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Residential Zoned Systems

It's Different Now

PG&E's Energy Training Center–Stockton

Pacific Gas and Electric Company®

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ENERGY TRAINING CENTER ETC STOCKTON

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Introduction

This Class

- Residential Zoning Practices
- Zoning Within Title 24
- Duct Design Basics
- Current Research and Zoning Methods
- Ducted Zoning
- Non-Ducted Zoning

Questions

- What Air Conditioners do you work on?
- How do you know if an Air Conditioner is working efficiently?
- What are the two things that an Air Conditioner removes from inside air?
- What are the climate differences between California and Florida?
- How does the outside air affect the inside air?

My Answers

- What Air Conditioners do you work on?
  - Residential and Commercial, Split, Package, Window, Mini-Split, Domestic and Foreign
- How do you know if an Air Conditioner is working efficiently?
  - Test the airflow, T' Split, Watts, Superheat, Subcooling, and compare to conditions
- What are the two things that an Air Conditioner removes from inside air?
  - Sensible Heat (temperature) and Humidity
- What are the climate differences between California and Florida?
  - Humidity
- How does the outside air affect the inside air?

Questions

- What do you want a California Air Conditioner to do more of sensible cooling or dehumidification?
- What are the ways to make it do that?
- What make it worse?

My Answers

- What do you want a California Air Conditioner to do more of sensible cooling or dehumidification?
  - Sensible Cooling
- What are the ways to make it do that?
  - Increase Airflow
  - Evaporate the Water Off the Coil After the Compressor is Off
- What makes it worse?
  - Low Airflow
  - Bypasses
  - Fan Off at Compressor Off

This Class

The primary purpose of zoning air conditioners, heat pumps, and furnaces is to improve comfort.

Increased comfort is attained by having the capacity of the HVAC system (cooling or heating delivered) **follow the shift in load** as it changes across the house.

Should We Zone This?

Should We Zone This?

Why Zone a Residence?

Why Zone a Residence?

- A residence may be a candidate for zoning if cooling, heating, or dehumidification loads shift over time due to:
  - Solar Heat Gain
  - Occupancy
  - Use of the Area
  - Large Intermittent Internal Gains
  - Large Moisture Input
  - Tall Buildings
  - Above Grade and Below Grade
  - Summer vs. Winter

34% of the Ducted Systems in the California New Home Study were Multi-Zoned

Dampered Zoned Split	**10 (1Heat Pump) (12%)**
Single Split	28 (not Zoned)
Multiple Split	17
Ducted Hydronic w AC	11
Heat Pump	5 (not Zoned)
Package	6
Furnace Only	3
Total	**80**

Once Upon A Time

The Old Days

Zoning

The primary purpose of zoning air conditioners, heat pumps, and furnaces is to improve comfort.

Increased comfort is attained by having the capacity of the HVAC system (cooling or heating delivered) **follow the shift in load** as it changes across the house.

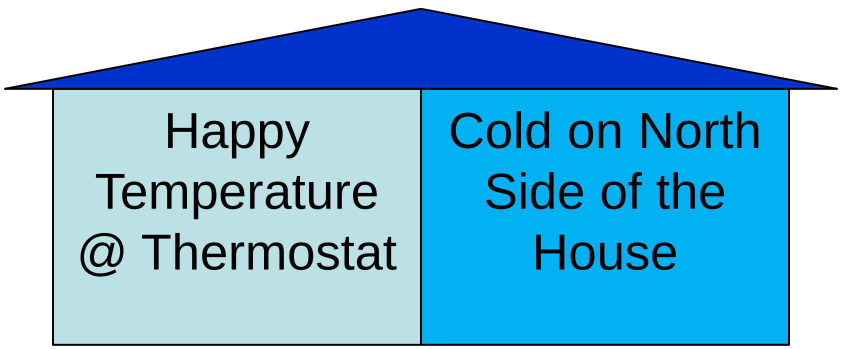
Is There Such a Thing as
Excess Air?

Is There Such a Thing as
Excess Capacity?

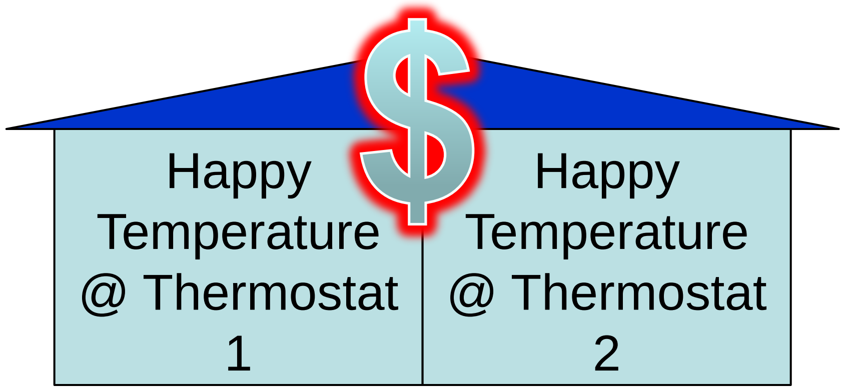
Is There Such a Thing as
Excess Efficiency?

Zone for Comfort

- Zoning can improve comfort for a structure that has significant variations in load
- Ducted Zoning is very unlikely to provide any reduction in energy bills and is capable of increasing the energy bills



Single Zone



Two Zones

An Example

- NAHB Test House (Kenney & Barbour 1994)
  - "Studies have demonstrated that a multi-zone system will use more energy than a central thermostat system when a constant setpoint is used."
  - "A 35 percent increase was documented (Oppenheim 1991) as a direct result of a multi-zone system being more responsive to the cooling needs of the entire house.."

Zoning Criteria

- All portions of the zone should have a similar load pattern. A somewhat isolated West side for example.
- All portions of the zone should have a similar occupancy pattern. Sleeping areas vs. Daytime use for example.

Zoning Methods

- Heating Only Convectors
- Ductless Mini-Split Systems
- Multiple Systems
- Ducted Multi Capacity System
- Ductless Multi-Split Systems
- Ducted Mini- or Multi-Split Systems
- Ductless or Ducted Single Package (PTAC)
- **Ducted Single Capacity System**

Heating Only Convectors

Hydronic or Electric

Energy Savings is Possible with These

Ductless Mini-Split

- Single Speed
- Variable Speed
- One or more Heads
- Single Thermostat

Energy Savings is possible with these

Multiple Systems

- Relatively Simple Design
- Design the Duct System

Multi-Split Systems

- Two or More “Heads”
- Each Serving a Compatible Zone
- Two or More Thermostats
- Can Produce Lower Efficiency

Ducted Mini or Multi-Split

- DANGER – Static Pressure !!!
- Design the Duct System

PTAC & PTHP

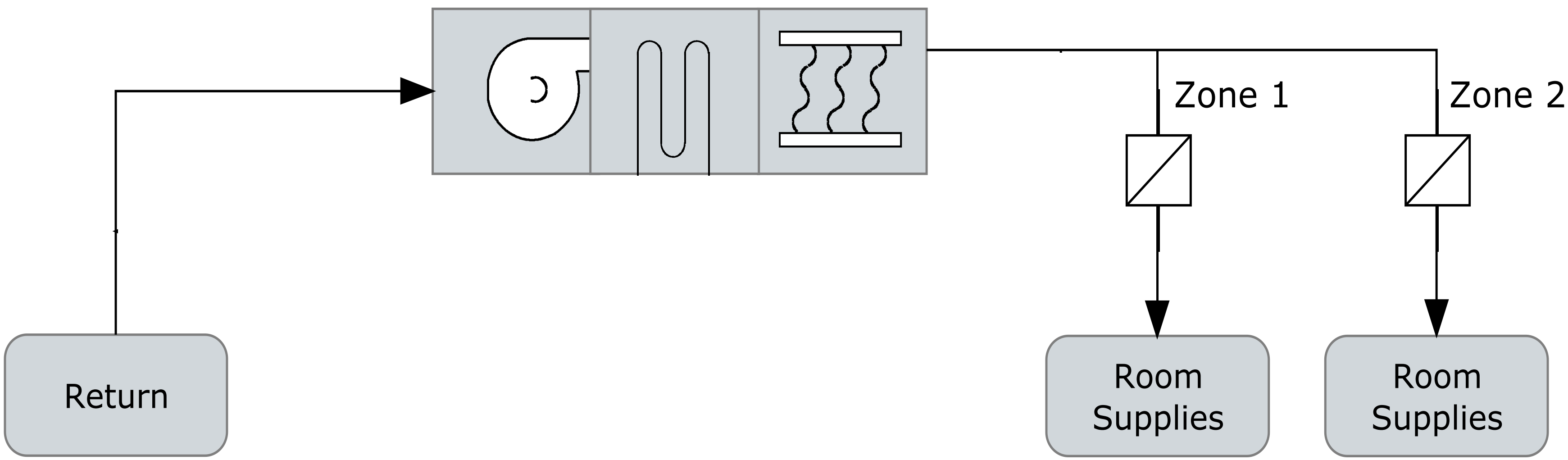
- Small sleeve wall units have low efficiency, but higher efficiency than electric baseboards.
- Highest EERs are 12 to 13 (55 listed HP)
- 6000 BTU heat 7000 BTU cool

Ducted Systems First Priority Reduce or Eliminate Differences

- Shading
- Low E Glass
- Infiltration Control (air sealing)
- Insulation
- Reduce the size of the Air Conditioner
- Work toward equal CFM in heating and cooling
- Design a Proper Duct System (reduce room to room temperature differences)

Multiple Capacity System

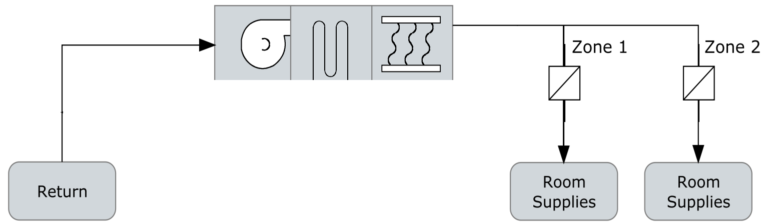
- Match Zones to AC Capacity at All Speeds
- Variable Speed Compressor and Fan



At least 350 CFM per Delivered Ton in all modes
Vary Compressor and Fan speeds with demand from zones
Limited by the range of the variable capacity

Multiple Capacity System

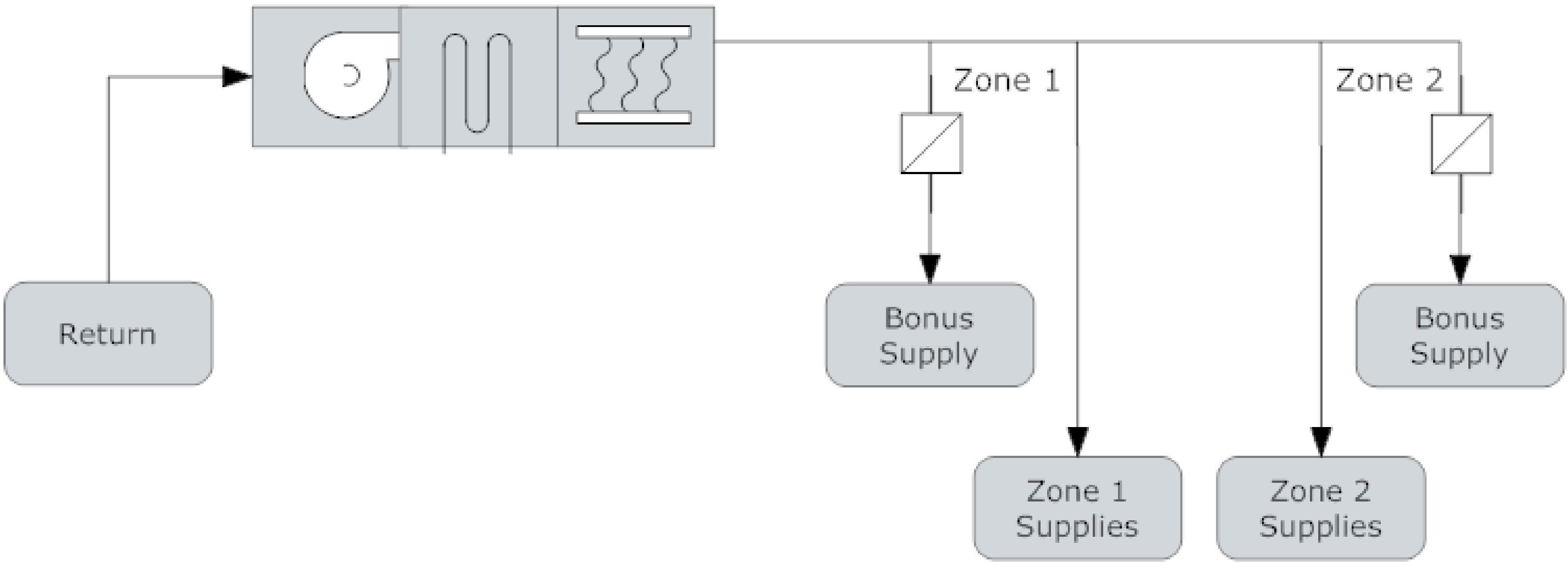
(2 or more compressor speeds) in Title 24



- At least 350 CFM per Nominal Ton INTO THE RETURN on Highest Compressor Speed with all Zones Calling
- Fan Watt Draw =< .58 W per CFM under above conditions
- Additional performance credit available if higher airflow and/or better fan efficacy is modeled and verified under the above conditions
- A bypass may be used if it is modeled in the compliance software

A Good Single Capacity System

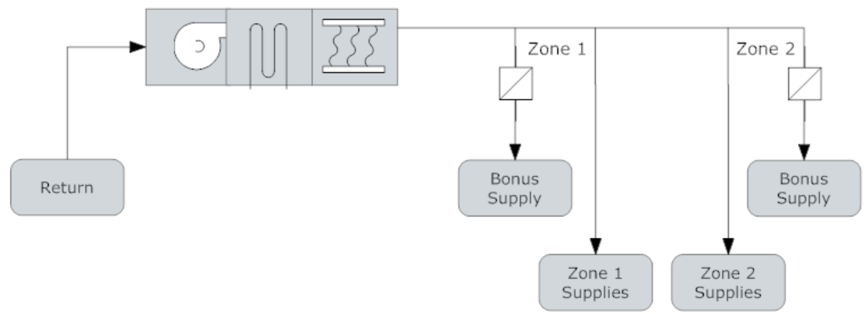
- Move Part of the Capacity from One Zone to Another based on Load



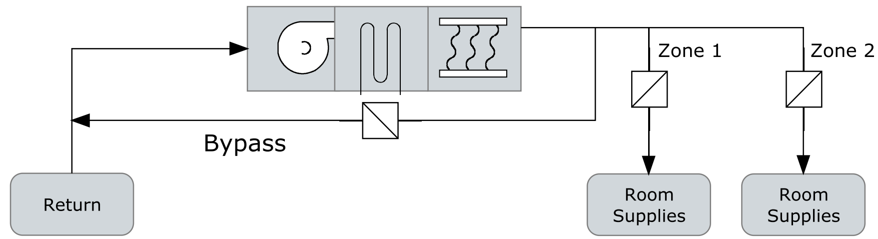
At least 350 CFM per Ton in All modes

A Single Capacity System in Title 24

A. Prescriptive Compliance: At least 350 CFM per Nominal Ton INTO THE RETURN in all modes. Bypass Duct Not Allowed



B. Performance Compliance: At least 350 CFM per Nominal Ton INTO THE RETURN WITH ALL ZONES CALLING. This methods carries with it a large efficiency penalty (assumes 150 CFM per ton). Bypass Duct Allowed



C. Performance Compliance with Reduced Penalty or Additional Performance Credit: B above except more than 150 CFM per nominal ton and/or less than 0.58 W/CFM modeled and verified in all modes

Title 24 Questions

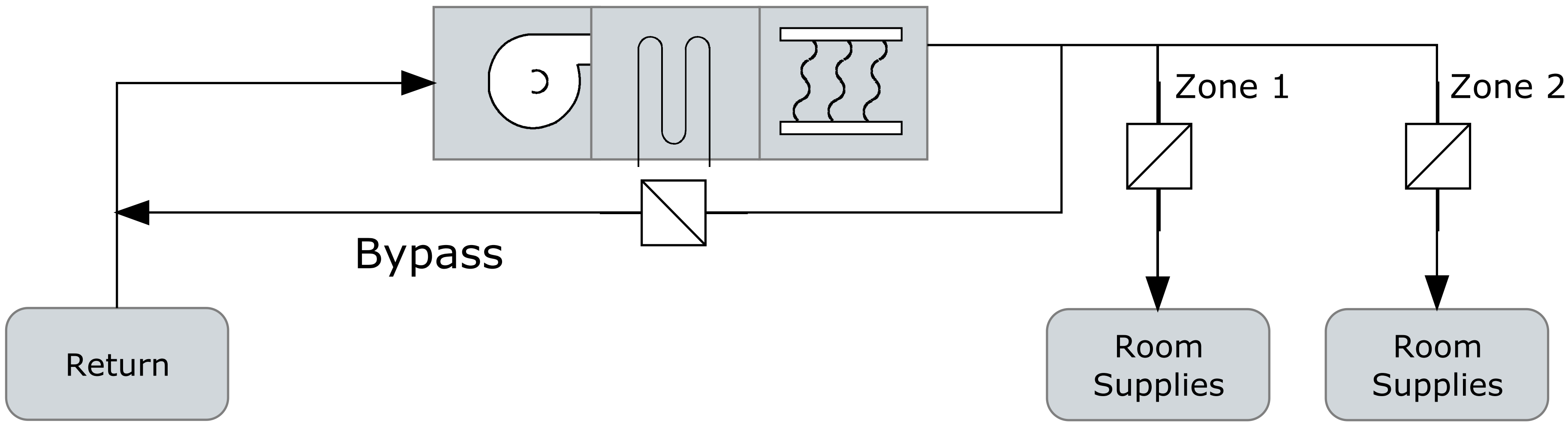
- “There used to be compliance credit requirements that included
  - a return in every zone and
  - no flow out of registers in zones not calling and
  - no more than 40 ft^2 non-closable opening area between zones.”

Question: “Do we have to meet those (on top of every thing else already discussed) when there is a zoned system?”

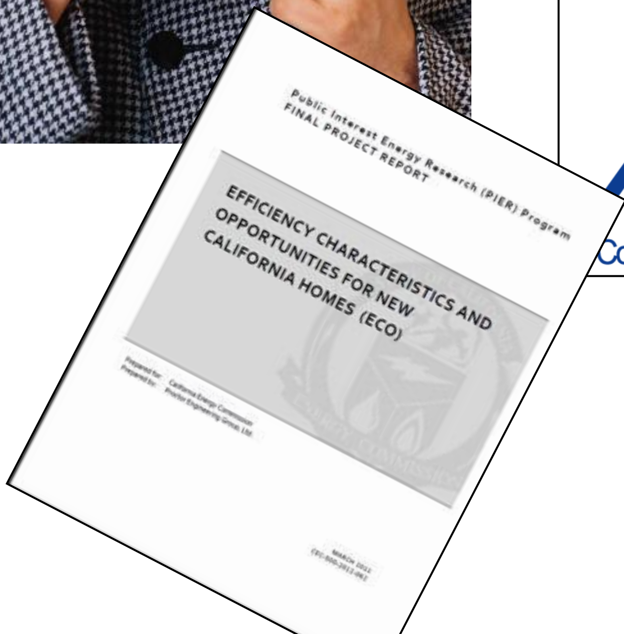
Answer: No the above requirements are only for heating where you are asking for a Title 24 credit for zoning in heating. If you are not asking for the credit they do not apply.

Zoned Dampered Systems
The Old Way

A Typical Dampered Multi-Zone AC System With Bypass Duct



What Does Research Show Us?



Carrier

ASHRAE

NAHB
National Association of Home Builders

ACCA
Conditioning Contractors of America

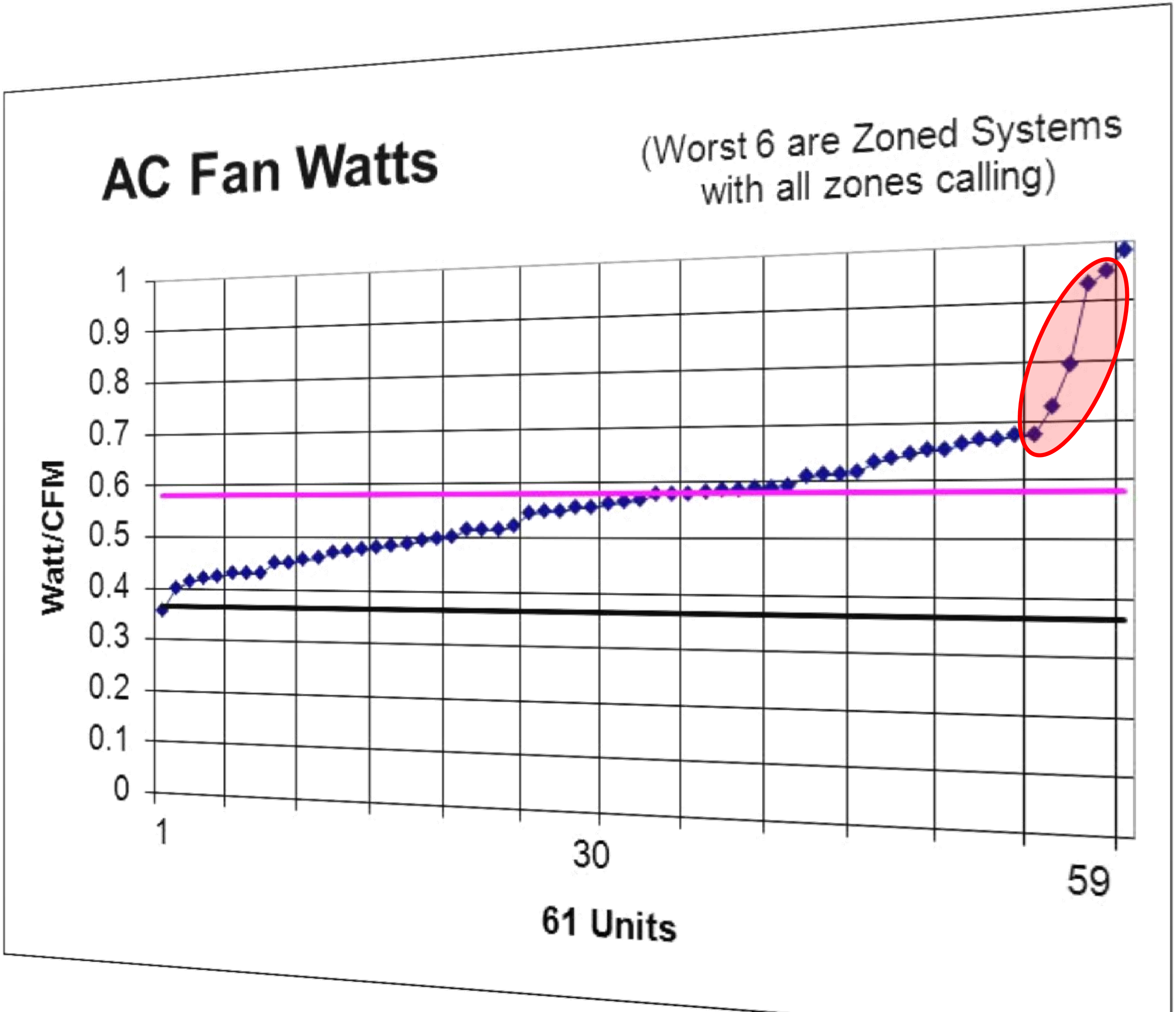
CMHC SCHL
Canada

Efficiency Characteristics and Opportunities for New California Homes (ECO)

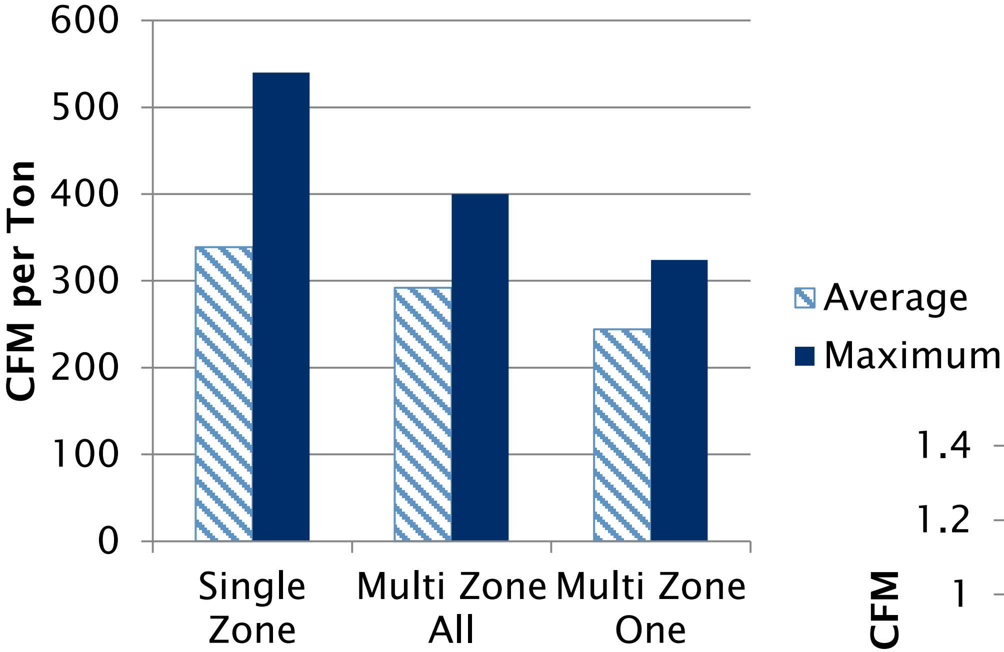
- Field survey of an 80 unit sample of new CA homes and found:
  - AC systems have low capacity and efficiency
  - Cooling duct pressures are very high
  - Cooling Fan Watts are high

http://www.proctoreng.com/dnld/ECO_Report_CEC.pdf

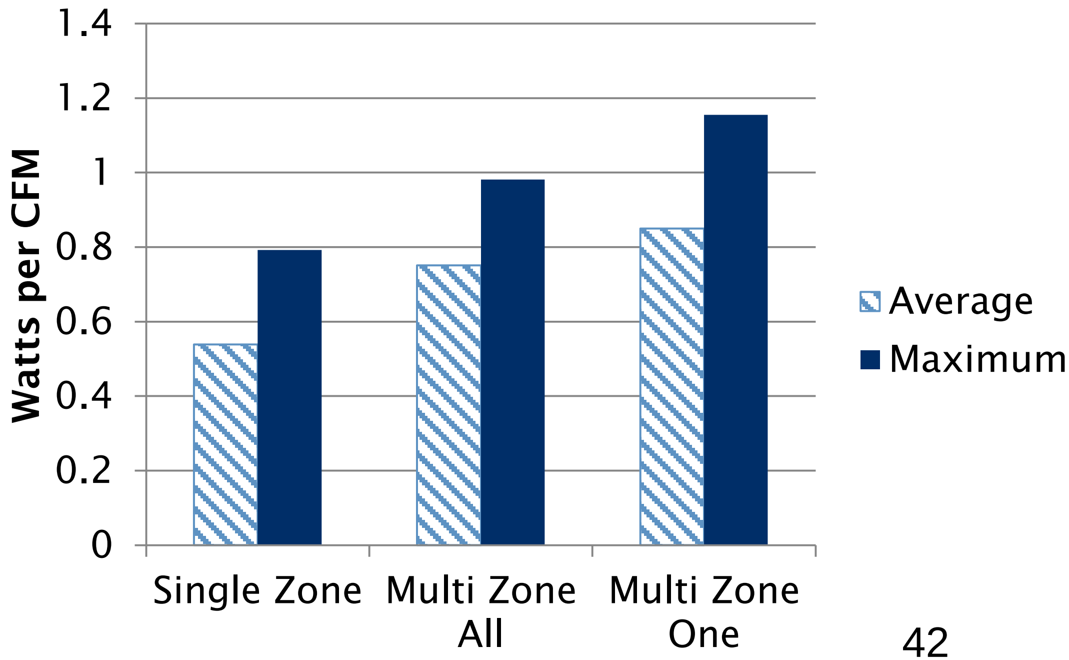
Watts per Delivered CFM



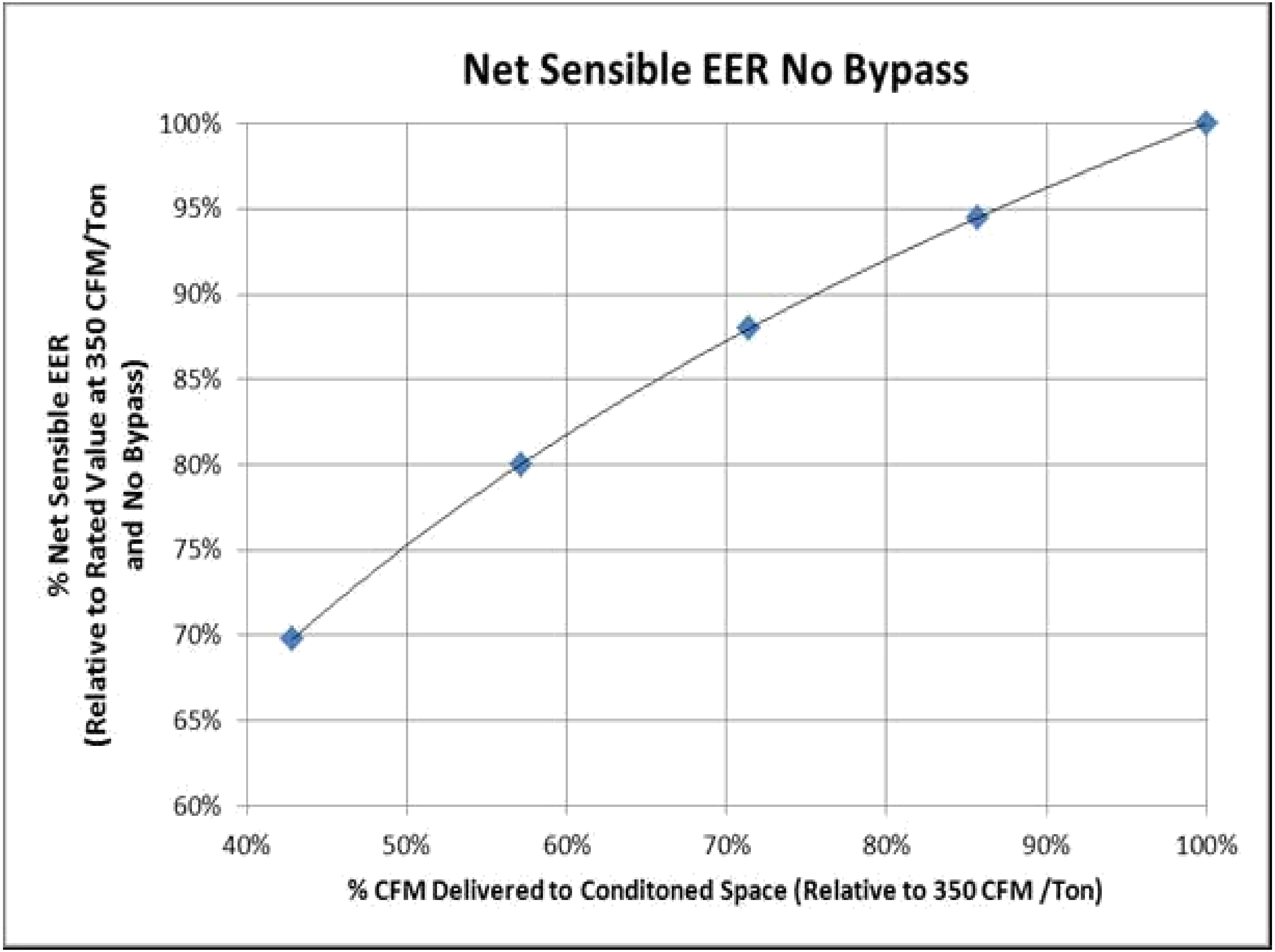
Dampered Multi-Zone Systems have Low CFM per Ton and High Cooling Fan Power per CFM



and Low Sensible EER

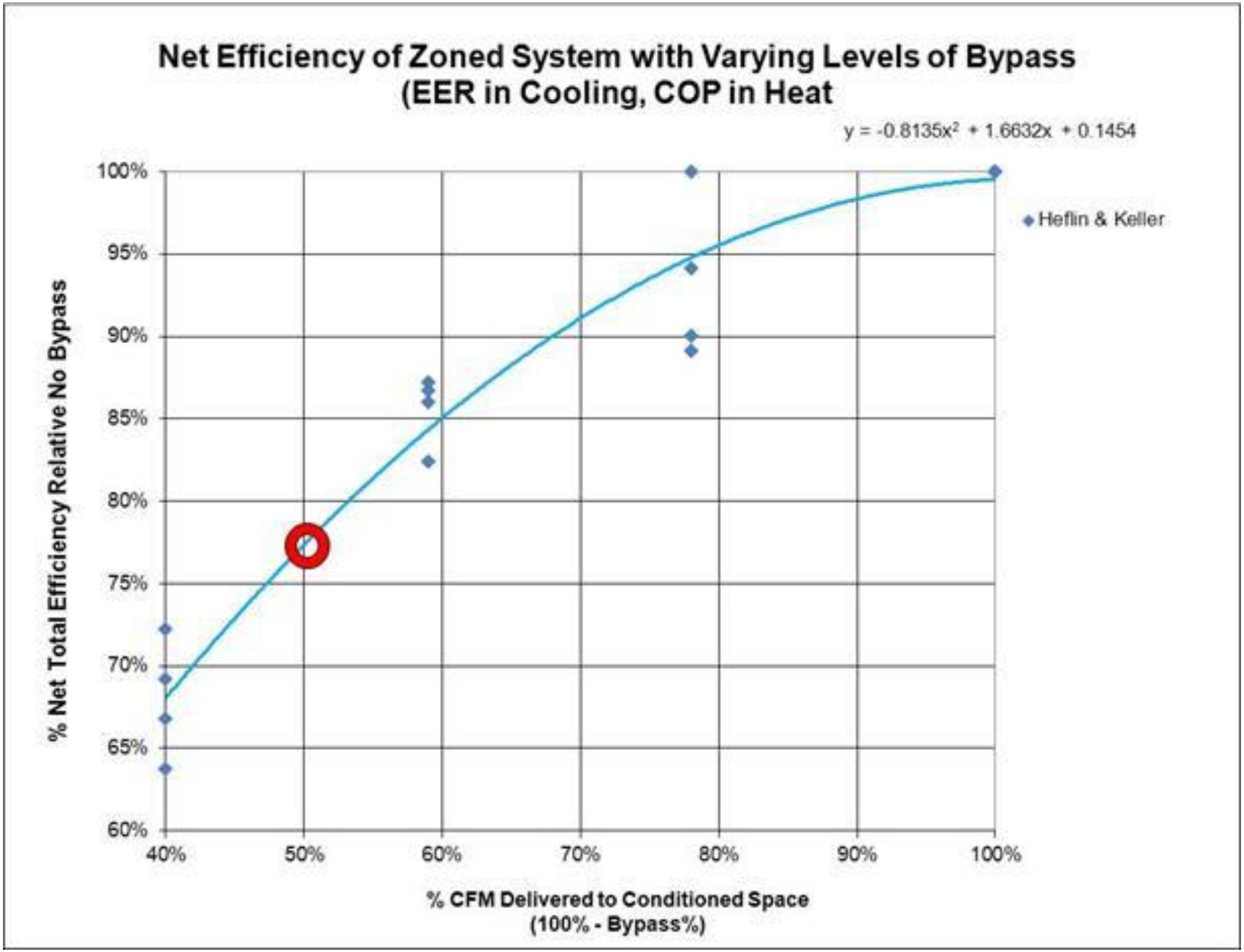


Low Airflow



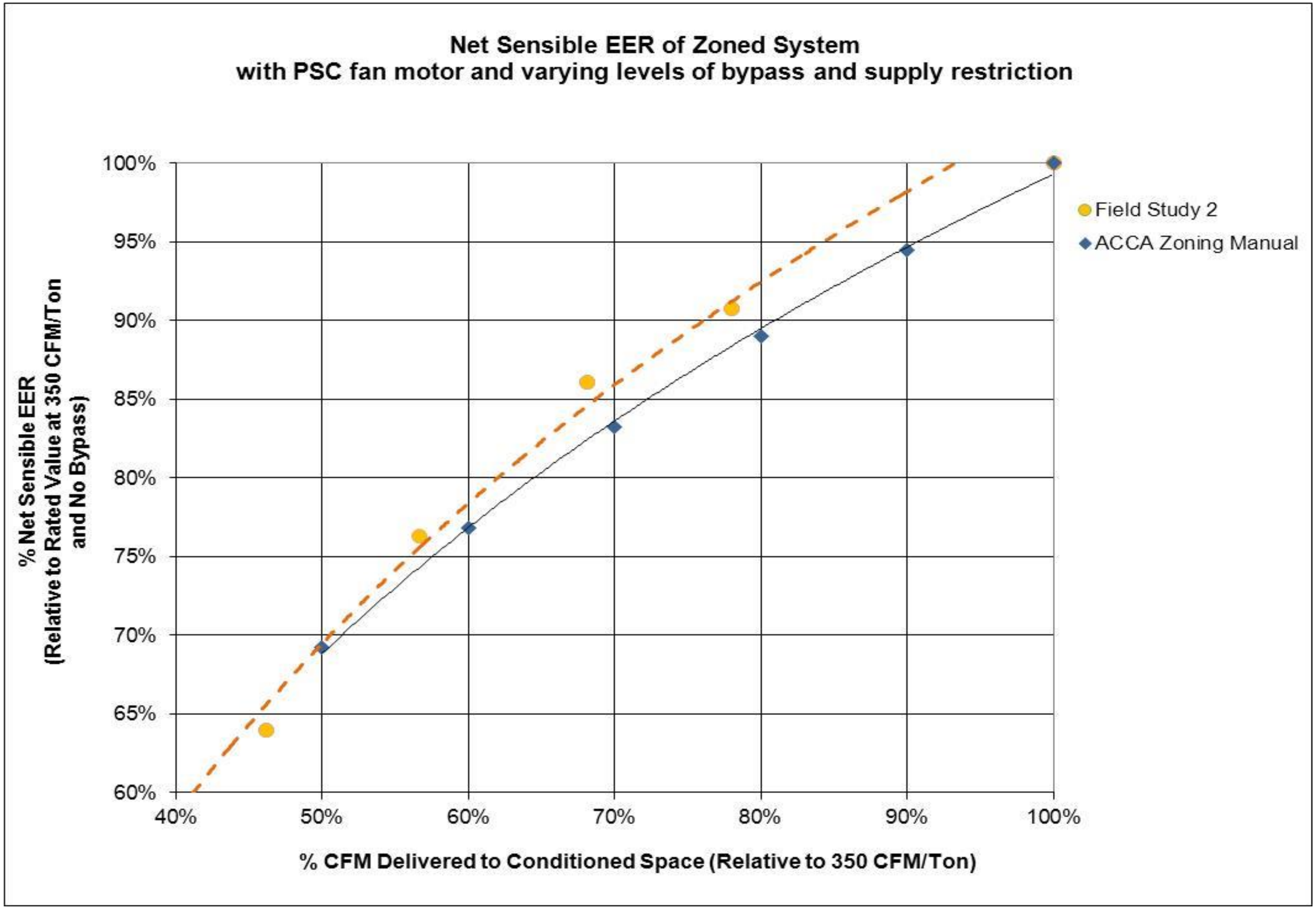
Net Sensible EER No Bypass
100%
95%
90%
85%
80%
75%
70%
65%
60%
% Net Sensible EER (Relative to Rated Value at 350 CFM/Ton and No Bypass)
40%
50%
60%
70%
80%
90%
100%
% CFM Delivered to Conditoned Space (Relative to 350 CFM /Ton)

Bypass Graph
(Carrier Laboratory Tests 1993)



Bypass and Supply

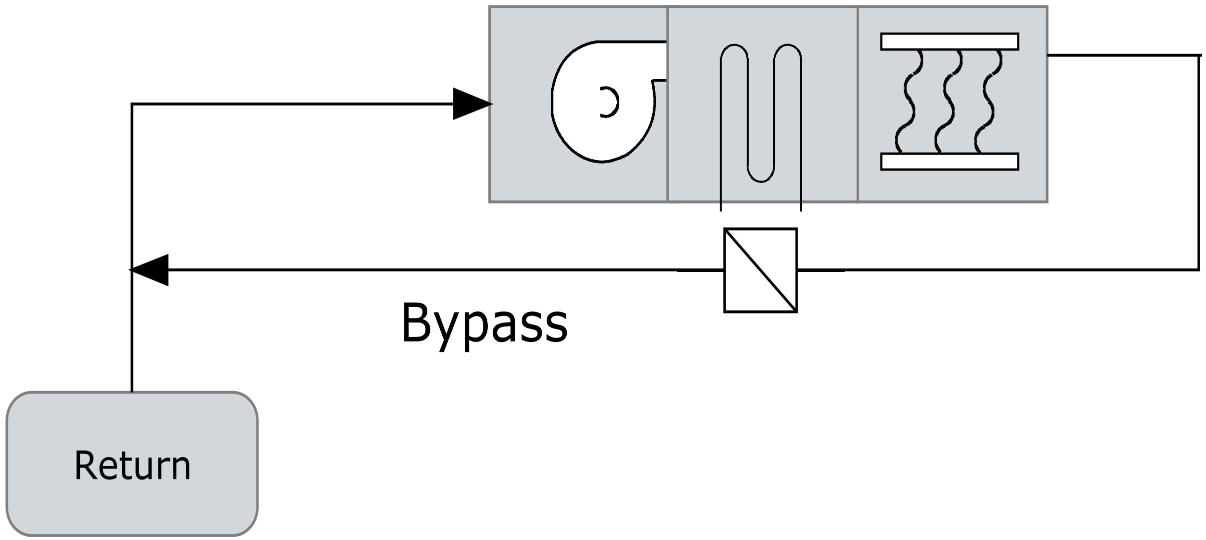
(ACCA Manual* and Field Data)



***Manual Zr*, Zoned Comfort Systems for Residential Low-Rise Buildings First Edition, Version 1.00 Review Draft 8.10anc — April 21, 2011**

Bypasses: Why are They so Bad?

Imagine this



Think of the equipment entering temperature
in heating and
in cooling.

Heating hot air is hard
Cooling cold air is hard

Demon-stration

Zoning with Ducts – What Works?

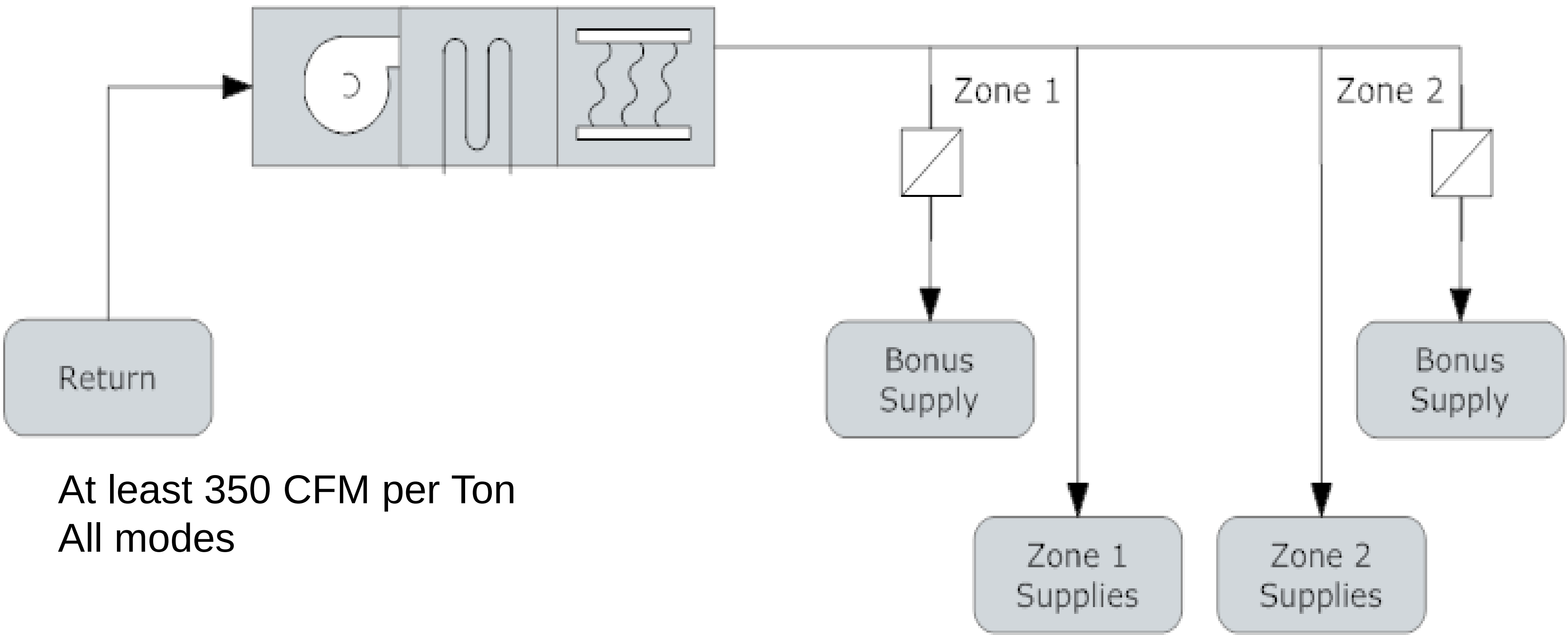
1. Keep it Simple
2. Use Less Ducts
3. Use Shorter Ducts (then they may not have to be larger)
4. Don’t use Bypasses
5. Increase Duct Insulation – Duct Conduction is your enemy

The Modern Way

How to Design a Single Capacity Multi-Zone System that Provides Comfort and Efficiency

Single Capacity System

- Move Part of the Capacity from One Zone to Another based on Load



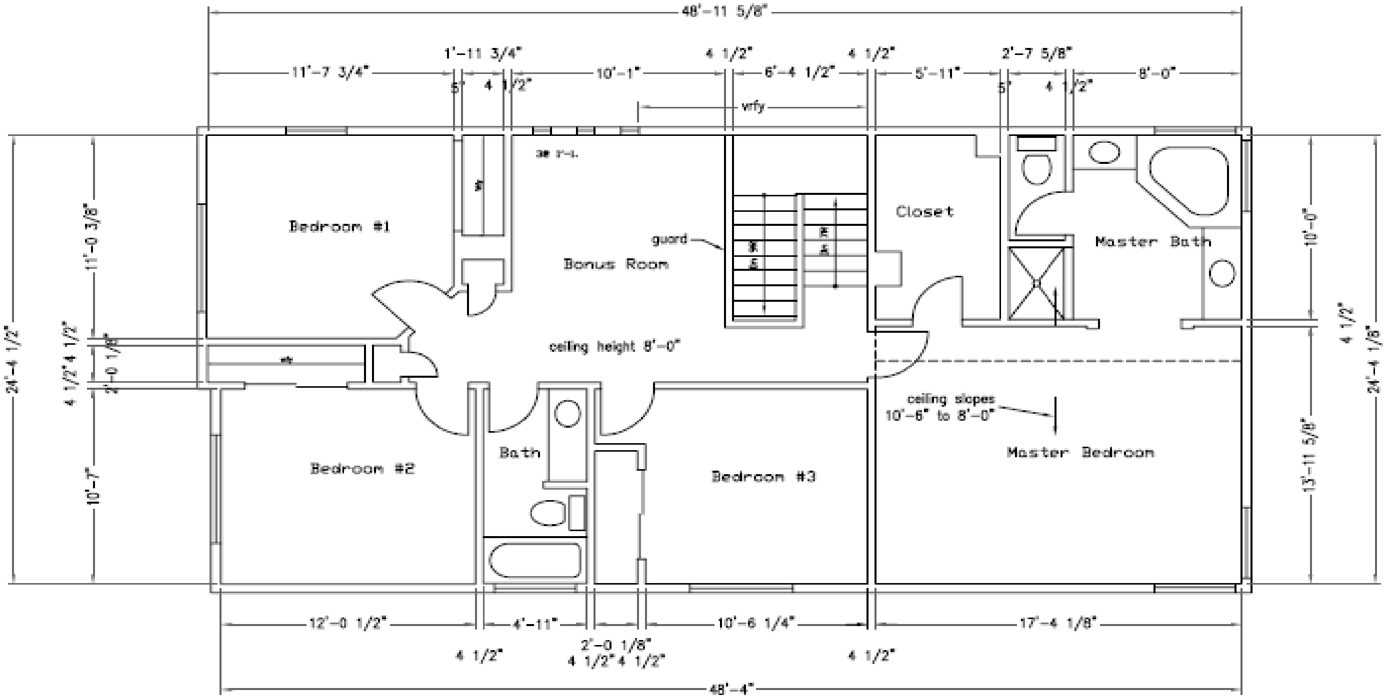
At least 350 CFM per Ton
All modes

Proper Design & Selection – Estimate Loads

1. Estimate Design Heating Loads

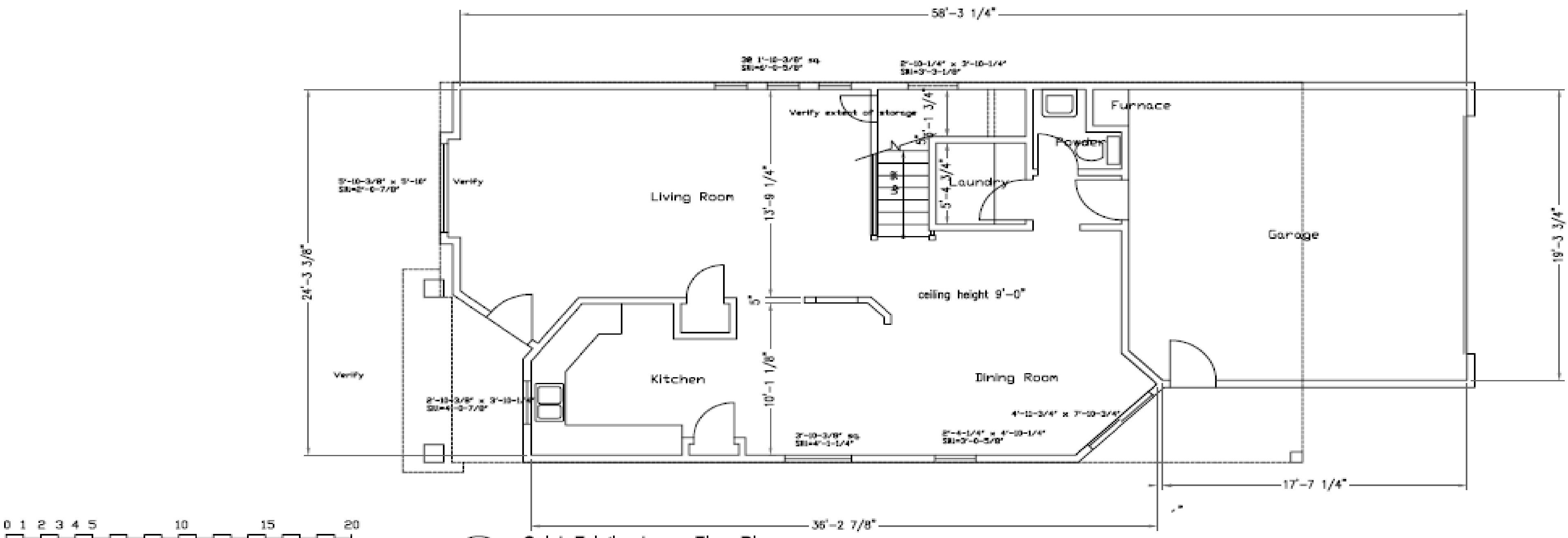
2. Estimate Design Cooling Loads – Sensible and Latent

3. Determine the airflow required to each room



2 Caleb Existing Upper Floor Plan

SCALE: 1/4" = 1'-0"



1 Caleb Existing Lower Floor Plan

SCALE: 1/4" = 1'-0"

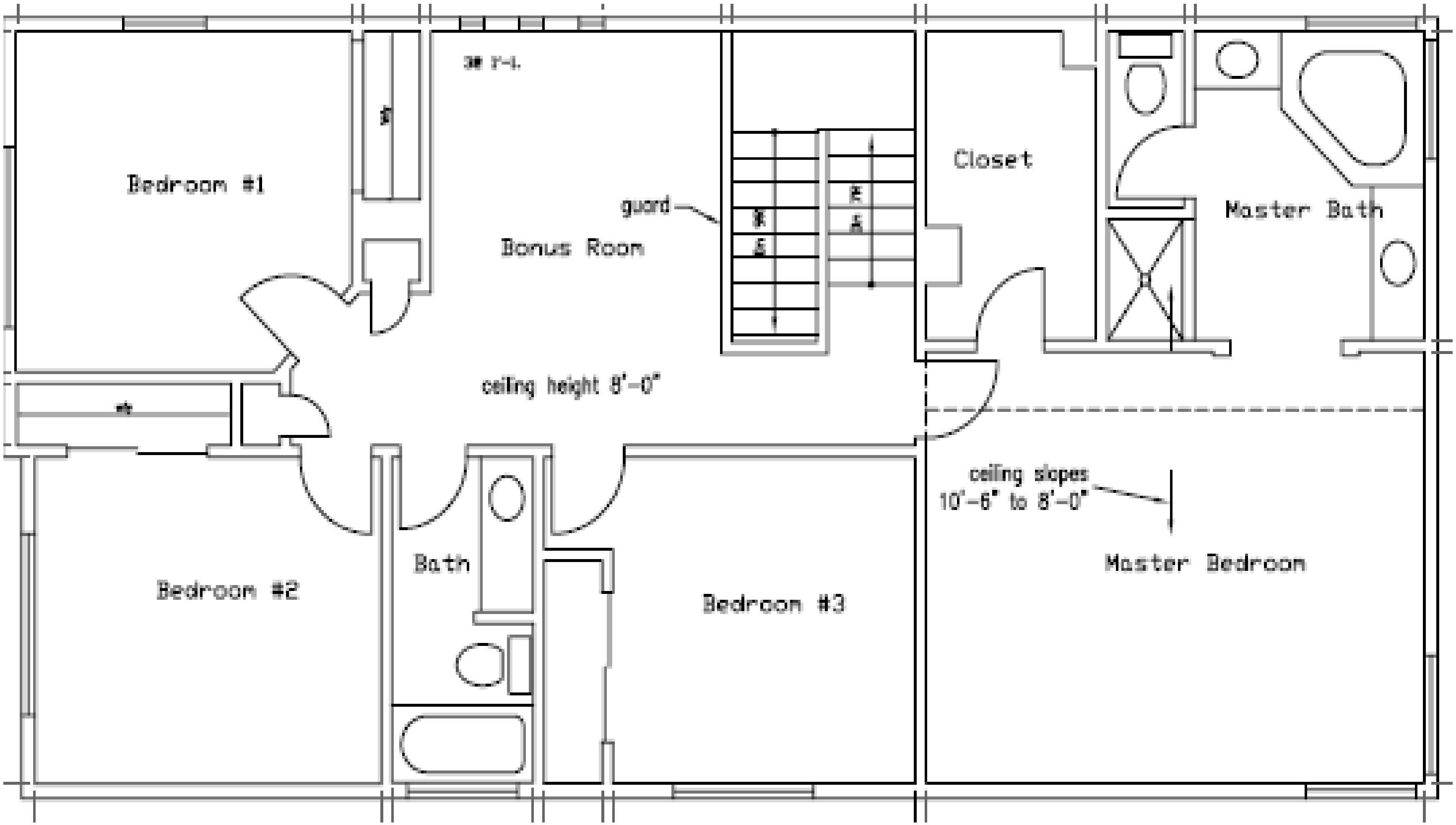
Manual J Heating and Cooling Sensible Loads

Upstairs	Cooling	Heating
Bedroom 1	1,842	1,750
Bedroom 2	1,601	1,795
Bedroom 3	1,354	990
Master BR	3,892	4,238
Common/Bth	1,434	1,324
Upstairs	10,123	10,097
Downstairs		
Living Room	3,587	6,726
Dining/Kitchen	2,878	5,706
Downstairs	6,465	12,432

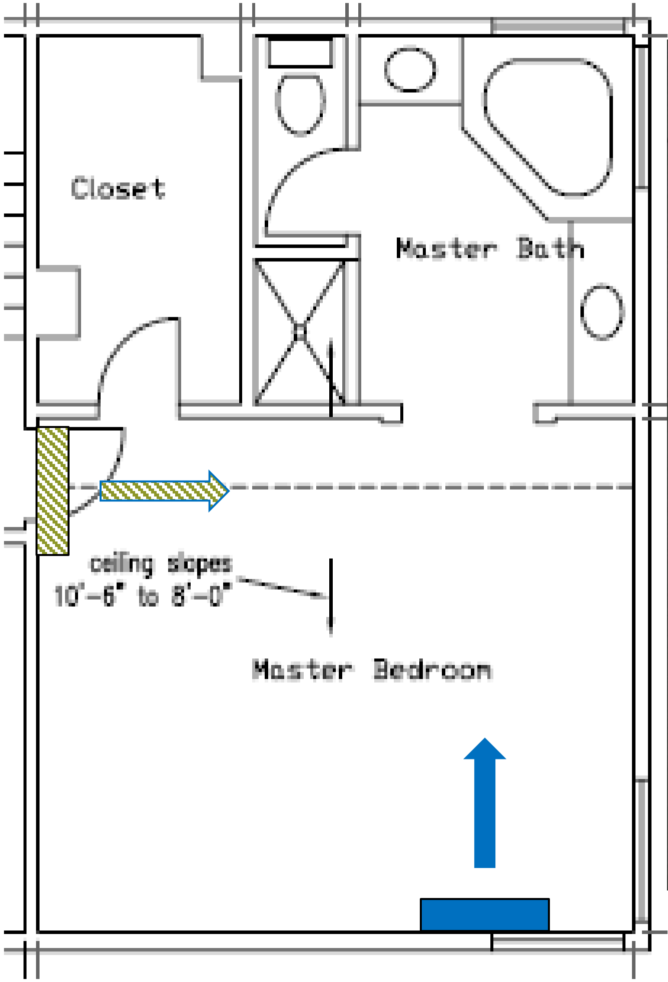
Options

- Single Zone
- Two Zones
  - Ducted Multi Split (single outside unit, three heads [could be 3 zones])
  - Ductless Mini or Multi Splits
  - Ducted Dampered Two Speed System
  - Ducted Dampered Single Speed System

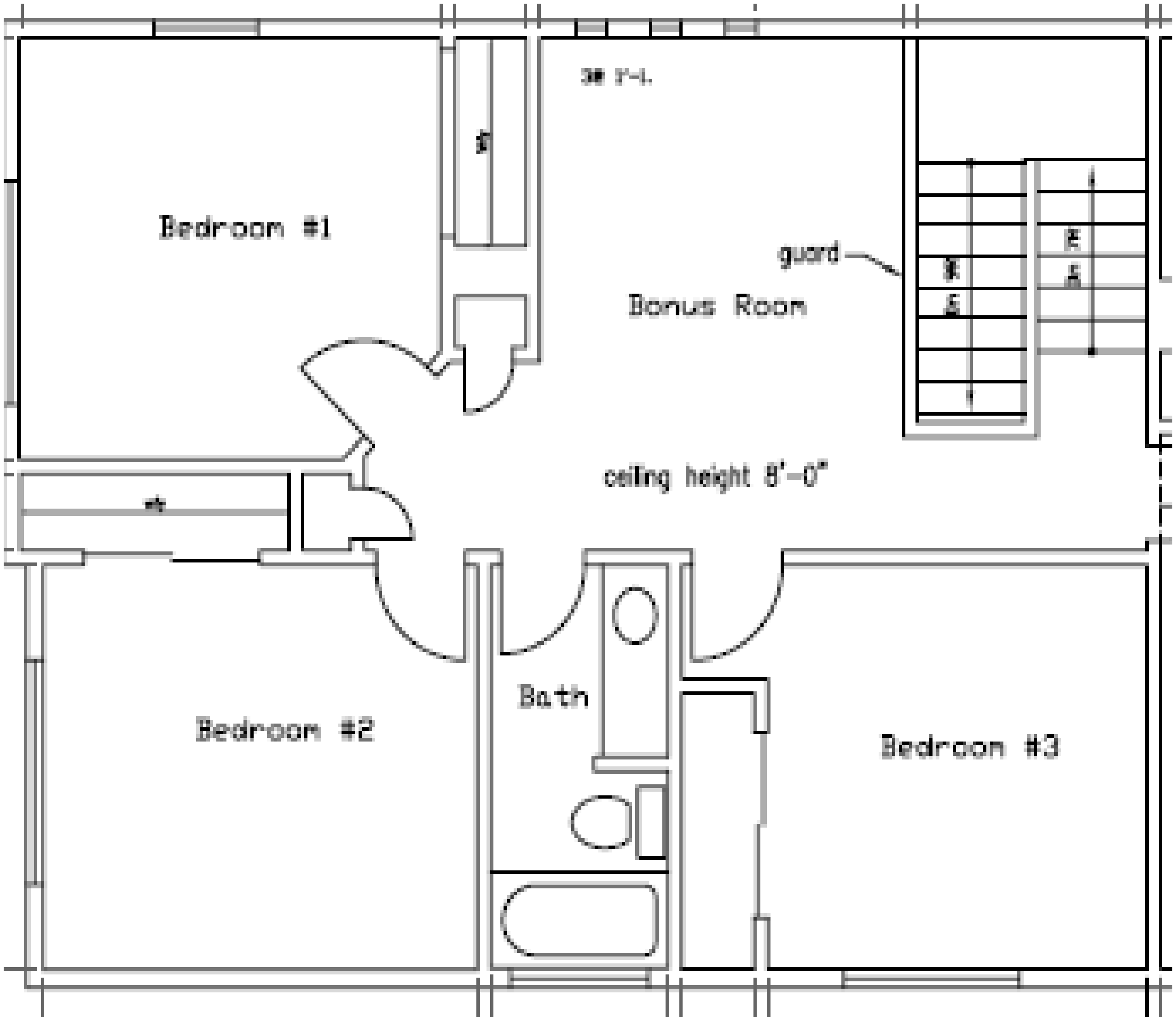
Ductless or Ducted M-split

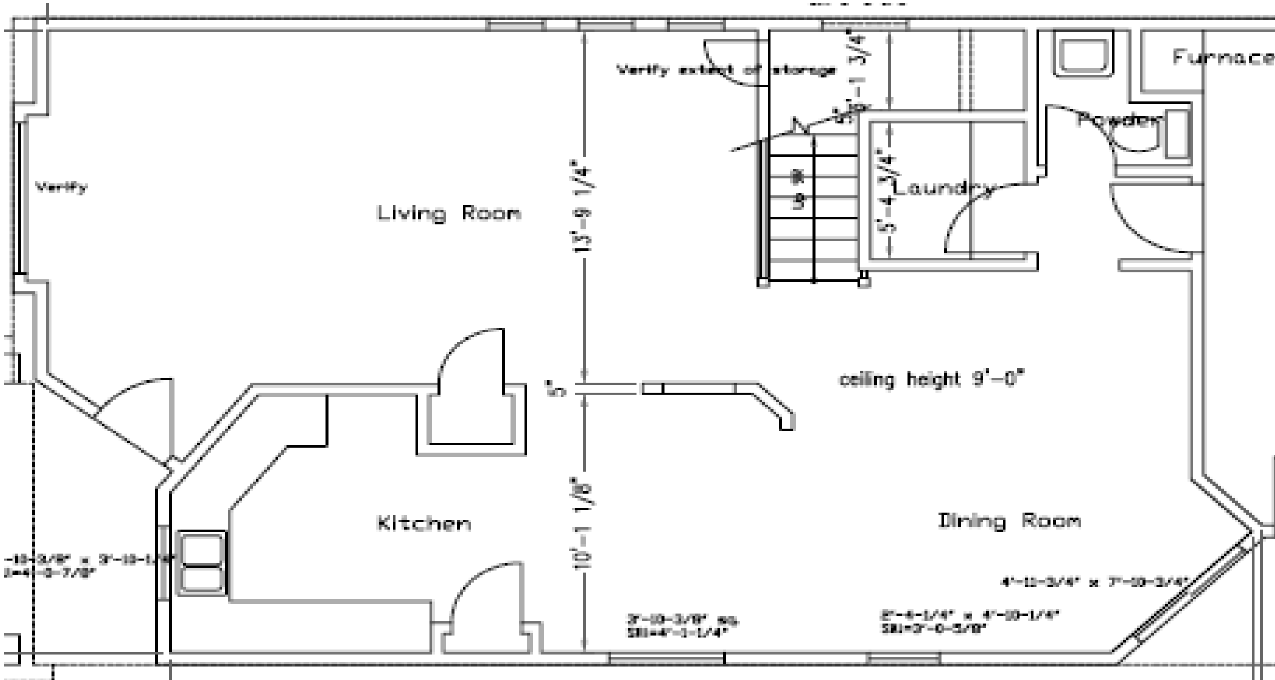


Ductless or Ducted M-split

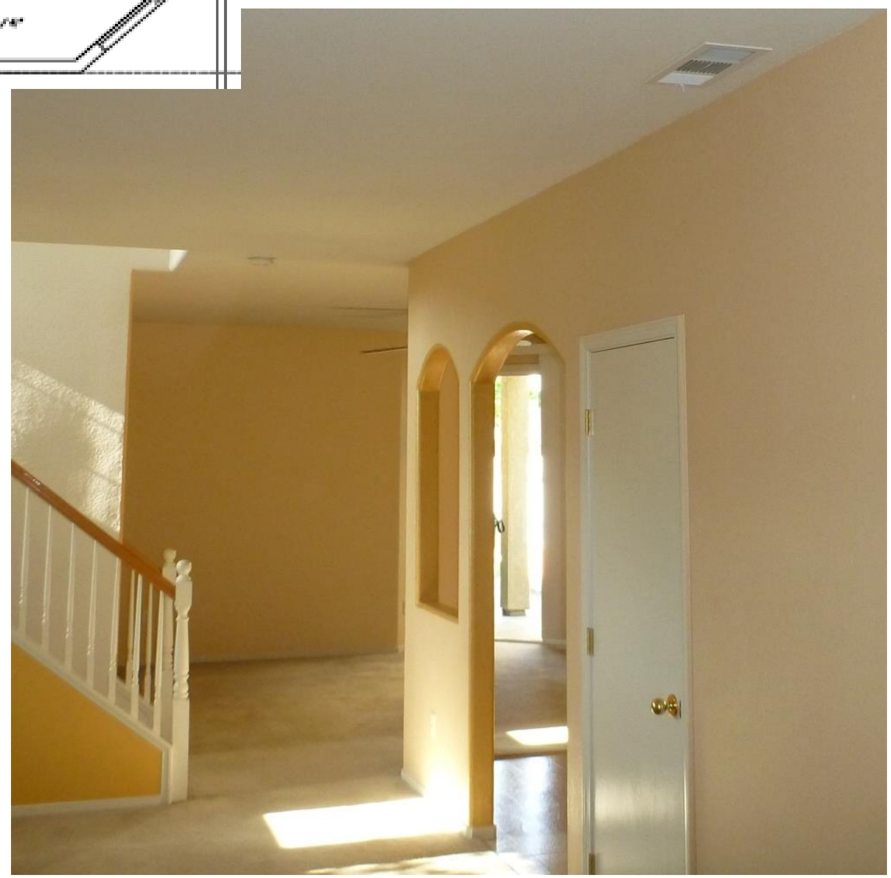


Ductless or Ducted M-split





Ductless or Ducted M-split



Options

- **Single Zone**
- Two Zones
  - Ducted Multi Split (single outside unit, three heads)
  - Ductless Mini or Multi Split
  - **Ducted Dampered Two Speed System**
  - **Ducted Dampered Single Speed System**

Manual J Heating and Cooling Sensible Loads

Upstairs	Cooling	Heating
Bedroom 1	1,842	1,750
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Upstairs	10,123	10,097
Downstairs		
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Dining/Kitchen	2,878	5,706
Downstairs	6,465	12,432

Calculate CFM from BTUh

Upstairs	Cooling BTUh	Heating BTUh
Total	16,588	22,529
Equipment	2 Tons	40,000

Cooling at 500 CFM per Ton = 1000 CFM
1000 CFM/16,588 BTUh = **0.060 CFM/BTUh**

Heating at 400 CFM per Ton = 800 CFM
800 CFM/22,529 BTUh = **0.036 CFM/BTUh**

Cooling CFM by Room

Upstairs	Cooling		Cool CFM
Bedroom 1	1,842	1,842 × 0.06	= 111 CFM
Bedroom 2	1,601	1,601 × 0.06	= 97 CFM
Bedroom 3	1,354	1,354 × 0.06	= 81 CFM
Master BR	3,892	3,892 × 0.06	= 234 CFM
Common/Bth	1,434	1,433 × 0.06	= 86 CFM
Upstairs	10,123		
Downstairs			
Living Room	3,587	3,587 × 0.06	= 215 CFM
Dining/Kitchen	2,878	2,878 × 0.06	= 173 CFM
Downstairs	6,465		

Heating CFM by Room

Upstairs	Heating		Heat CFM
Bedroom 1	1,750	1,750 × .036	= 62 CFM
Bedroom 2	1,795	1,795 × .036	= 64 CFM
Bedroom 3	990	990 × .036	= 35 CFM
Master BR	4,238	4,238 × .036	= 150 CFM
Common/Bth	1,324	1,324 × .036	= 47 CFM
Upstairs	10,097		
Downstairs			
Living Room	6,726	6,726 × .036	= 239 CFM
Dining/Kitchen	5,706	5,706 × .036	= 203 CFM
Downstairs	12,432		

Manual J Standard CFM for Single Zone

Upstairs	Cool CFM	Heat CFM	Design Single Zone CFM
Bedroom 1	111 CFM	62 CFM	111 CFM
Bedroom 2	97 CFM	64 CFM	97 CFM
Bedroom 3	81 CFM	35 CFM	81 CFM
Master BR	234 CFM	150 CFM	234 CFM
Common/Bth	86 CFM	47 CFM	86 CFM
Upstairs	610 CFM	359 CFM	610 CFM

Downstairs			
Living Room	215 CFM	239 CFM	239 CFM
Dining/Kitchen	173 CFM	203 CFM	203 CFM
Downstairs	390 CFM	441 CFM	441 CFM

Manual J Standard CFM for Single Zone

Don’t like this heat cool CFM difference because of different velocities at delivery terminals

Upstairs	Cool CFM	Heat CFM	D
Bedroom 1	111 CFM	62 CFM	111 CFM
Bedroom 2	97 CFM	64 CFM	97 CFM
Bedroom 3	81 CFM	35 CFM	81 CFM
Master BR	234 CFM	150 CFM	234 CFM
Common/Bth	86 CFM	47 CFM	86 CFM
Upstairs	610 CFM	359 CFM	610 CFM
Downstairs			
Living Room	215 CFM	239 CFM	239 CFM
Dining/Kitchen	173 CFM	203 CFM	203 CFM
Downstairs	390 CFM	441 CFM	441 CFM

Re-Calculate CFM

Upstairs	Cooling BTUh	Heating BTUh
Total	16,588	22,529
Equipment	2 Tons	40,000

Cooling at 500 CFM per Ton = 1000 CFM
1000 CFM/16,588 BTUh = 0.060 CFM/BTUh

Heating at 500 CFM per Ton = 1000 CFM
1000 CFM/22,529 BTUh = 0.044 CFM/BTUh

New Heating CFM by Room

Upstairs	Heating		Heat CFM
Bedroom 1	1,750	1,750 × .044	= 77 CFM
Bedroom 2	1,795	1,795 × .044	= 79 CFM
Bedroom 3	990	990 × .044	= 44 CFM
Master BR	4,238	4,238 × .044	= 186 CFM
Common/Bth	1,324	1,324 × .044	= 58 CFM
Upstairs	10,097		
Downstairs			
Living Room	6,726	6,726 × .044	= 296 CFM
Dining/Kitchen	5,706	5,706 × .044	= 251 CFM
Downstairs	12,432		

Manual J Standard CFM for Single Zone

Upstairs	Cool CFM	Heat CFM	Design Single Zone CFM
Bedroom 1	111 CFM	77 CFM	111 CFM
Bedroom 2	97 CFM	79 CFM	97 CFM
Bedroom 3	81 CFM	44 CFM	81 CFM
Master BR	234 CFM	186 CFM	234 CFM
Common/Bth	86 CFM	58 CFM	86 CFM
Upstairs	610 CFM	444 CFM	610 CFM
Downstairs			
Living Room	215 CFM	296 CFM	296 CFM
Dining/Kitchen	173 CFM	251 CFM	251 CFM
Downstairs	388 CFM	547 CFM	547 CFM

For a Single Zone System

Proceed with Manual D type process to:

1. Lay out terminals and duct system
2. Select terminals based on CFM, throw and room configuration
3. Calculate total effective length (TEL)
4. Calculate available static pressure (ASP) for selected equipment (change equipment selection if necessary)
5. Determine friction factor *IWC drop per 100 ft.* (ASP / TEL x 100)
6. Select duct sizes based on CFM and friction factor

Back to the Zoning for Comfort

- Review the issue
- Review the CFM delivery desires
- Look at ducted zoning options

Manual J Heating and Cooling Sensible Loads

Upstairs	Cooling	Heating
Bedroom 1	1,842	1,750
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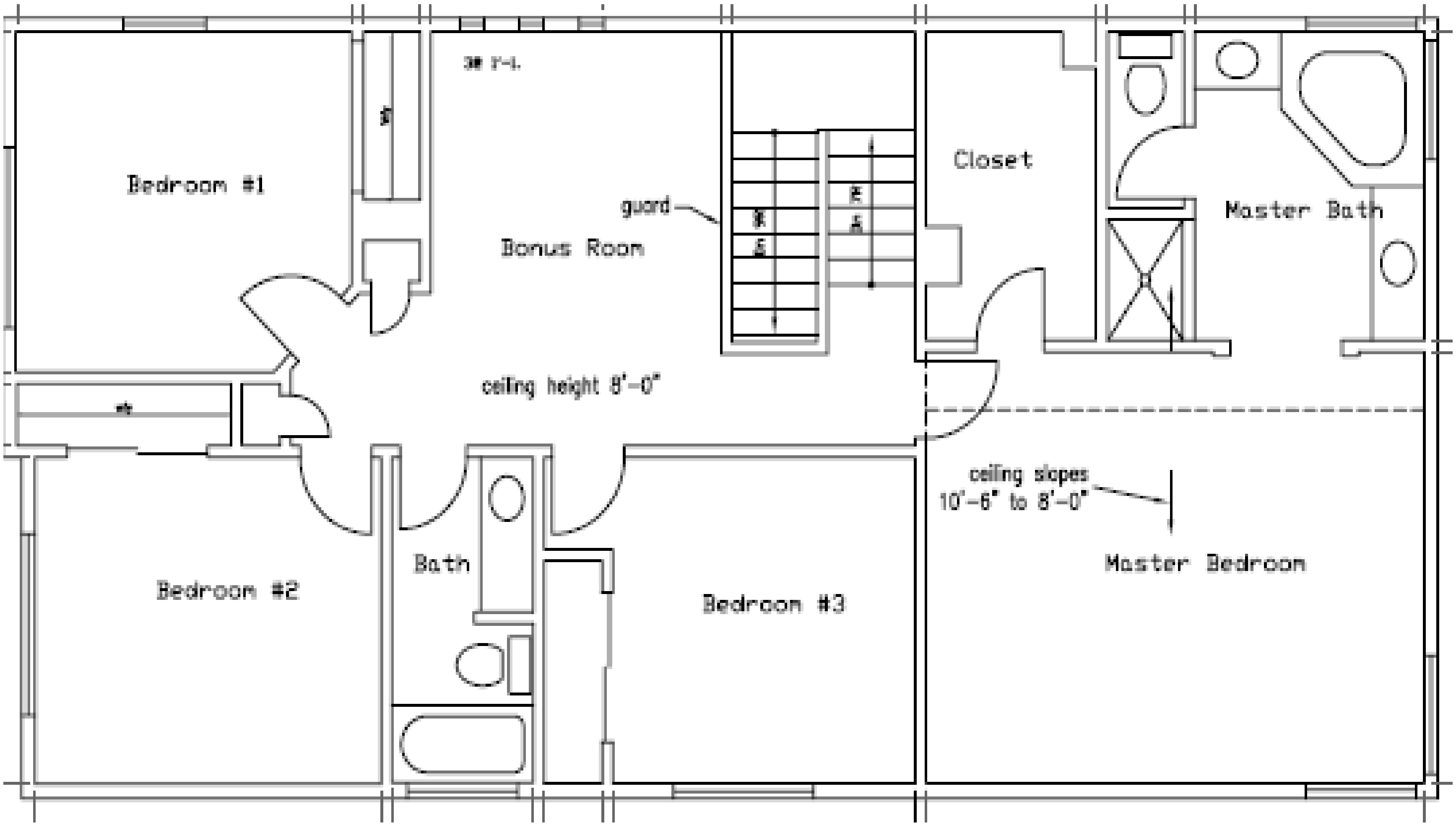
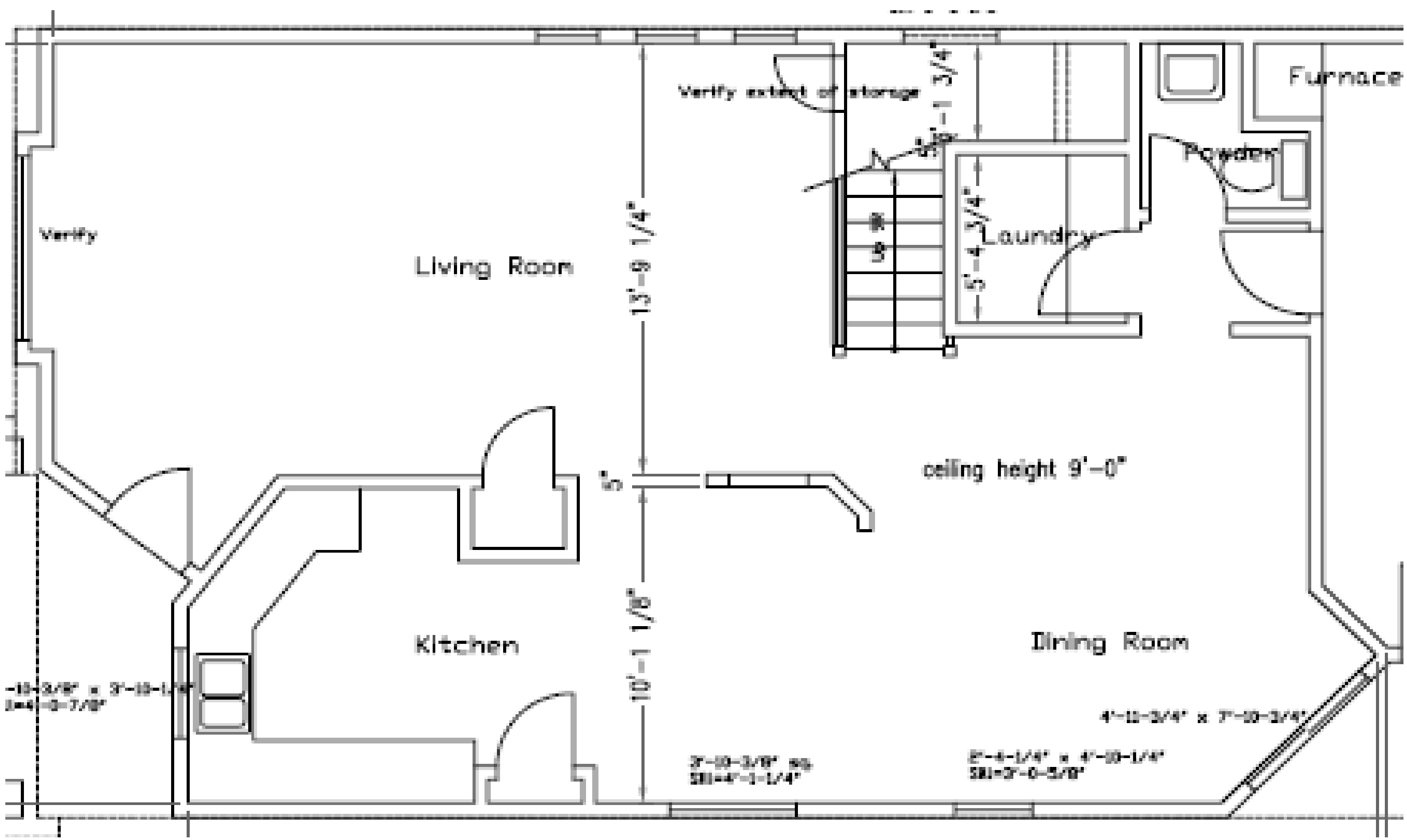
Downstairs	6,465	12,432

Where Shall We Put the Upstairs Bonus Supply?



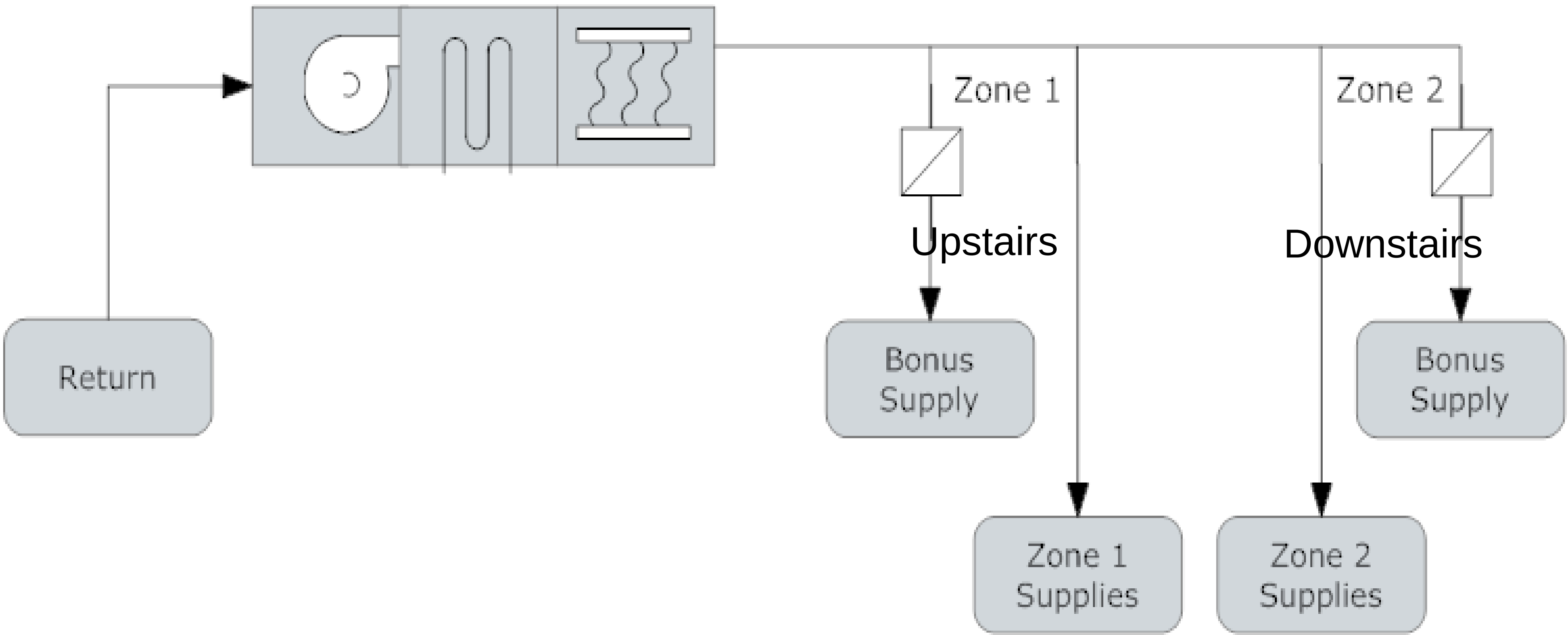
It needs to be where the thermostat is

Where Shall We Put the Downstairs Bonus Supply?



Single Capacity Zoned System

- Move Part of the Capacity from One Zone to Another based on Load (Capacity Shift Zoning)



Manual J Standard CFM

(at 500 CFM per ton cooling and heating)

Upstairs	Cool CFM	Heat CFM	Design Single Zone CFM
Bedroom 1	111 CFM	77 CFM	111 CFM
Bedroom 2	97 CFM	79 CFM	97 CFM
Bedroom 3	81 CFM	44 CFM	81 CFM
Master BR	234 CFM	186 CFM	234 CFM
Common/Bth	86 CFM	58 CFM	86 CFM
Upstairs	610 CFM	444 CFM	610 CFM
Downstairs			
Living Room	215 CFM	296 CFM	296 CFM
Dining/Kitchen	173 CFM	251 CFM	251 CFM
Downstairs	388 CFM	547 CFM	547 CFM

Shift Capacity

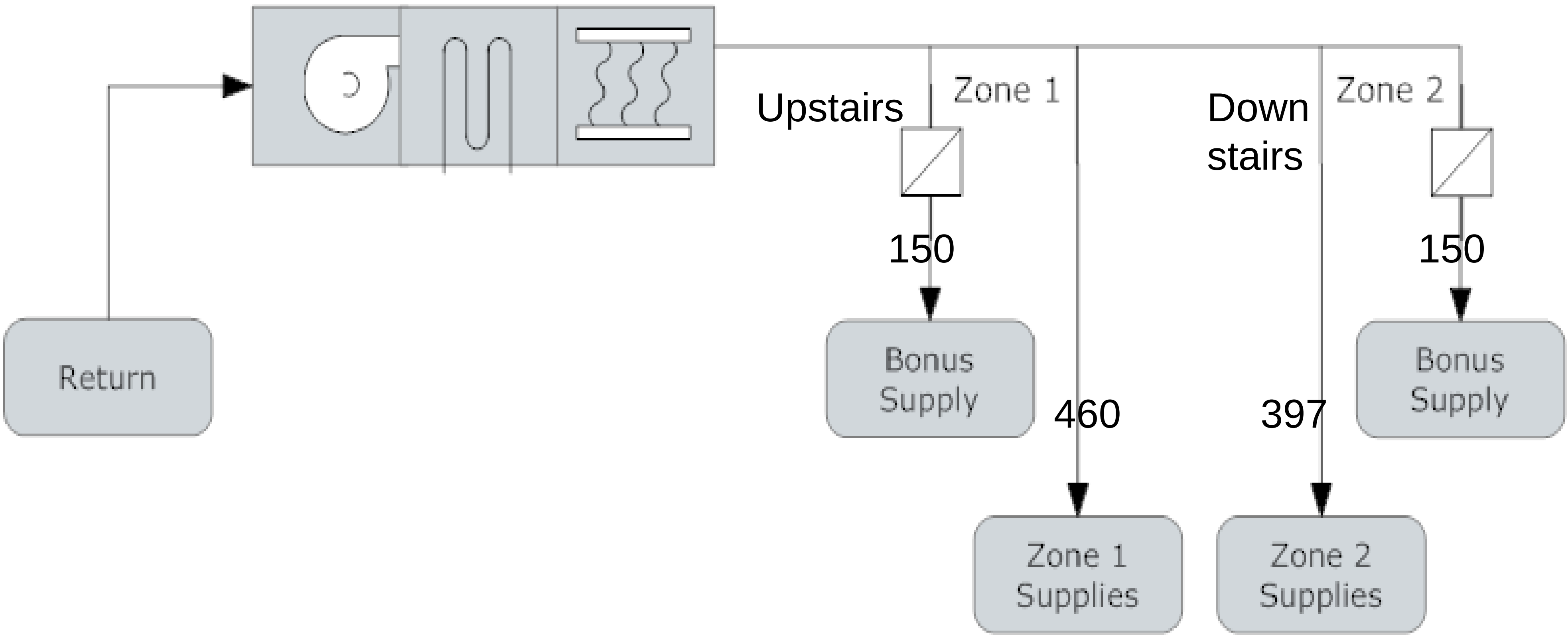
- Recommended Shift 20% to 30%
- In this case 20% of 610 CFM = 120 CFM
- 30% of 547 CFM = 164 CFM
- Call it 150 Shifted CFM to Bonus Supplies

Determine CFM to Always Open Supplies:

- Upstairs Supplies 610 – 150 = 460 CFM
- Downstairs Supplies 547 – 150 = 397 CFM

Single Capacity Zoned System

- Move Part of the Capacity from One Zone to Another based on Load



Re-estimate Supply Flows

- We moved 150 CFM out of the always open supplies, so they don't have to be as big
- So what is the new upstairs flow (% of old)?

  _________ / ___________ = _________

- So what is the new downstairs flow (% of old)?

  _________ / ___________ = _________

Upstairs	“Std” CFM	Zone CFM
Bedroom 1	111	× .754 = 84
Bedroom 2	97	× .754 = 73
Bedroom 3	81	× .754 = 61
Master BR	234	× .754 = 176
Common/Bth	86	× .754 = 65
Master BR Bonus		75 CFM
Common/Bath Bonus		75 CFM
Upstairs	610	609
Downstairs		
Living Room	296	× .725 = 215
Dining/Kitchen	251	× .725 = 182
Living Bonus		150 CFM
Downstairs	547	547

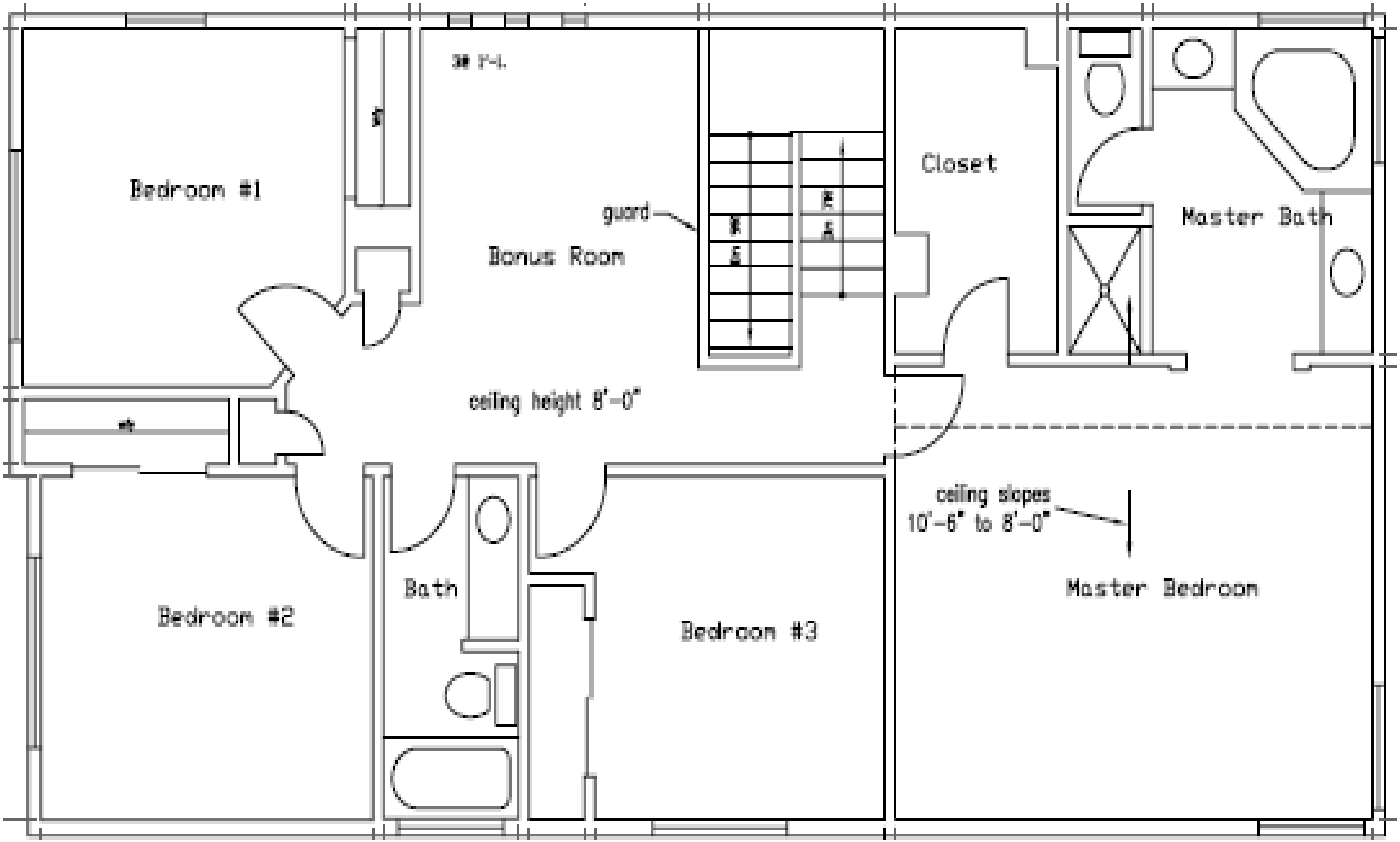
Proper Design

1. Determine the best locations and size for the air terminals (registers)

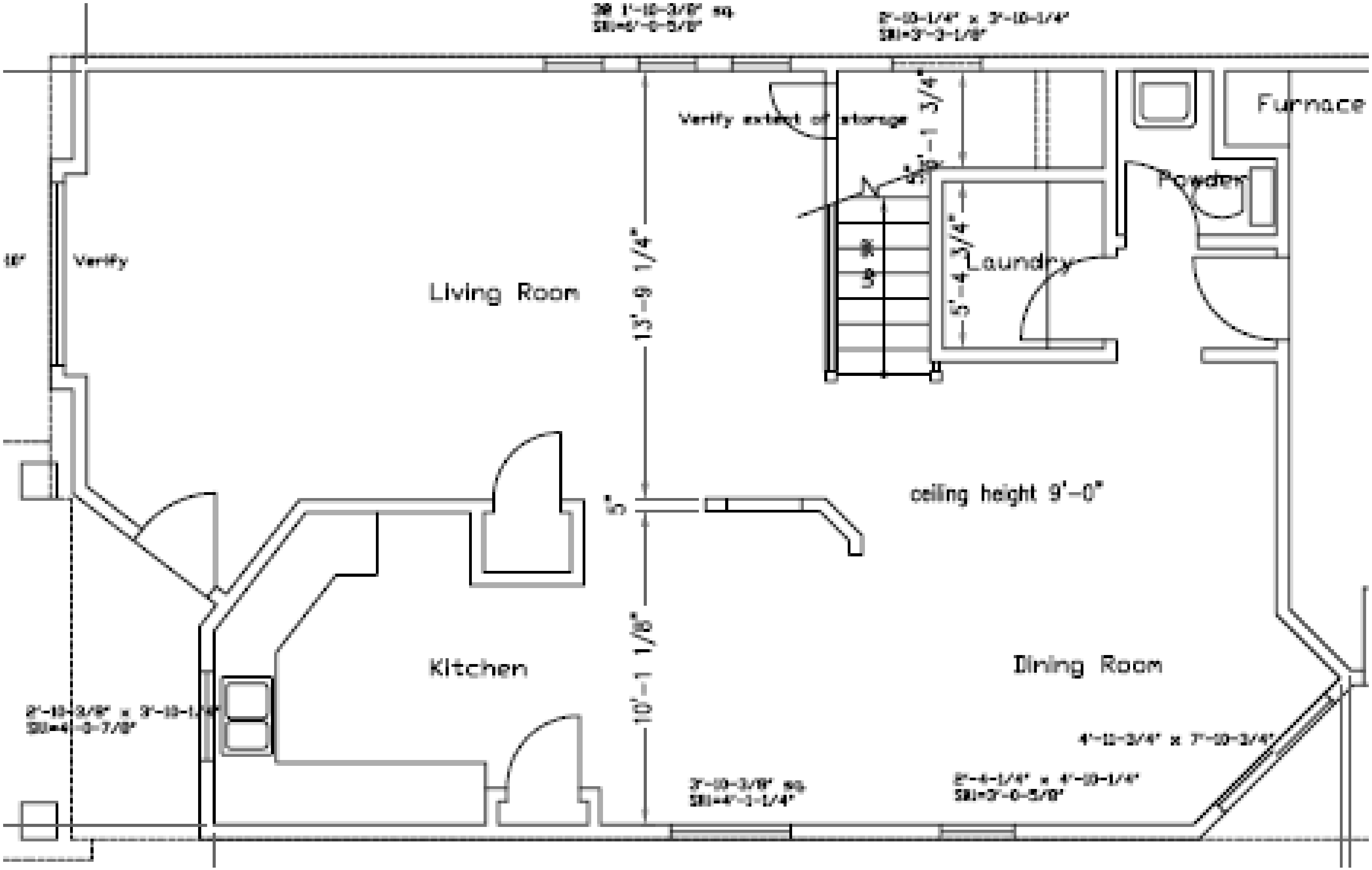
   Use ACCA Manual T

2. Design the duct system to the available pressure and minimize the effective length

   Use ACCA Manual D or Equivalent



Bedroom #1
Bonus Room
guard
Closet
Master Bath
ceiling height 8'-0"
ceiling slopes
10'-6" to 8'-0"
Master Bedroom
Bath
Bedroom #2
Bedroom #3



Living Room
Kitchen
Dining Room
Laundry
Powder
Furnace
Verify
Verify extent of storage
ceiling height 9'-0"
13'-9 1/4"
5"
10'-1 1/8"
5'-4 3/4"

To Size Our Ducts We Need to Know How Much Static Pressure We Have

To do that we need to know the air handler and coil we will use

We start with the Load and CFM

	Cooling BTUh	Heating BTUh
Upstairs	10,123	10,097
Downstairs	6,465	12,432
Total	16,588	22,529
CFM	1000	1000

Select the AC Unit

DETAILED COOLING CAPACITIES# CONTINUED

EVAPORATOR AIR | CONDENSER ENTERING AIR T

CFM	EWB °F (°C)	95 (35) Capacity MBtuh Total	95 (35) Capacity MBtuh Sens‡	95 (35) Total System KW**
		)31 Outdoor Section With CAP**241		
700	72 (22.2)	24.63	12.41	2.06
	67 (19.4)	22.71	15.56	2.05
	63 (17.2)††	21.29	15.11	2.05
	62 (16.7)	20.99	18.67	2.05
	57 (13.9)	20.79	20.79	2.05
900	72 (22.2)	25.10	13.63	2.13
	67 (19.4)	23.21	17.59	2.13
	63 (17.2)††	21.82	17.01	2.12
	62 (16.7)	22.11	22.11	2.12
	57 (13.9)	22.11	22.11	2.12

COOLING INDOOR MODEL	CAPACITY	POWER
*CAP**2414A**	1.00	1.00
CAP**2417A**	1.00	1.00
CAP**3014A**	1.01	1.01
CAP**3017A**	1.01	1.01
CAP**3617A**	1.01	1.01
CAP**3619A**	1.01	1.01
CAP**3621A**	1.02	1.02
CNPH*2417A**	1.00	1.00
CNPH*3017A**	1.01	1.01
CNPH*3117A**	1.02	1.02
CNPV*2414A**	1.00	1.00
CNPV*2417A**	1.00	1.00
CNPV*3014A**	1.01	1.01
CNPV*3017A**	1.01	1.01
CNPV*3117A**	1.02	1.02
CSPH*2412A**	1.00	1.00
CSPH*3012A**	1.01	1.01
FB4CNF024	0.99	0.99

What matching Coils are there?

Select the AC Coil
Looking for low Static Pressure Drop

COIL STATIC PRESSURE DROP (in. w.c.) PURO

CNPHP / CNRHP

UNIT SIZE	S								
	400	500	600	700	800	900	1000	1100	120
2417	0.048	0.068	0.090	0.112	0.140	0.170	0.203		
	0.064	0.091	0.122	0.150	0.188	0.224	0.263		
3017	0.042	0.060	0.080	0.102	0.128	0.157	0.188	0.222	0.2
	0.055	0.076	0.104	0.127	0.158	0.190	0.225	0.266	0.3
3117	0.031	0.046	0.063	0.083	0.105	0.130	0.156	0.193	0.2
	0.039	0.056	0.075	0.097	0.121	0.149	0.179	0.212	0.2
3617	0.043	0.061	0.082	0.103	0.128	0.157	0.189	0.221	0.2
	0.056	0.079	0.107	0.133	0.166	0.200	0.236	0.276	0.3

PERFORMANC

CAPMP / CARMP

COIL STATIC PRESSURE DROP (in. w.c.) PURON

UNIT SIZE	STAND								
	400	500	600	700	800	900	1000	1100	1200
2417	0.056	0.076	0.097	0.123	0.151	0.182	0.215		
	0.060	0.082	0.105	0.132	0.163	0.195	0.231		
3014	0.054	0.077	0.102	0.133	0.167	0.206	0.248	0.296	0.347
	0.059	0.084	0.111	0.142	0.181	0.223	0.269	0.319	0.375
3017	0.043	0.059	0.077	0.096	0.119	0.144	0.171	0.201	0.232
	0.046	0.063	0.083	0.105	0.130	0.157	0.186	0.219	0.252
3614	0.047	0.069	0.093	0.119	0.151	0.187	0.227	0.270	0.317
	0.053	0.076	0.101	0.129	0.162	0.200	0.241	0.286	0.335
3617	0.023	0.036	0.052	0.069	0.089	0.110	0.135	0.160	0.189
	0.042	0.058	0.076	0.095	0.117	0.142	0.169	0.198	0.231
3621	0.026	0.037	0.050	0.062	0.077	0.092	0.109	0.128	0.148
	0.029	0.040	0.053	0.065	0.082	0.099	0.119	0.138	0.160

Select the Furnace for CFM and Watt Draw (BPM preferred)

58STA/STX

AIR DELIVERY - CFM (With Filter)

UNIT SIZE	RETURN-AIR SUPPLY	SPEED	EXTERNAL STATIC PRESSURE (In. W.C.)									
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
045-08	Bottom or Side(s)	High Med-High Med-Low	1085 920 820	1035 875 775	975 830 730	915 770 680	845 710 620	770 640 555	675 555 470	565 440 360	390 250 190	195 — —
045-12	Bottom or Side(s) Low	High Med-High Med-Low	1450 1360 1250	1375 1300 1210	1305 1240 1160	1225 1175 1100	1145 1115 1040	1050 1040 965	955 950 885	845 850 790	705 725 670	510 575 520
070-08	Bottom or Side(s)	High Med-High Med-Low	1030 835 725	1010 815 700	980 790 675	945 760 645	900 720 600	845 675 555	775 610 475	680 490 390	490 375 300	335 265 —
070-12	Bottom or Side(s)	High Med-High Med-Low	1425 1320 1200	[illegible]	[illegible]	[illegible]	[illegible]	1125 1075 990	1035 995 920	940 905 840	830 790 725	655 620 555
070-16	Bottom or Side(s)	High Med-High Med-Low	1805 1630 1460	[illegible]	[illegible]	[illegible]	[illegible]	1445 1330 1220	1360 1255 1155	1280 1170 1080	1180 1080 995	1075 990 910
090-14	Bottom or Side(s)	High Med-High Med-Low	1650 1515 1385	1600 1485 1360	1535 1440 1320	1465 1380 1260	1385 1300 1195	1285 1220 1120	1175 1115 1025	1055 990 915	895 830 710	645 600 565
090-16	Bottom or Side(s)	High Med-High Med-Low	2060 1790 1505	1985 1765 1505	1915 1715 1480	1820 1645 1440	1720 1560 1375	1610 1470 1300	1490 1345 1190	1340 1195 1045	1135 1010 890	925 820 740
	Bottom Only	High Med-High Med-Low	2405 2225 2020	2310 2155 1955	2220 2080 1880	2130 1995 1805	2025 1895 1730	1920 1785 1630	1790 1675 1535	1660 1565 1420	1530 1420 1275	1350 1260 1135

This Furnace has a 14” Cabinet

Final Furnace and Coil Selections

- Furnace
  - 045-12
  - Flow = 1040 CFM @ 0.5 IWC (Medium Low)
  - Replace PSC with BPM or Select a Different Furnace
- Diffuser Transition
  - 14” to 21”
- Evaporator Coil
  - 3621
  - ΔP = 0.12 IWC @ 1000 CFM

Determine the Available Static Pressure for the Supply Side

• Total at Air Handler	0.50
- Return	-0.17
- A Coil	-0.12
- Terminal	-0.02
AVAILABLE	0.19

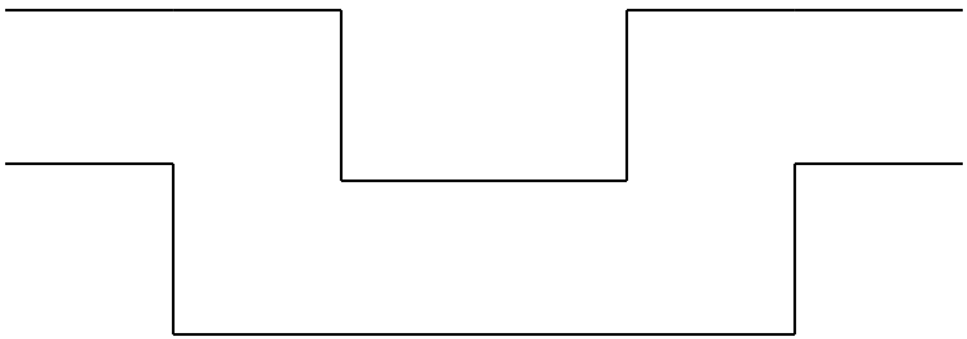
This is available for supply trunks and standard branches using Manual D methods.

- Control Damper	-0.05
Available for Bonus Runs	0.14

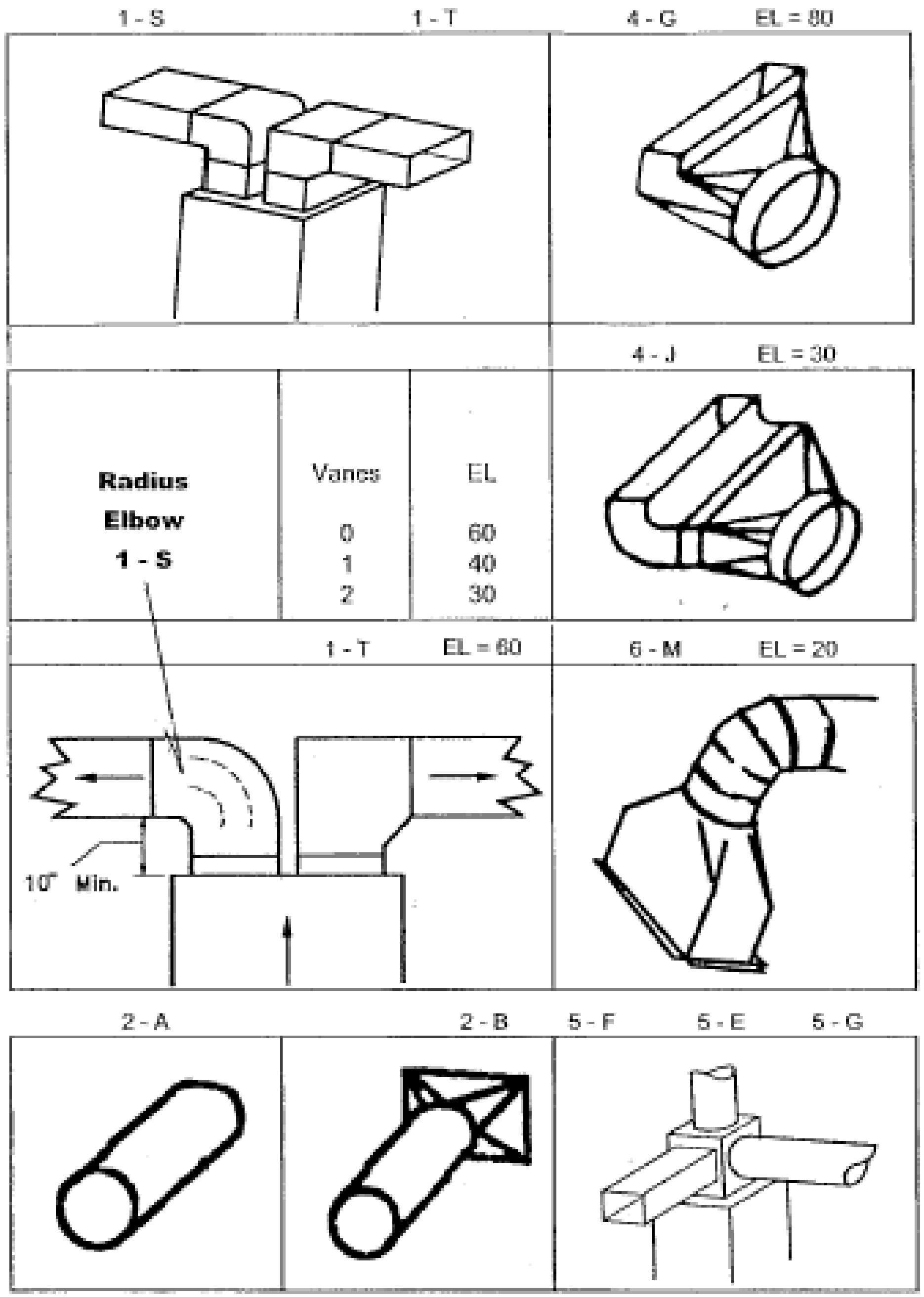
How Long is the Duct System? (from an air molecule's view)

- A 200 ft. straight pipe is 200 feet long

- This 4 ft. section of pipe is how long?



330 Feet



*Excerpted from ACCA Manual D

Determine the Total Effective Length (TEL)

- Zone 1 Always Open

Straight Duct	30
Fittings	100
	130

- Zone 1 Bonus 120
- Zone 2 Always Open 100
- **Zone 2 Bonus 150**

Calculate the Friction Rate

Zone 1 and Zone 2 except Bonus Runs	
Available Supply Static Pressure	0.19 IWC
Longest Equivalent Length	130 Ft.

Friction Rate

FR = 0.19 / 130 * 100

= 0.138 IWC per 100 Ft.

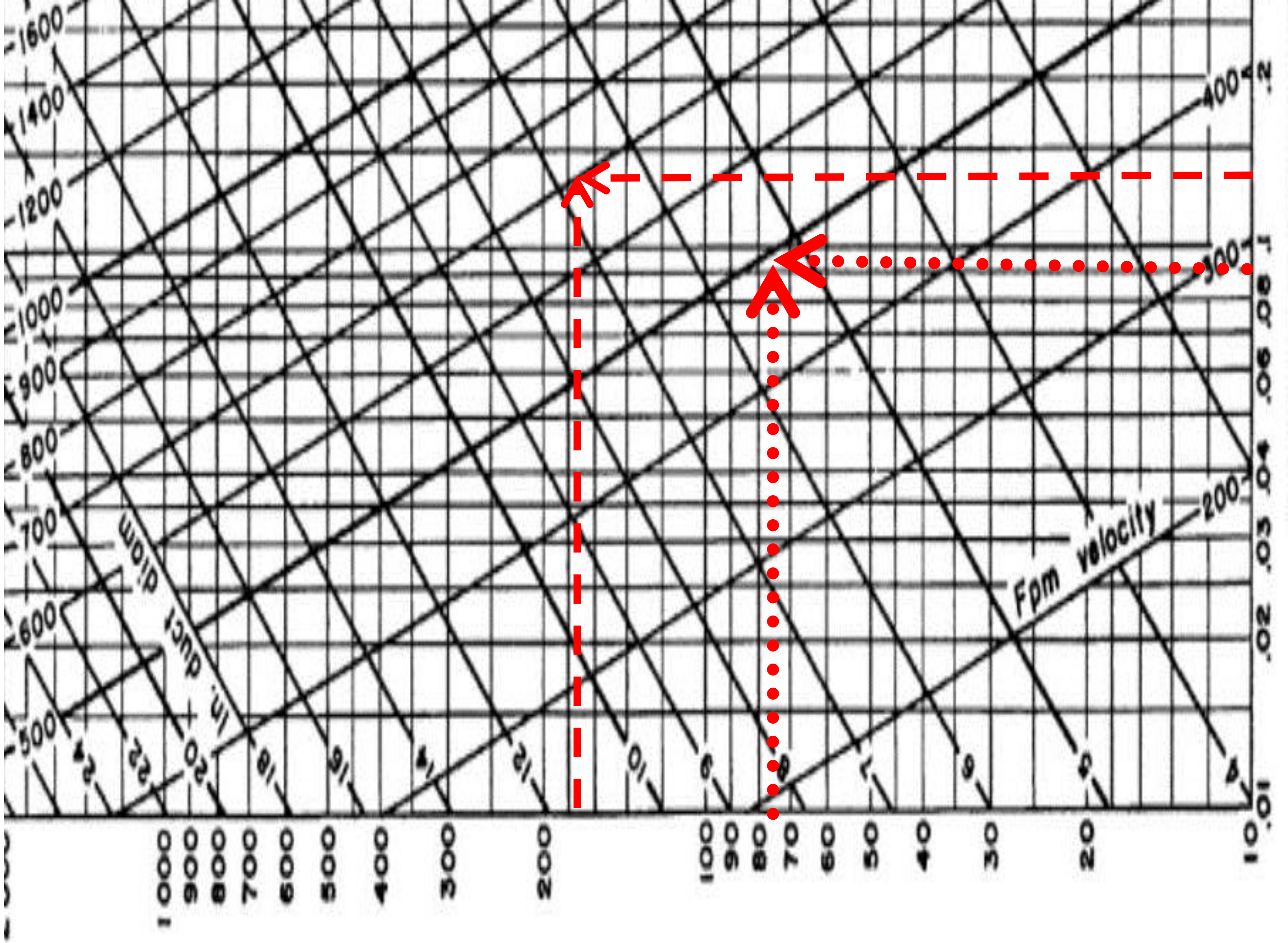
Bonus Runs	
Available Supply Static Pressure	0.14 IWC
Longest Equivalent Length	150 Ft.

Friction Rate

FR = 0.14 / 150 * 100

= 0.093 IWC per 100 Ft.

Upstairs	Zone CFM
Bedroom 1	84
Bedroom 2	73
Bedroom 3	61
Master BR	**176**
Common/Bth	65
Master BR Bonus	**75**
Common/Bath Bonus	75
Upstairs	609
Downstairs	
Living Room	215
Dining/Kitchen	182
Living Bonus	150
Downstairs	547


1600
1400
1200
1000
900
800
700
600
500
24
22
20
18
16
14
12
10
9
8
7
6
5
4
in. duct diam
Fpm velocity
400
300
200
1000
900
800
700
600
500
400
300
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90
80
70
60
50
40
30
20
10
.2
.1
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.04
.03
.02
.01

A Good Duct Design Provides

- Quiet
- Efficient
- Comfort

Efficient

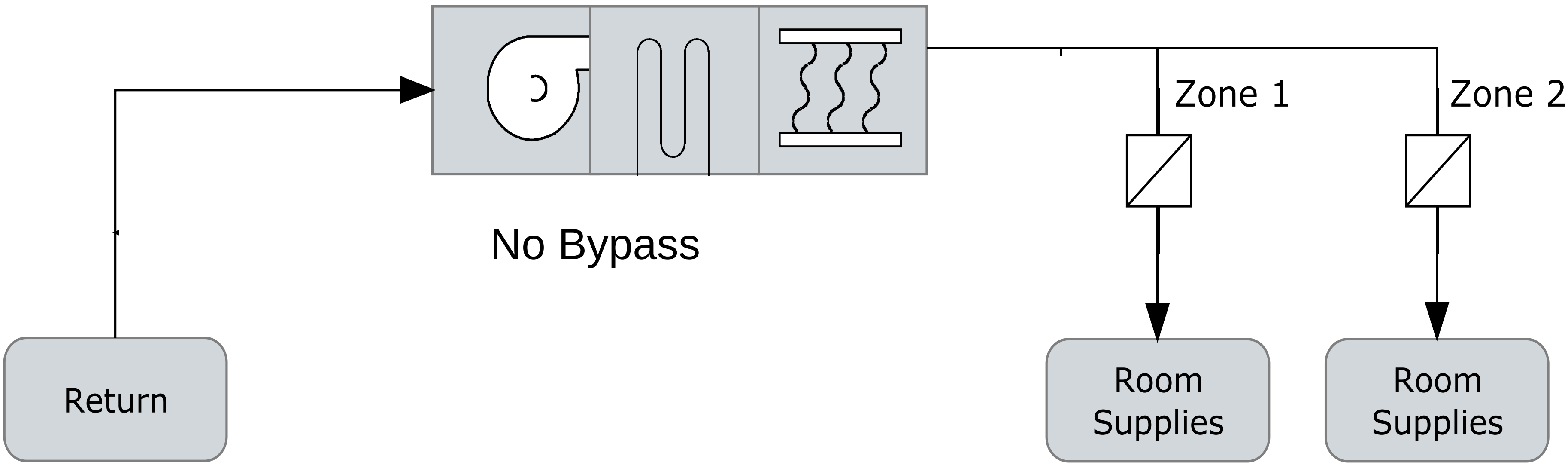
- **FAN WATT DRAW REDUCTION**
- **SUFFICIENT AIRFLOW**
  - USE METAL DUCT AND **FITTINGS**
- LOW CONDUCTION LOSS
  - SHORT RUNS
  - FEWER LARGER DIAMETER RUNS
  - PUT INSIDE THE CONDITIONED SPACE or INSULATE THE HECK OUT OF IT

So Does It Work?

- Test Airflow in all configurations
  - Zone 1 Only Calling
  - Zone 2 Only Calling
  - All Zones Calling
  - Every Combination
- Test at Returns
  - Flow Grid
  - Pressure Matching
  - Powered Flow Hood
  - Passive Flow Hood

A Less Desirable Solution

- Damper stop relief
- Intentionally Leaky Dampers
- Use Oval Damper Door if Possible
- Keep Dampers away from Supply Terminals

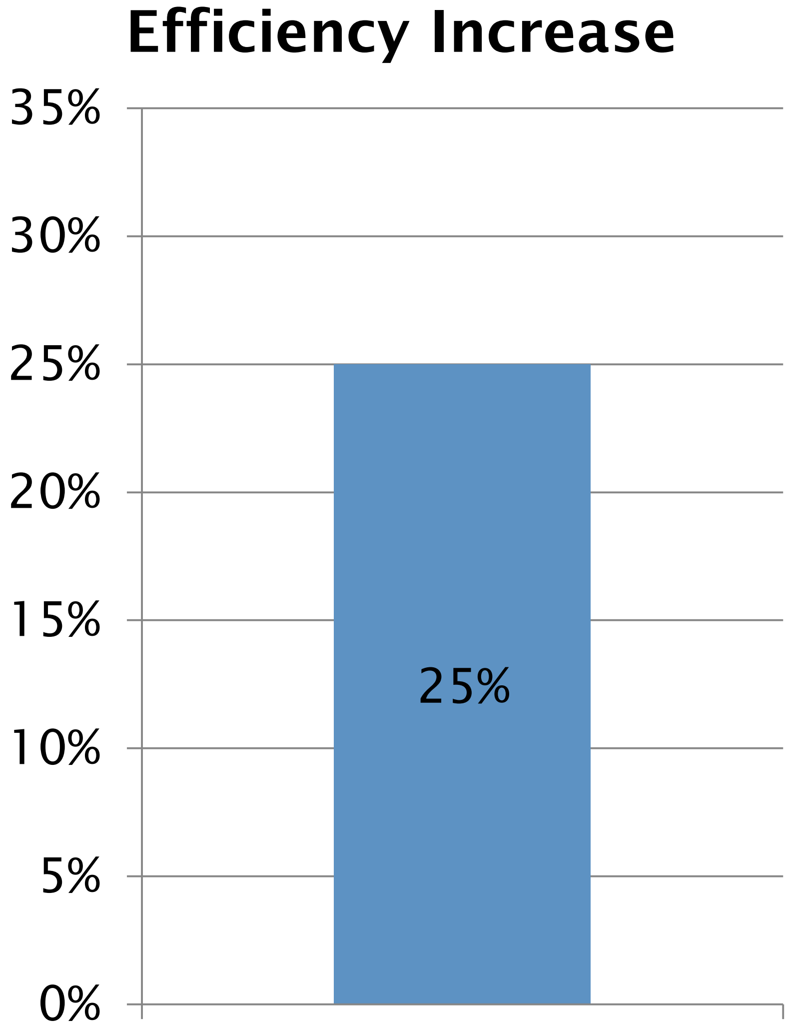


Reviewing Problems with the Old Way using Bypass

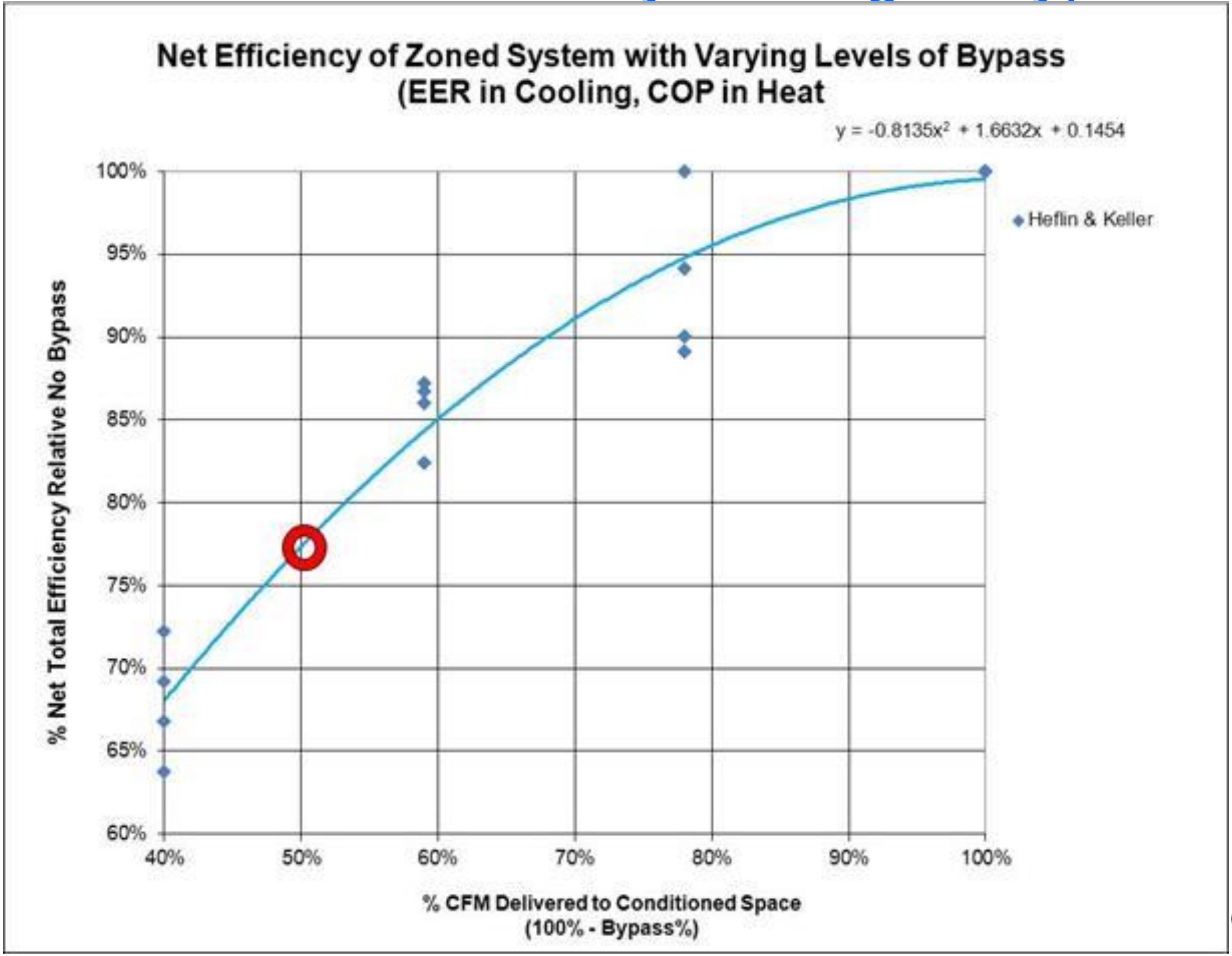
Average Energy Impact

- In typical homes with dampered multi-zone systems:
  - Air Conditioning SEER and EER are degraded by 17%
  - Furnace AFUE is degraded by 4.4%

Eliminate Bypass and Obtain a Minimum Airflow



Carrier Laboratory Testing of Bypass



Carrier ASHRAE Paper Literature Review

- Papers cited by AHRI to support the zoning performance credit
  - "All but one study employed variable or two speed equipment."
  - "… the homes were unoccupied and zone separation (closed doors) was maintained throughout testing caused energy losses to be minimized. Thus, the documented field studies could be considered a 'best case scenario' in terms of energy savings."

More Information

- http://www.proctoreng.com/energy-efficiency/zones.html
- http://www.proctoreng.com/dnld/H114.pdf
- http://www.energy.ca.gov/2014publications/CEC-400-2014-005/CEC-400-2014-005.pdf