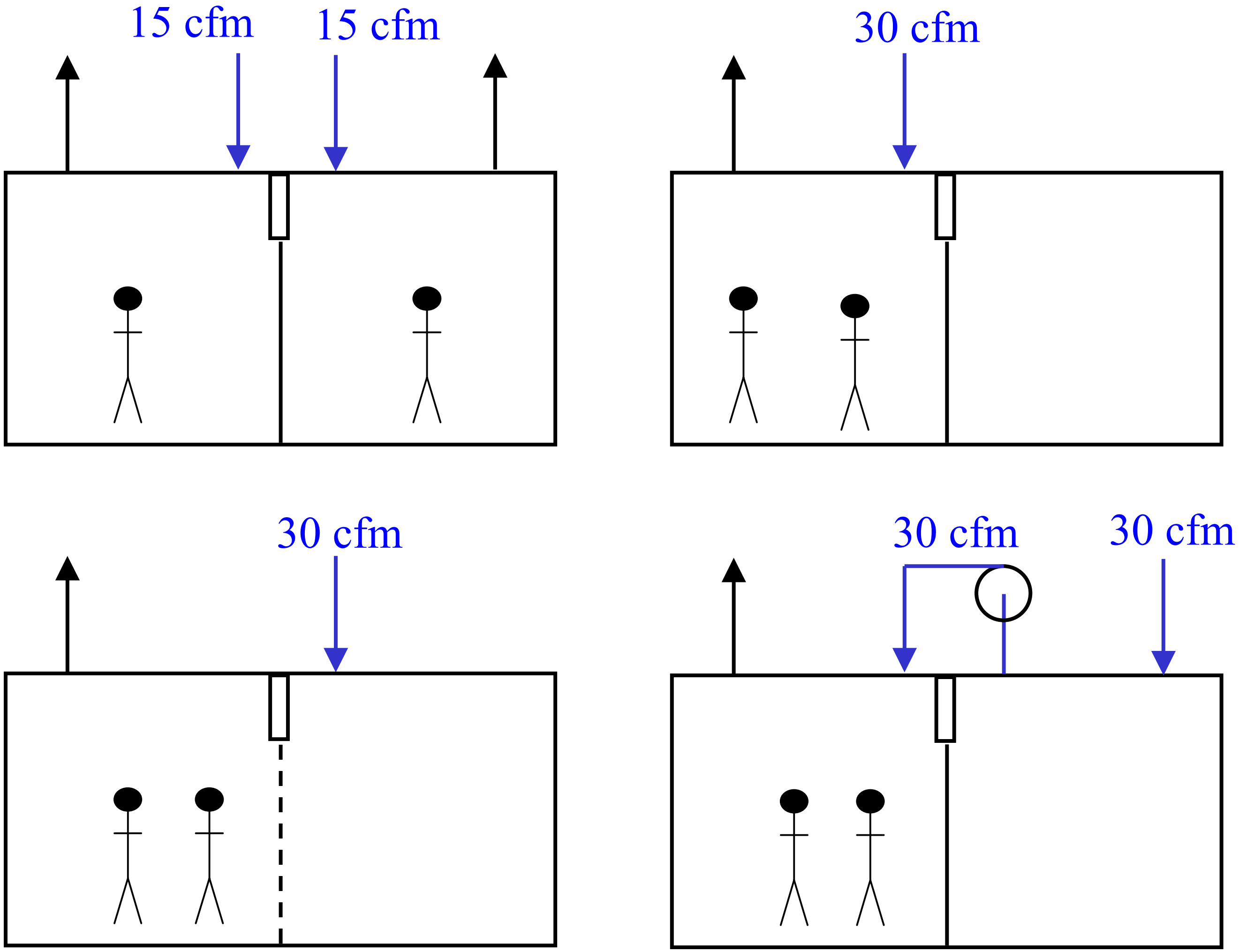
1.2.3 OA fraction in supply air



Control system senses CO_2 concentration rise between outdoors and supply air.

Intent is to maintain a fixed minimum OA fraction in the supply air.

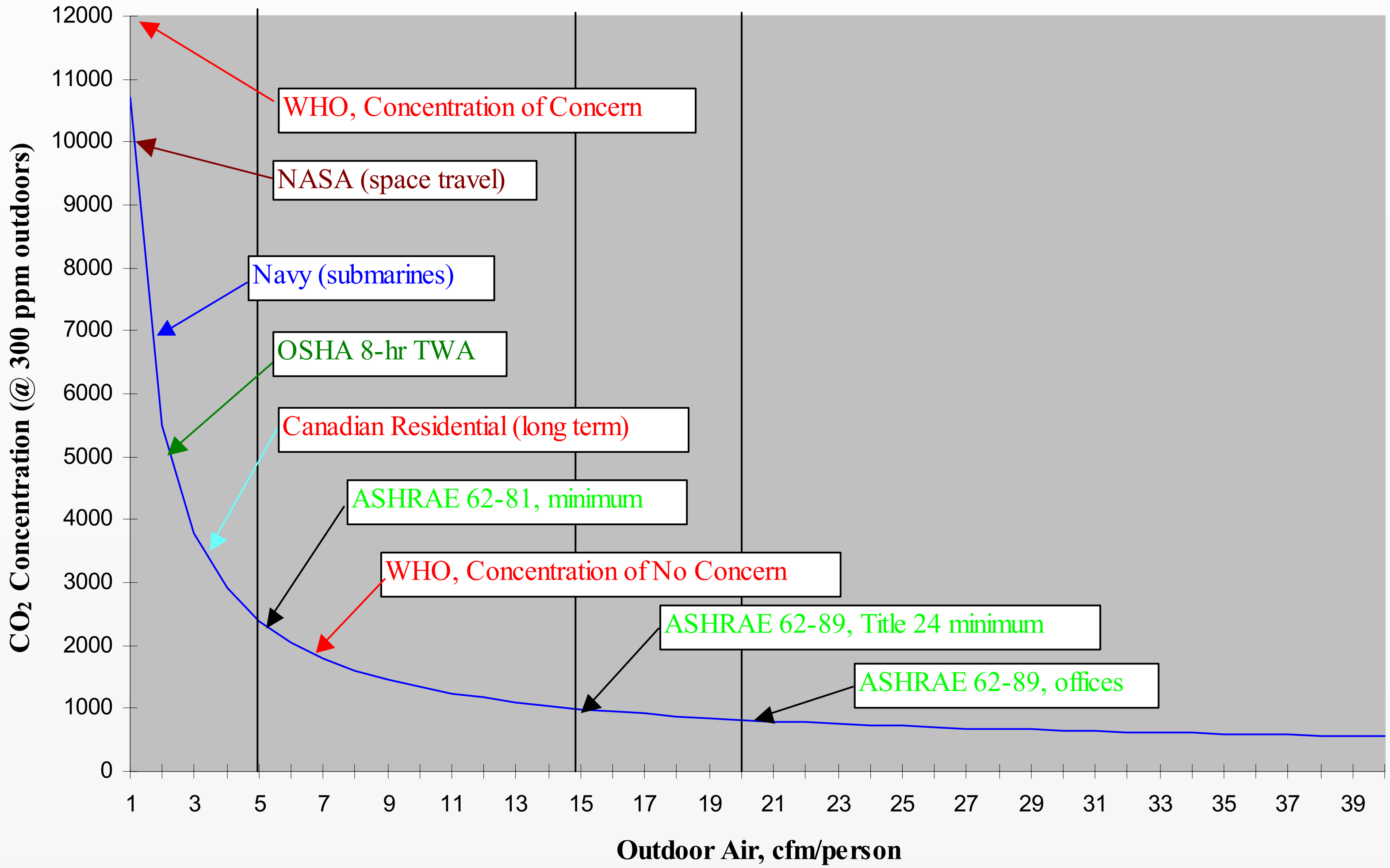
1.3 Unused Outdoor Air



1.4.1

CO_2 Concentration

It's not the concentration that matters!



1.4.2 CO_2 and Ventilation rates

It's the difference in concentration.

Based on steady state conditions.

$$C_L - C_E = 1{,}000{,}000 \times N \times M / V_o$$

Where:

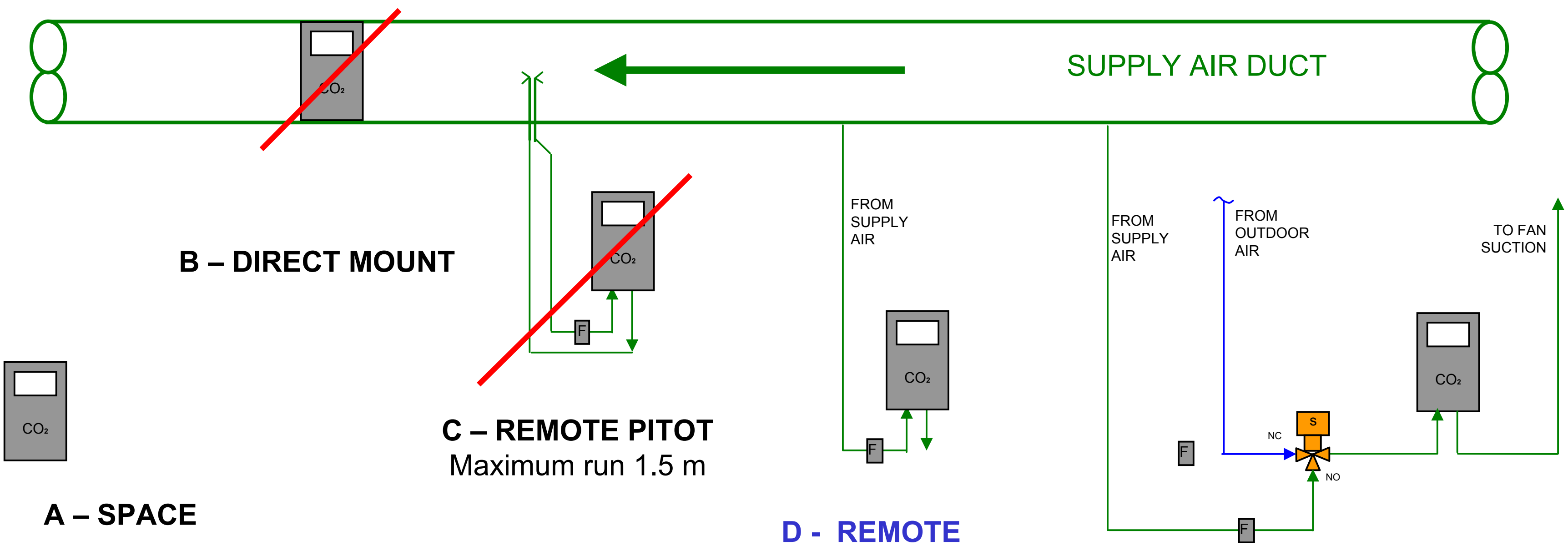
- C_L = CO_2 concentration leaving, ppm (C_S in Std 62)
- C_E = CO_2 concentration entering, ppm
- N = base CO_2 generation rate per person, L / sec / person
- M = Metabolic rate (Met)
- V_o = Outdoor air flow rate per person, L / sec / person

Ref: ASHRAE Standard 62-2001 Appendix C (different terms)

1.4.3 CO_2 Sensors

1. Not perfect devices
2. Now good enough
3. Select and apply carefully

1.4.4 CO_2 Sensor Installation



D - REMOTE

For supply ducts only, as positive pressure is required.
Run can be 10 m or more.
Sensor located for easy inspection & maintenance.

E – OUTDOOR AIR REFERENCE

Much more accurate.
Works anywhere.
Long run OK.
Sensor located for ease of service.
Automatic alarm possible.

1.4.5 CO_2 Sensors - consider

1. Accuracy and stability
2. Local readout
3. Calibration scale
4. Ease of calibration
5. Auto calibration

2 OA CALCULATIONS

For multiple space recirculating system

- Need a multiple space calculation method
- Standard 62 requires this but is confusing at best

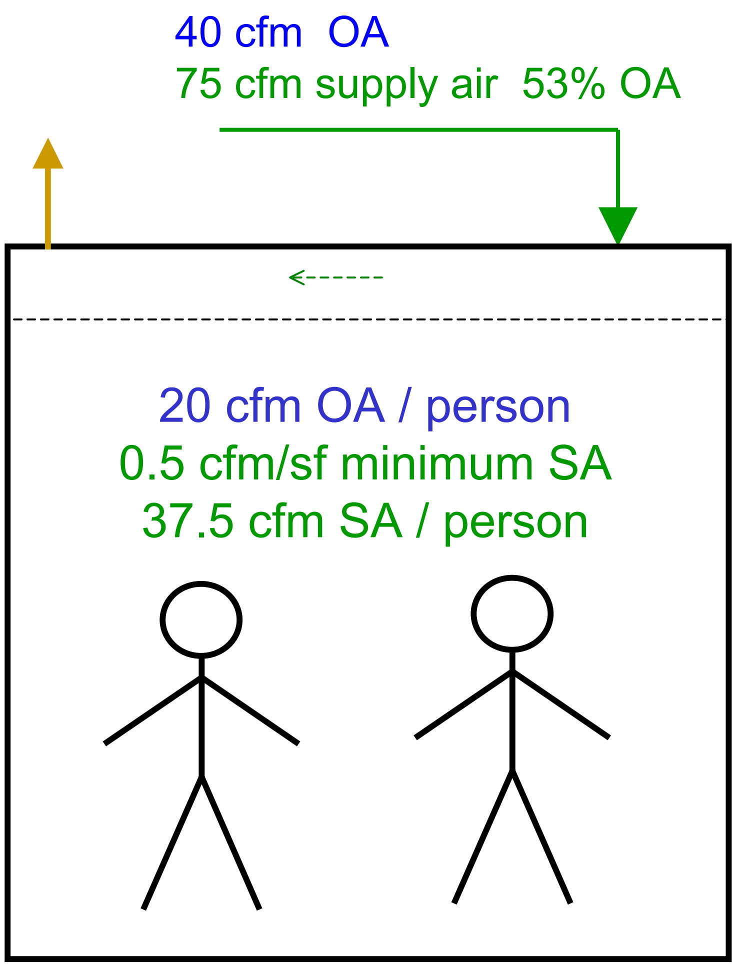
Calculation steps:

1. OA fraction needed in supply
2. Supply air needed in each space type
3. OA used in system
4. Minimum OA intake

Explains outdoor air in multiple space systems.

Much easier and better than the traditional calculation approach

2.1 OA Fraction in Supply Air



<u>Based on</u>

Private office, 150 sf,

210 watts from lights and equipment,

57 deg F supply air,

two people present

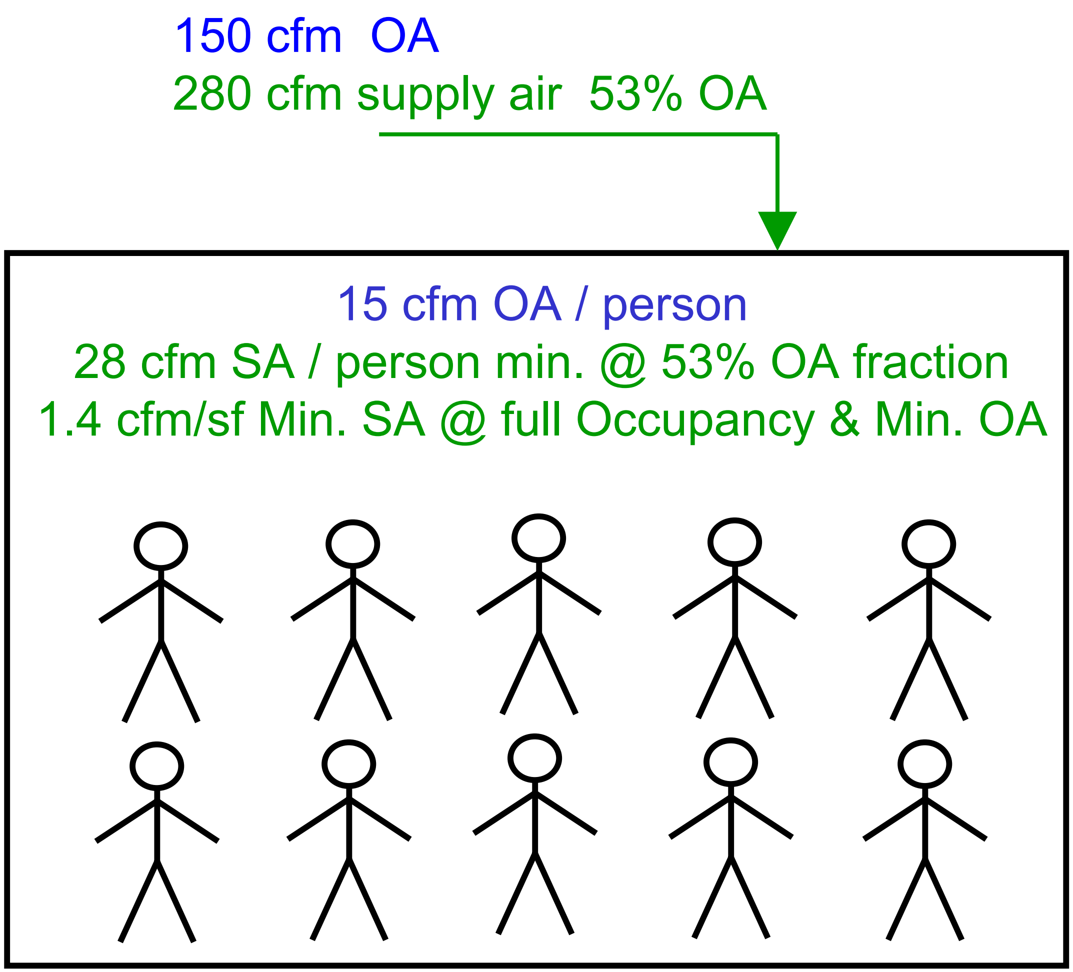
0.5 cfm/sf (VAV min.)

$E_{ac} = 1$

Fraction of outdoor air needed in supply air. Z = Voz/Vsz

Z = 20 / 37.5 = 0.53

2.2 Min. SA to each space type



Example:

<u>Meeting Room Spaces</u>

20 sf/person

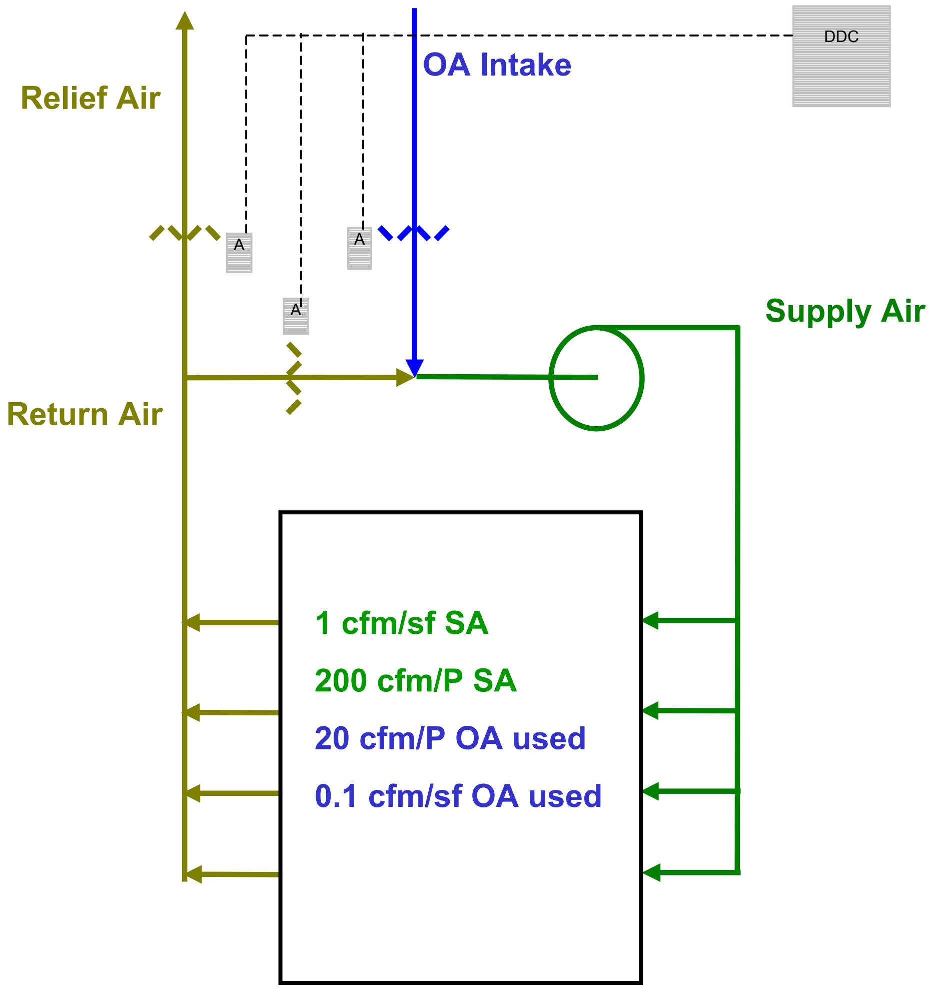
Eg. 10 people in 200 sf

Supply flow to meet peak ventilation demand using known min. OA fraction

Rsz = Roz / Z = 15 / 0.53 = 28 cfm/person

Vsz = Rsz / Ap = 28/20 = 1.4 cfm/sf

2.3 Outdoor air "used" in system



<u>Based on</u>

VAV System

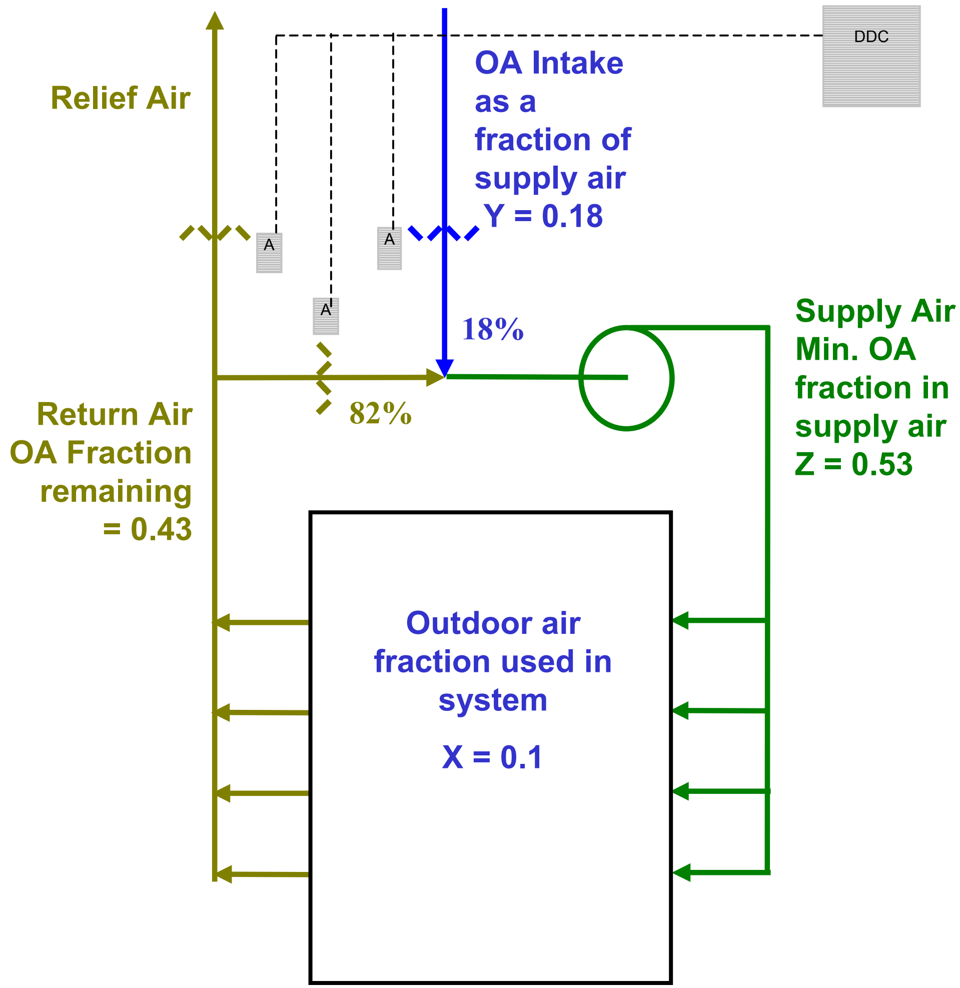
200 sf/person

All people in "office" space (worst case)

1 cfm/sf

X = Outdoor air used as a fraction of supply air = 20 / 200 = 0.1

2.4 Minimum OA Intake



Equation 6-1 (std 62)

$$Y = X / [1 + X - Z]$$

X = outdoor air used as a fraction of system SA = 0.1

Z = outdoor air fraction needed in SA = 0.53

$Y = 0.1 / [1 + 0.1 - 0.53] = 0.18$

i.e. outdoor air intake 18%

Needed for

- Equipment sizing
- Flow set point with std. Control
- Reality Check

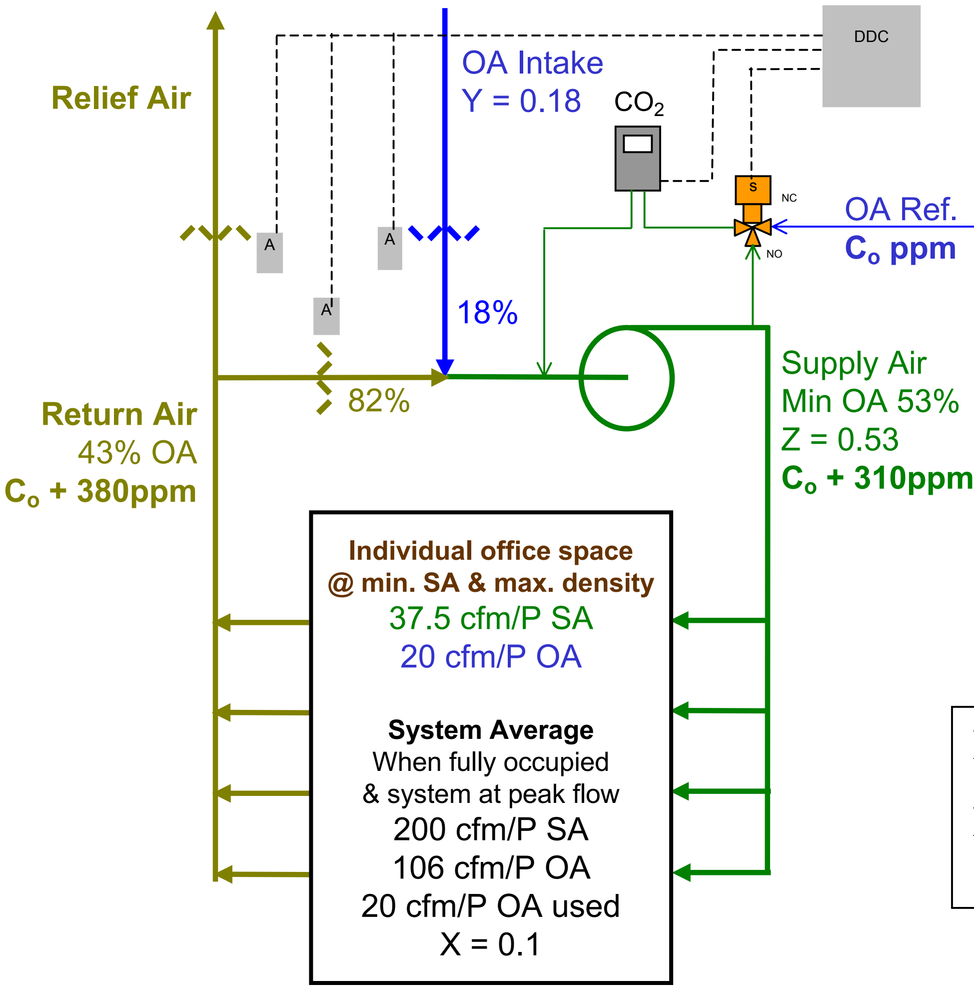
3 CO_2 CALCULATIONS

For SA CO_2 control

- Maximum SA CO_2 rise

First a word about CO_2

3.3 SA CO_2 Rise



If all of outdoor air supplied by the system were used, the concentration rise to the return air would be:

$$C_u - C_o = 1{,}000{,}000\ N\ M / V_o$$

$$= 1{,}000{,}000 \times 0.011 \times 1.2 / 20 = 660 \text{ ppm}$$

If $C_s - C_o = 660$ ppm, there is no outdoor air in the supply and if $C_s - C_o = 0$ ppm there is 100% outdoor air in the supply.

So when Z = 0.53 (OA fraction of 53%)

$$C_s - C_o = (1 - 0.53) \times 660 = 310\text{ppm}$$

For this system

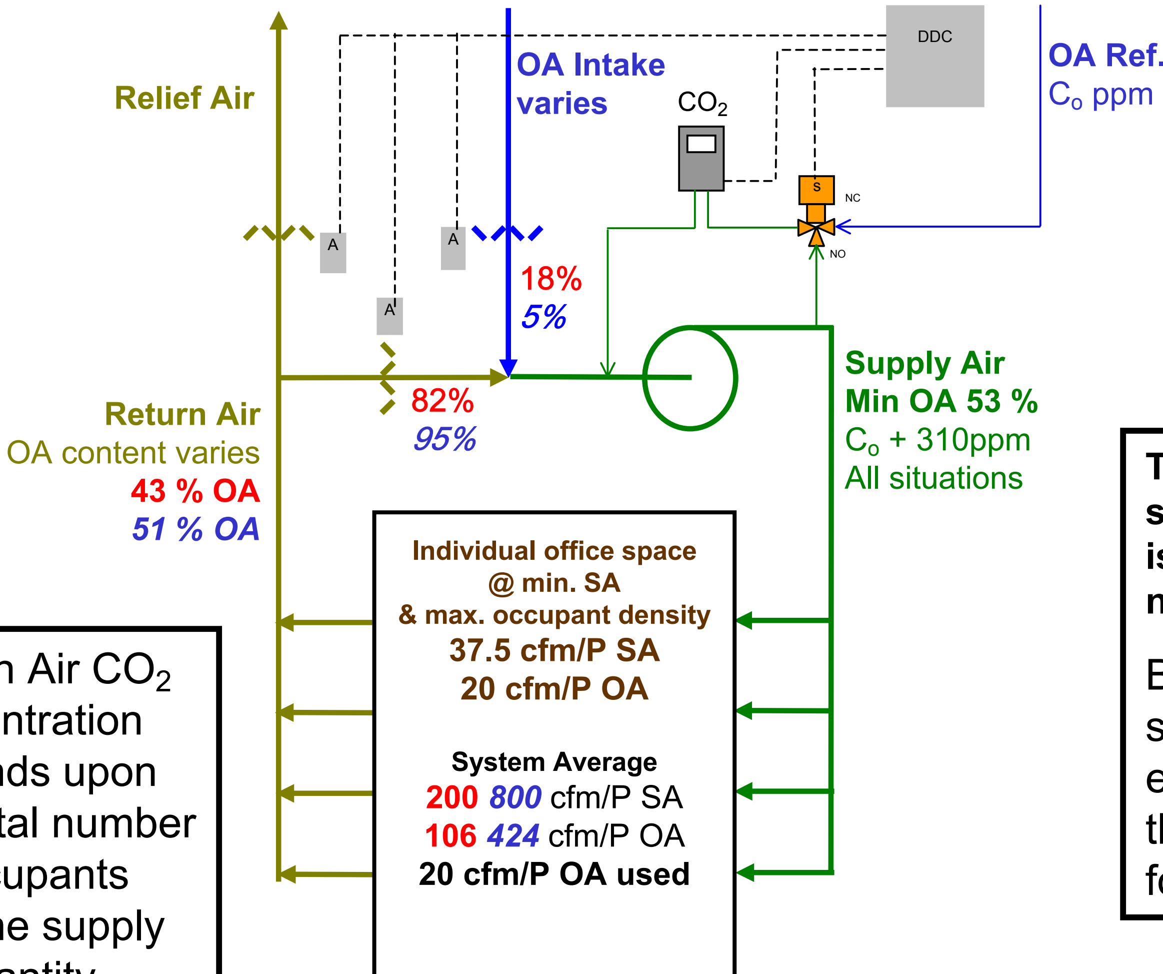
If the supply air is no more than 310ppm above outdoors than ventilation is OK.

4 SUPPLY AIR CO_2 CONTROL

How does it work?

How does it measure up?

4.1 SA CO_2 @ Peak & *Partial* Occupancy



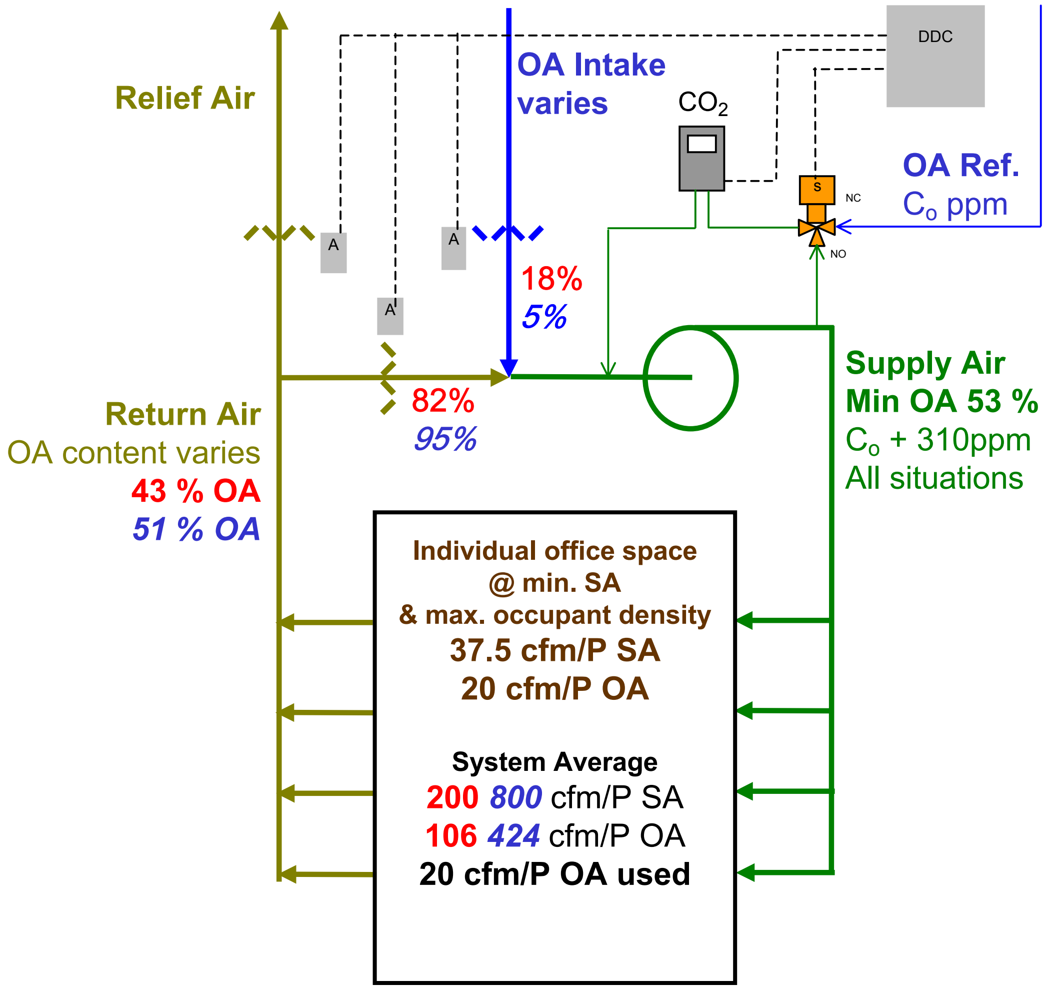
Minimum OA intake reduces when the total number of occupants reduces even if some spaces are still at peak design occupancy.

Return Air CO_2 concentration depends upon the total number of occupants and the supply air quantity.

The maximum acceptable supply air CO_2 concentration is unaffected by the total number of occupants.

Both **Peak** and ***Partial*** supply air contains just enough outdoor air to satisfy the peak design condition for an individual space.

4.1 SA CO_2 Performance



Set up at any time in minutes

Adjusts for short circuiting of relief air & for open windows

Stability not perfect but it can alarm faults and

Function is easily checked

Can log performance

Reasonable cost

Energy saving through DCV

Handles VAV

5 OA Control Alternatives

If it ain't broke don't fix it. Unfortunately its broke!

Fixed Setting

- Min. position for OA Damper
- Separate OA Damper
- Separate OA Fan

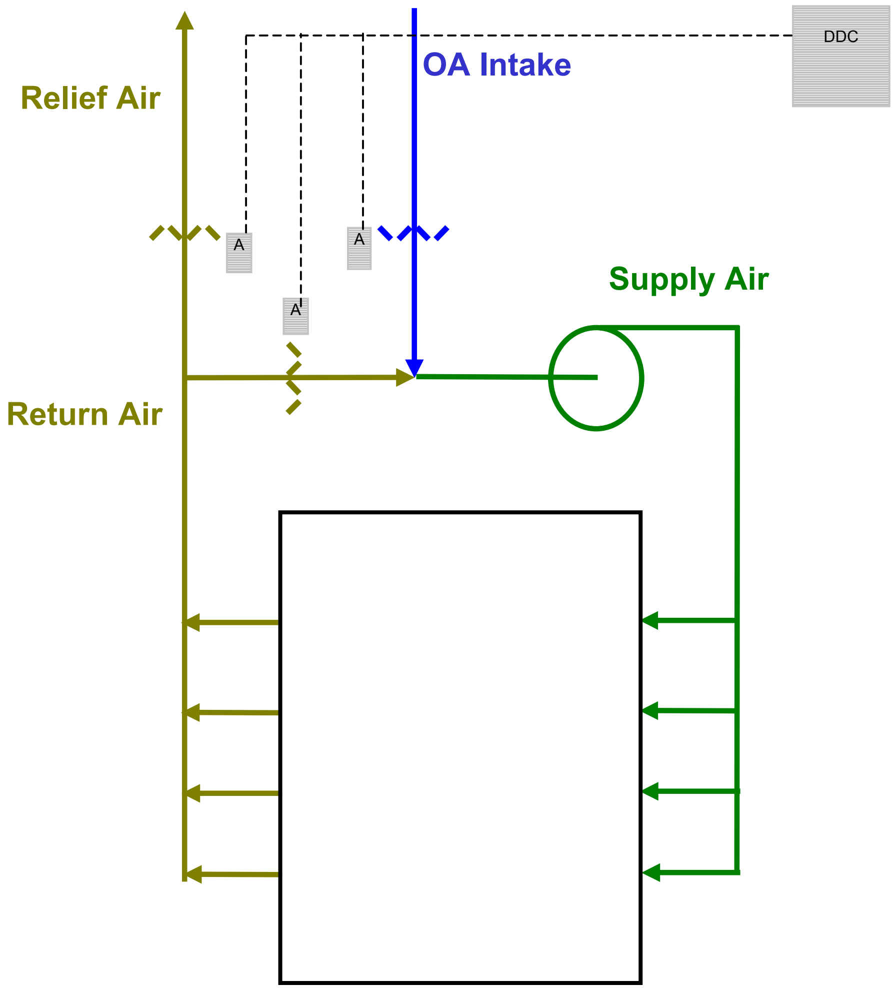
Active Control

- Temperature balance
- OA Flow sensor
- Constant pressure drop

DCV

- Space CO_2
- Return Air CO_2
- Supply Air CO_2

5.1 fixed minimum position intake



Control system sends a fixed minimum signal to the dampers (Say 20%).

Set up problems: Generally can't measure minimum intake flow and can only do temperature balance in cold weather.

Damper positioning unreliable

No indication of failure

No easy way to check if its working

No record of performance

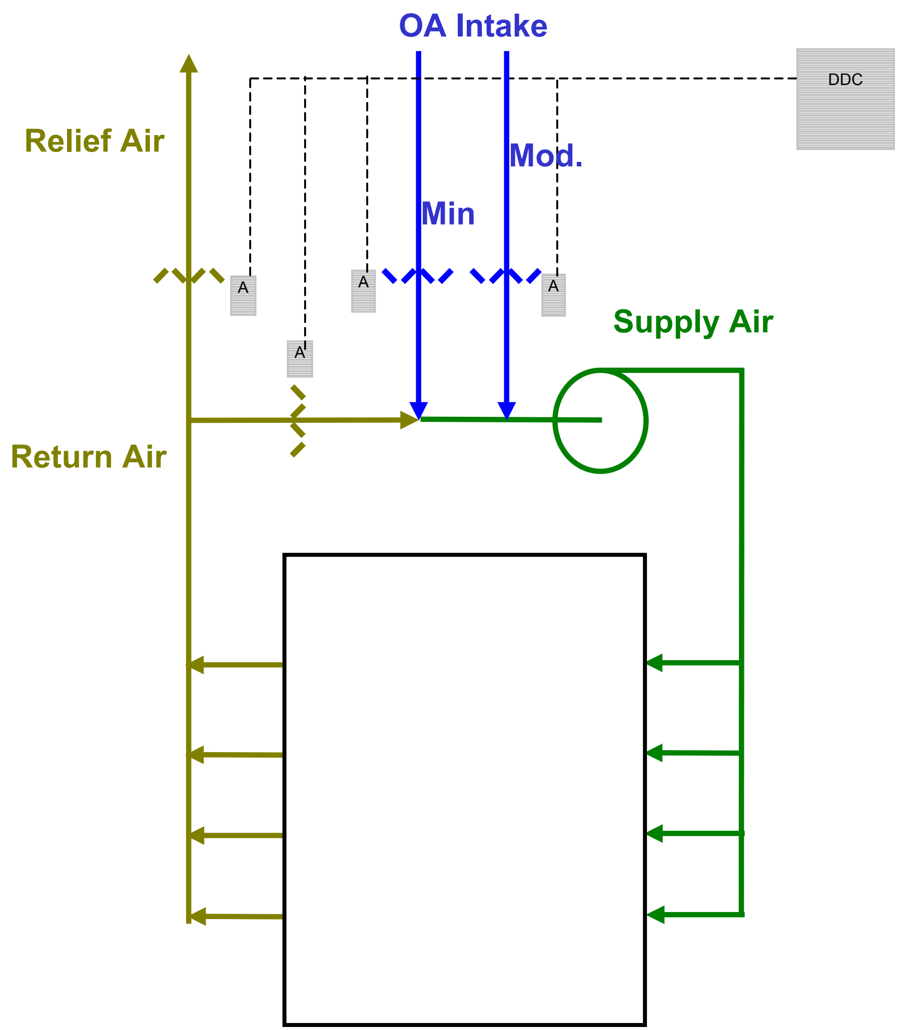
Cheap to install,

Expensive to recalibrate

Does not respond to demand

Does not handle VAV

5.2 Separate minimum OA damper



Control system sends a fixed minimum signal to the min OA damper (Say 80%).

Generally can't measure minimum intake flow and can only do temperature balance in cold weather.

Damper positioning unreliable

No indication of failure

No easy way to check if its working

No record of performance

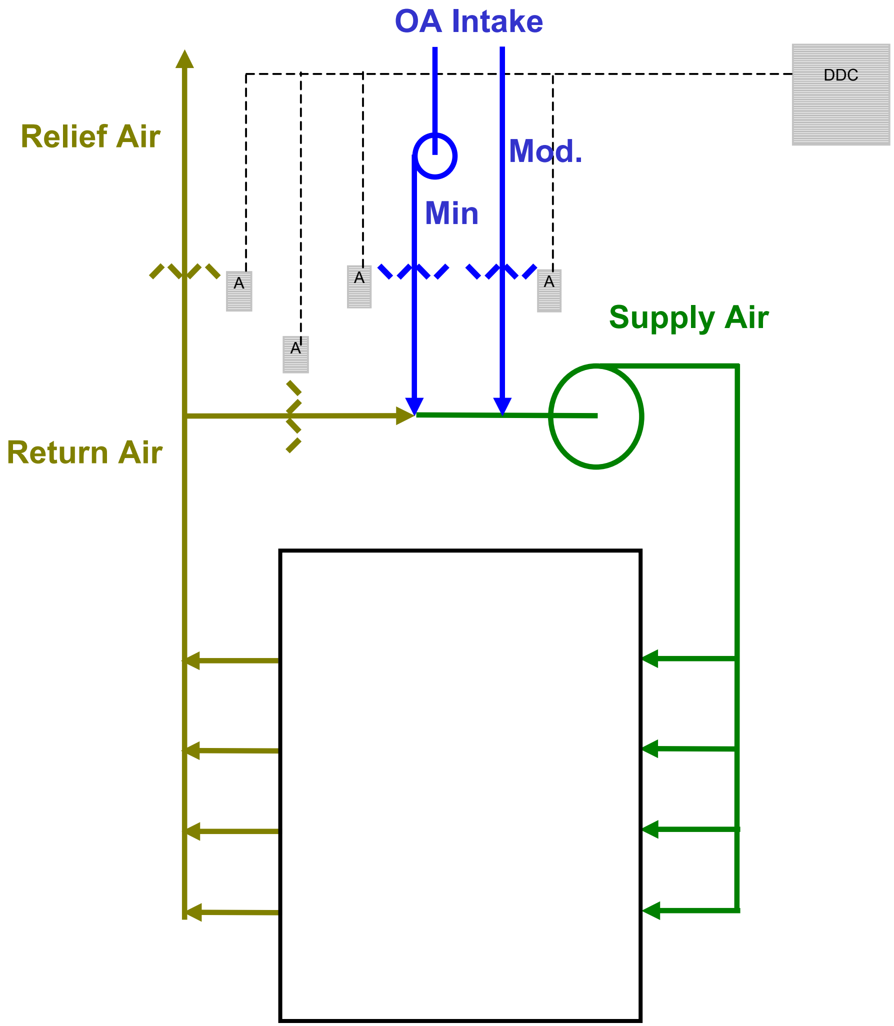
Reasonable cost

Expensive to recalibrate

Does not respond to demand

Does not handle VAV

5.3 Separate minimum OA fan



Dedicated fan delivers minimum OA to meet peak ventilation needs.

Can usually measure min. OA flow

Can see if its failed & can alarm it

Can record operation (not result)

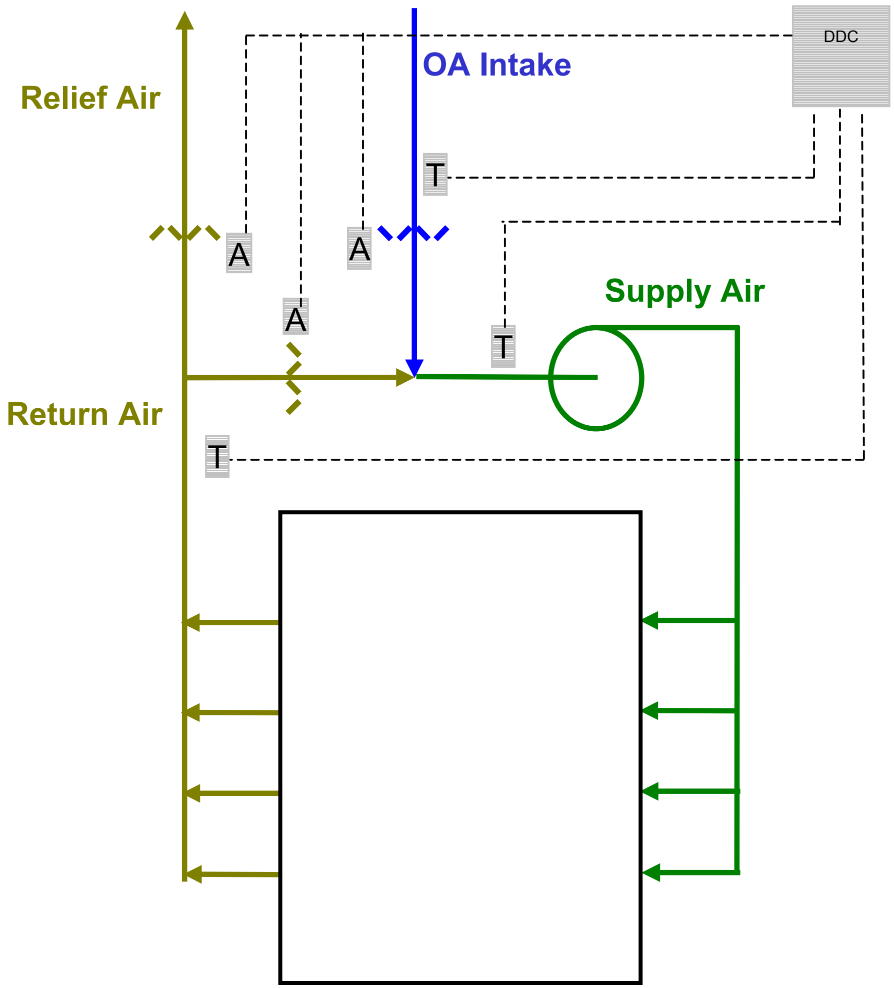
Extra Cost

Recalibration affordable and not often needed

Does not respond to demand

Handles VAV

5.4 temperature balance



System calculates OA intake fraction based on temperature readings. Calculates intake flow based on total flow and controls intake to maintain fixed minimum flow.

Only works in cold weather

Getting a realistic reading on mixed air temperature usually a problem

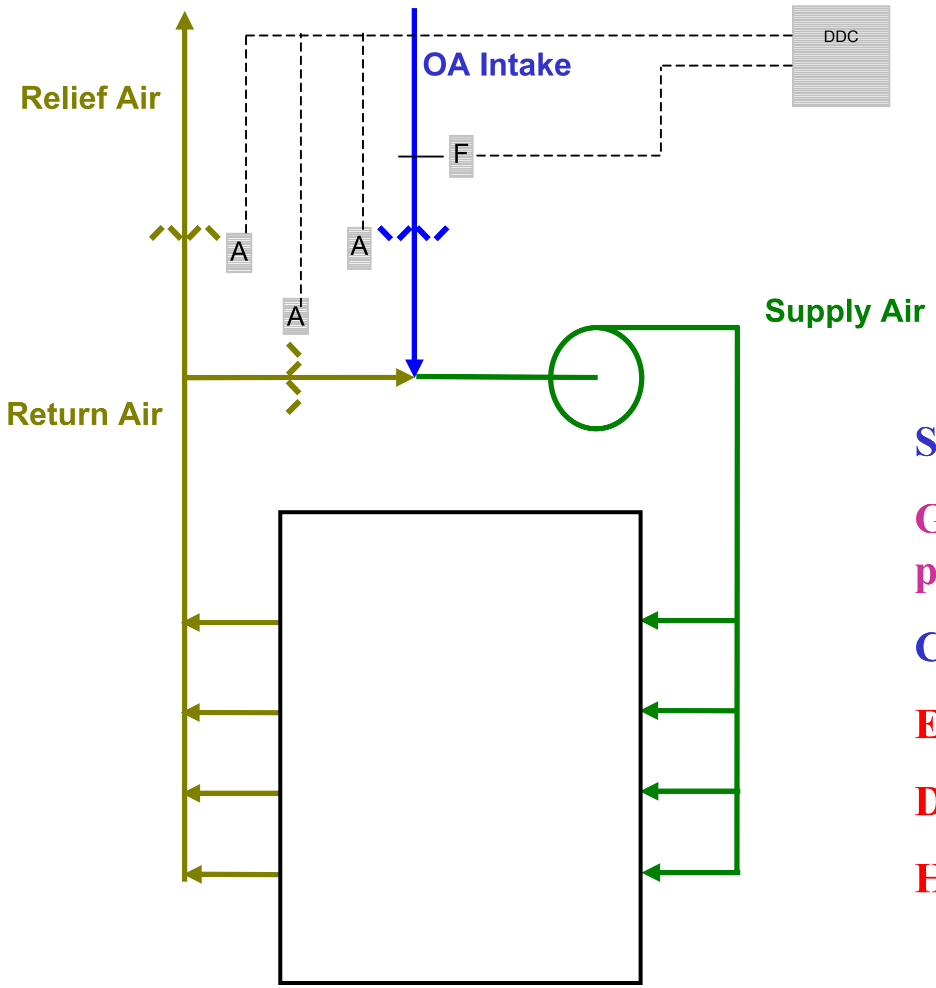
Can record performance if working

Cheap to install

Does not respond to demand

Does not handle VAV

5.5 flow sensing



Control system senses flow and controls dampers.

Intent is to maintain a fixed minimum outdoor air flow.

Set up OK

Getting a good flow reading can be a problem

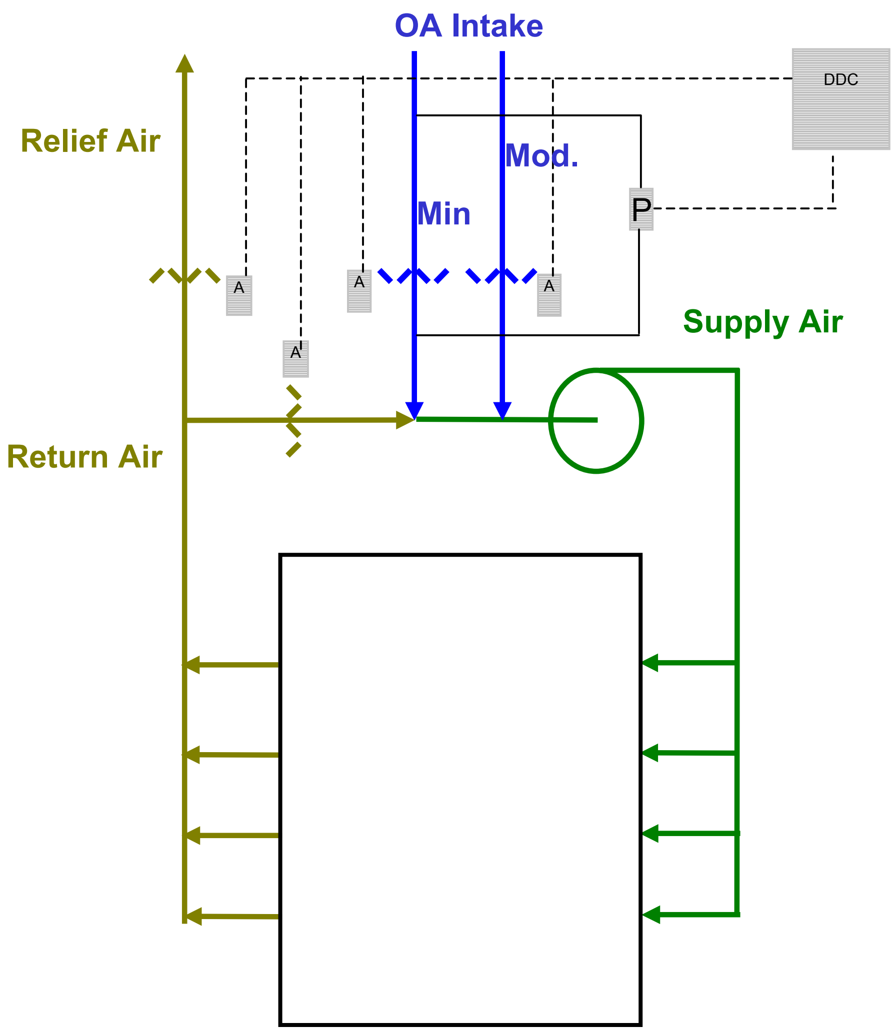
Can record performance

Expensive

Does not respond to demand

Handles VAV

5.6 constant pressure drop



Control system controls recirc damper so that pressure across fixed min OA damper is constant.

Generally can't measure minimum intake flow and can only do temperature balance in cold weather.

Damper positioning reasonable

Some indication of failure possible

Feasible to check

Partial record of performance

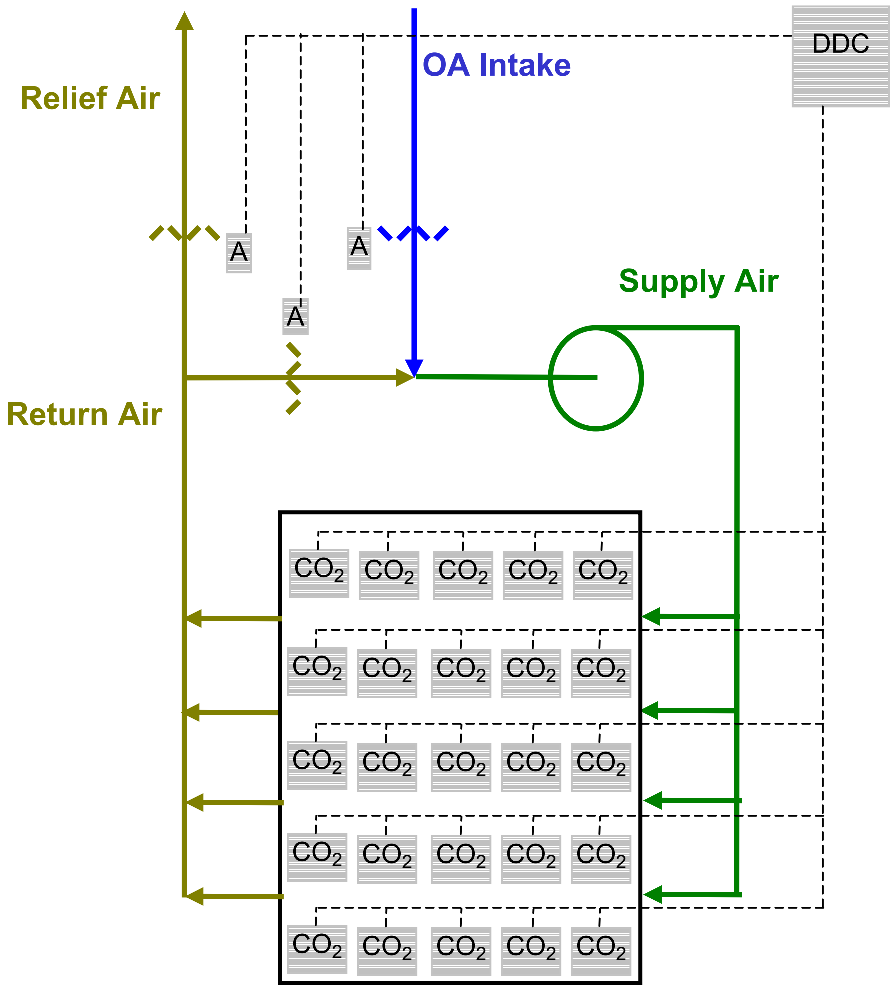
Reasonable cost

Expensive to recalibrate

Does not respond to demand

Handles VAV

5.7 Space CO_2



System controls intake to satisfy the space with the greatest demand.

Many sensors to set up.

Set up at any time

High Probability of failure

Large task to check

Can record performance

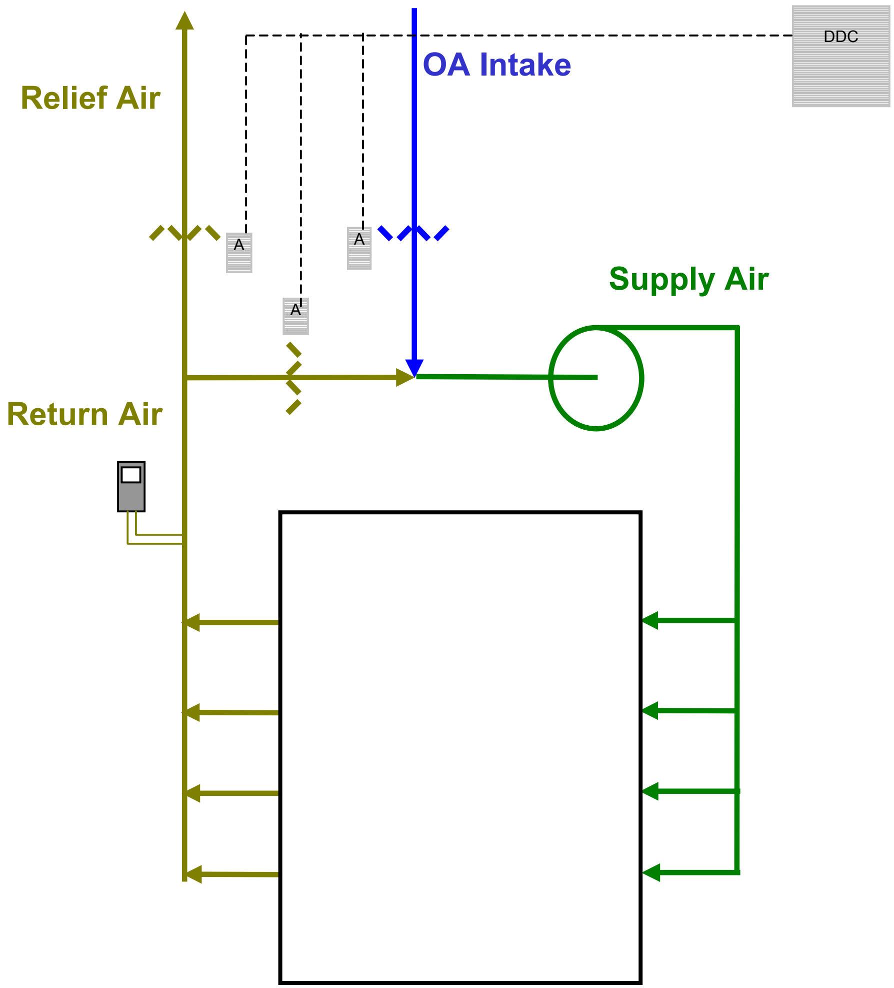
Very high cost

Expensive to recalibrate

Responds to demand

Handles VAV

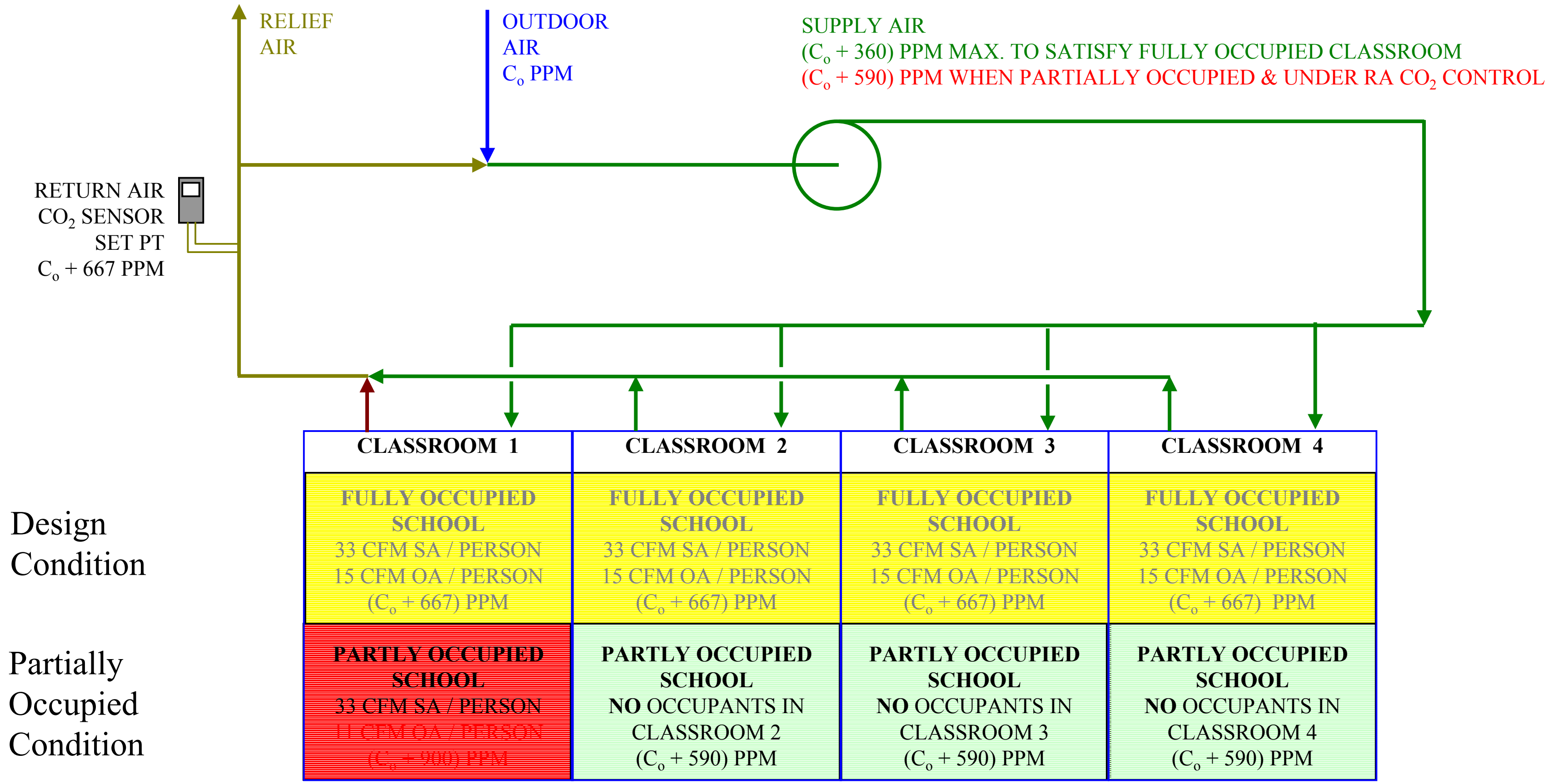
5.8a Average return air CO_2



Control system senses average return air and controls OA intake.

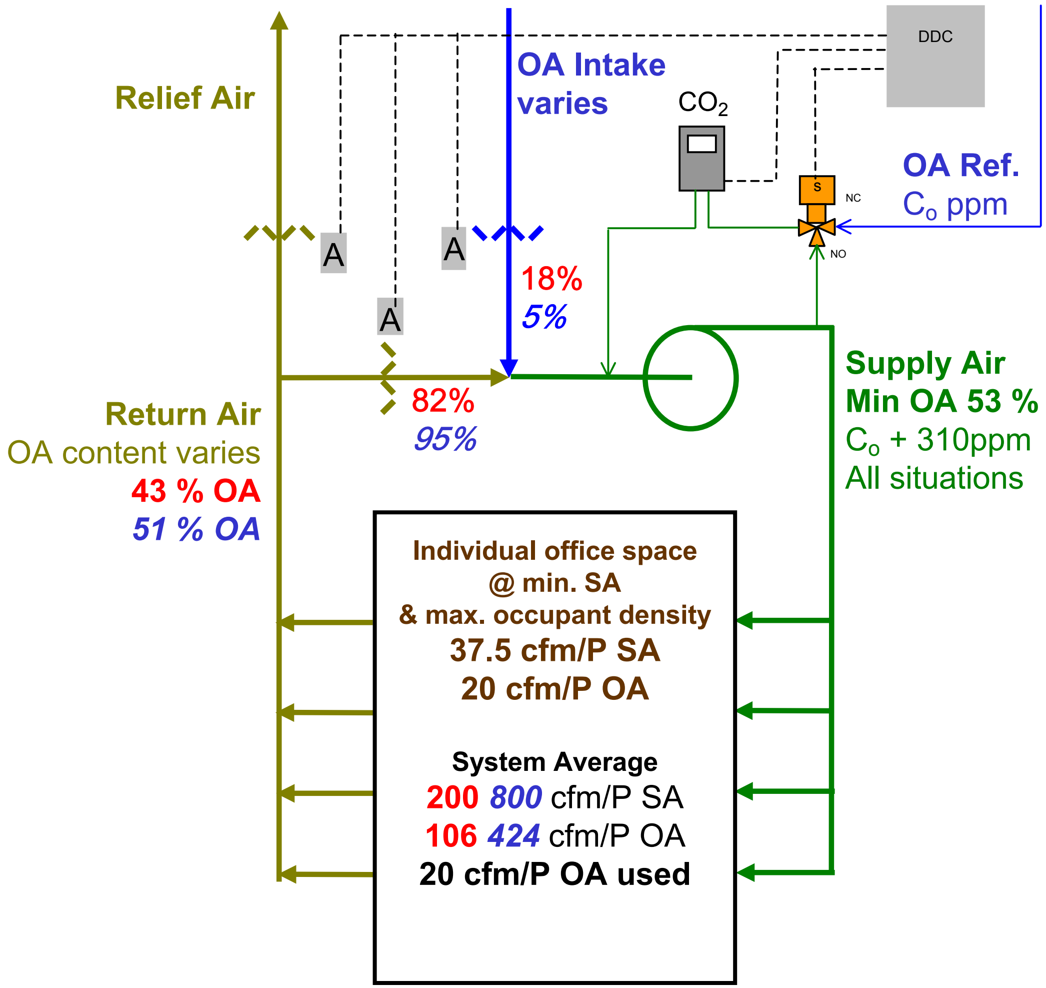
Does not work. See next slide

5.8b Av. RA CO_2 does not work!



When only one space is occupied, its CO_2 level rises to maintain RA CO_2 set point by offsetting supply air bypass through empty spaces.

5.9 SA CO_2



Set up at any time in minutes

Adjusts for short circuiting of relief air & for open windows

Stability not perfect but it can alarm faults and

Function is easily checked

Can log performance

Reasonable cost

Energy saving through DCV

Handles VAV

6 SA CO_2 - Overview

1. Saves energy
2. Better chance of good IAQ
3. Reasonable Cost
4. Applicable for a lot of systems

6.1 SA CO_2 - Benefits

1. Energy Savings
    1. Adjusts minimum OA for total number of occupants
    2. Provides for zone minimum flow reset when OA is higher
2. IAQ
    1. Easy to set up – any time
    2. Easy to check – any time
    3. Corrects for worn linkages and short circuiting
    4. Can chart ventilation delivery and alarm capability
3. Low Cost
    1. Only one sensor needed for most systems

6.2 SA CO_2 – Application Limits

For minimum OA / person in recirculating multiple space systems.

Its limits are:

1. 100% OA systems
2. Single space systems
3. Very small systems
4. Minimum intake not based on OA/person
    1. High make-up systems (still useful for VAV zone flow reset)
    2. Area rate (California Title 24)
    3. Mixed Rate (Std 62 Add. N - more complex strategy)
5. Checking and maintenance (Like any system)

Appendix 1.1

GOALS

1.1 Goals for Minimum OA Control

Function:	Can ensure delivery of min. OA to the occupants
Setup:	Easy to set accurately whenever needed
Reliability:	Long term stability & fault alarms
Verifiability:	Easy to check setup & to record performance
Cost:	Low initial and long term costs
Energy:	Maximize efficiency under all conditions – DCV
Applicability:	to many systems, specially problem systems

1.1.1 Function

Can the system ensure delivery of min. OA to the occupants?

Examples of Functional Problems

a Air enters building but is not delivered it to some occupants

b Sensing OA intake at a velocity that is too low for the sensor

c Fixed minimum damper position on a VAV system

d Controlling from temperature balance when there is no temperature difference

e Bypass of relief air into outdoor air intake

1.1.2 Setup

Is accurate set up feasible?

Is it easy?

Does it need cold weather?

Does it need an occupied building?

Examples of Setup issues

a Measuring OA flow @ 50 fpm

b Measuring mixed air temperature when its not mixed

c Waiting for cold weather to do a temperature balance

d Sustained occupancy for CO_2 concentration balance

1.1.3 Reliability

Will it provide consistent operation in the long term?

How do you know if its not working properly?

Examples of reliability issues

a Accurate damper positioning with no feedback

b OA flow sensors that are never serviced

c A CO_2 sensor that is never checked

d Any system that the operator cannot readily check

1.1.4 Verifiability

Can anyone easily check that set up is correct?
Does it provide a permanent record of performance?

Examples of verifiability issues

a Was setup correct?
b Is damper position exactly as intended?
c Is flow sensor in calibration?
d Does the system record and chart outcome in some manner?
(A record of a signal to a damper doesn't do this)

1.1.5

Cost

What does it cost to install?

What does it cost to keep it working properly?

What does it cost in energy compared to a more efficient system?

Examples of cost issues

a CO_2 sensor in every space

b Inlet flow sensing

c Separate OA system

d Systems that waste energy

1.1.6 Energy

Does it respond to demand ?
What if the number of occupants changes?
What if the windows are open?
Does it waste energy if things go wrong?

Examples of energy issues

a fixed minimum intake and variable occupancy
b Is sensor failure likely to cause unrecognized overventilation?

1.1.7 Applicability

Does it work for multi space systems?

Does it work for VAV systems?

Is it practical for small systems?

Examples of applicability issues

- a RA CO_2 doesn’t work for multiple spaces
- b Fixed intake fraction doesn’t work for VAV
- c Air flow sensing or CO_2 sensing cost for very small systems

Appendix 1.2

SUPPLY AIR CALCULATION

2.2.b Min. supply air spreadsheet

Minimum Supply Rate Calculation for each Zone Type						
Zone Type	Min. OA Rate / person cfm/person R_p	Zone Air Distribution Effectiveness E_z	OA Fraction in Supply Air Z	Min. Supply Air Rate / person cfm/P $V_z = V_{obz} / E_z Z$	Design Max. Occ. density ft²/person A_z/P_z	Min. Supply Air Rate / unit area cfm/ft² $V_{za} = R_p / E_z Z$
Office [a]	20	1.0	0.53 [a]	37.5	75 [d]	0.5
Office (heating) [b]	20	0.8 [b]	0.53	47	75 [d]	0.6 [f]
Meeting Room [c]	15	1.0 [c]	0.53	28	20 [e]	1.4 [g]

This replaces hundreds of calculations that may be needed following the 62N base method.

It also provides permanent guidelines for design and for future system modification

Appendix 7 special cases

Zone Reset

Resetting zone minimums when OA content is high

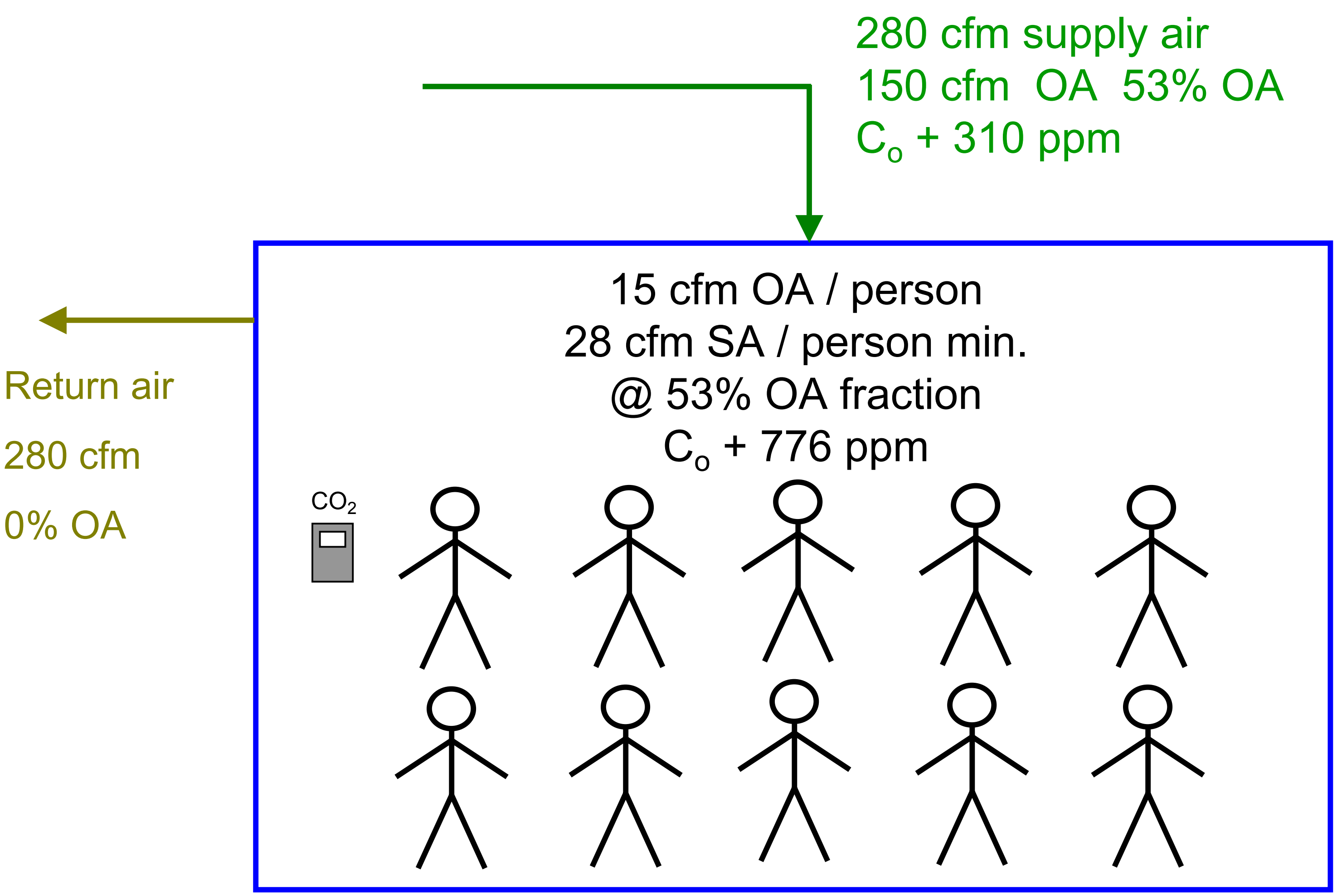
Person and Area rate Ventilation

Std 62 Add. N - more complex strategy needed

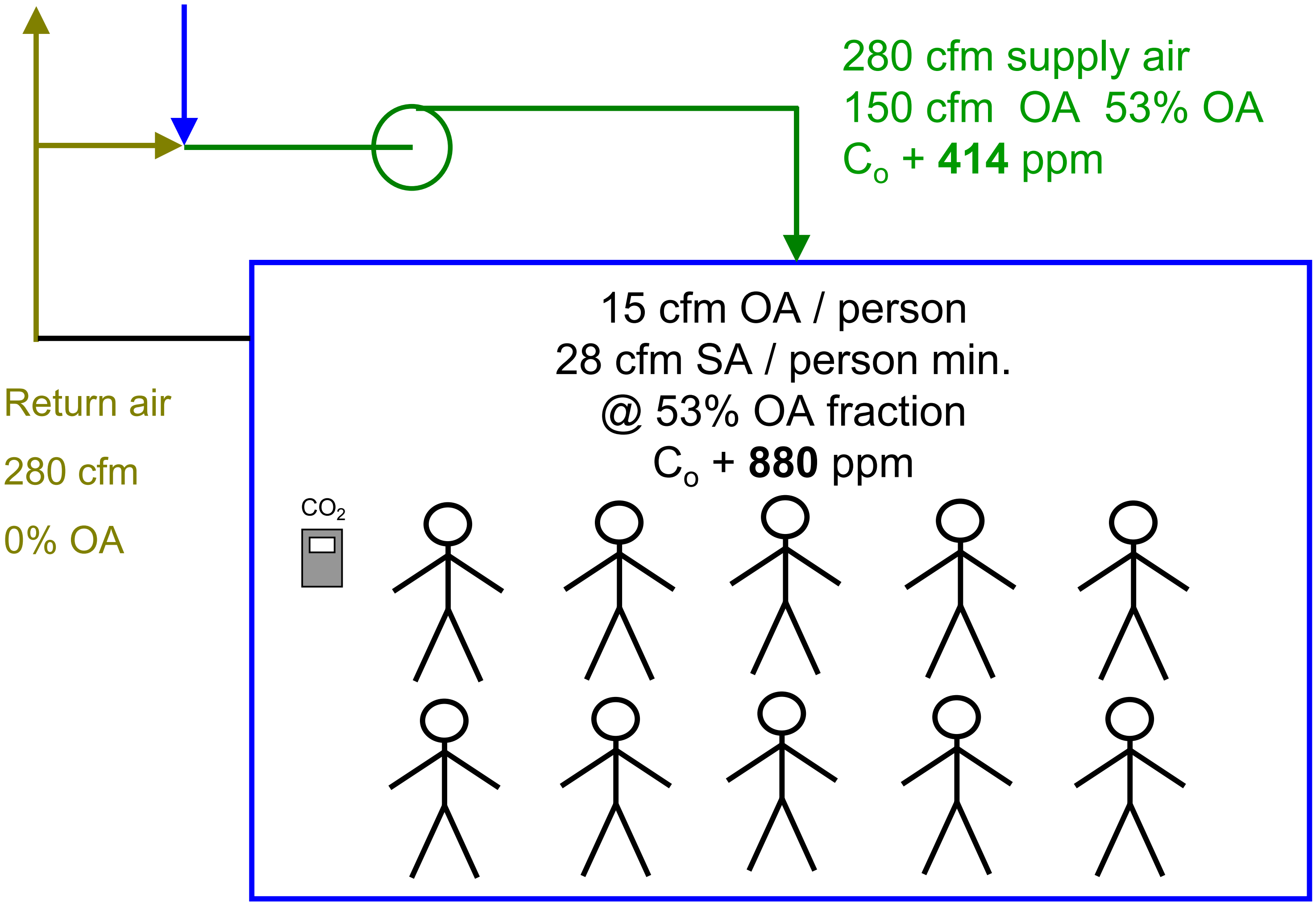
Dual Fan Systems

Best with both supply ducts monitored

7.1.a Meeting Room – Central System



7.1.b Meeting Room - Separate system



7.2 Addendum N Control