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Zoning Ducted Air Conditioners, Heat Pumps, and Furnaces: Summary of a Case Study prepared for the California Statewide Utility Codes & Standards Program

Prepared for:
San Diego Gas & Electric Co.
Southern California Gas
Southern California Edison
Pacific Gas & Electric Co.

November 2011

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Creators of CheckMe!®

1.1 Introduction

The primary purpose of zoning ducted 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. For example, it is common for two-story homes to be too hot on the second floor in both summer and winter. Zoning has the capability of diverting more of the HVAC capacity to the area with the higher load. Another common example is a home with a significant area of west-facing and east-facing windows. In the summer, the east rooms overheat in the morning and the west rooms overheat in the afternoon.

A letter sent to the California Energy Commission on June 6, 2011 by Mr. Glenn Hourahan, Senior Vice President of the Air Conditioning Contractors of America (ACCA), included the following conclusions:

> "Properly designed and installed systems improve comfort.
>
> A properly designed and installed system may or may not save a significant amount of energy, or may increase energy use to some extent."
> (Hourahan 2011)

Providing the most agreeable temperature to all the zones is comfortable, but it carries with it the distinct possibility of increased energy consumption. Since the most common home is single zoned and has only one thermostat placed near the center of the house, temperatures in the rooms distant from that thermostat will vary, sometimes significantly. If zoning is added, the more distant rooms can be conditioned to a more comfortable temperature. This increased conditioning requires more energy.

The National Association of Home Builders (NAHB) report, "Field Investigation of Carrier Residential Zoning System" (Kenney & Barbour 1994) notes that:

> "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... While there is an increase in energy consumption, a zone system does provide more uniform temperatures and better thermal comfort throughout the house than that offered by a central thermostat."

The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Transactions Paper, "Energy Implications of Blower Overrun Strategies for a Zoned Residential Forced Air System" by Oppenheim[1] (1991) states:

> "Zoning with a no-thermostat setup (Test 2) used more electricity for cooling than the system in a central configuration (Test 1) with no thermostat setpoint scheduling. The reason is that by having temperature control at three points

[1] This is possibly the Oppenheim 1991 paper referred to in the NAHB report quoted above. However the reference is not clear.

> instead of just one, the air-conditioning unit was more responsive to the house load."

This CASE topic was initiated for a number of reasons. The number of dampered multi-zoned systems installed in new California homes is significant. The PIER Efficiency Characteristics and Opportunities for New California Homes (ECO) project found that 12% of the ducted systems were dampered multi-zoned systems (Proctor, Chitwood & Wilcox 2011). Dampered multi-zoned systems use a single air conditioner /furnace to supply conditioned air to various zones of the house by opening and closing dampers in the duct system. They also typically recirculate conditioned supply air back into the return of the air conditioner/furnace, thereby lowering the efficiency of the unit. They deliver reduced heating and cooling to the house when only one zone is operating. When operated with single speed equipment, they deliver the reduced capacity at nearly the same expense of energy, dropping the system efficiency.

The ECO report postulated that by eliminating some of the common practices used in the dampered multi-zoned systems, those systems could be retained as a potential comfort item for customers without excessively increasing energy use.

1.2 Literature Review/Data Collection

1.2.1 Literature Review

The primary literature used to advocate for zoned systems consists of the two research reports on monitoring the NAHB research house (Kenney & Barbour 1994 and Oppenheim 1991). These two reports were supplied by Air-Conditioning, Heating, and Refrigeration Institute (AHRI) for inclusion in this CASE study. ACCA also provided their proposed Zoning manual for the study (Rutkowski 2011). Additional literature reviewed includes Leslie & Kazmer (1989) on a different research house, Levins (1985 and 1989), Temple (2005), and Heflin & Keller (1993). Each of these reports is discussed below.

Figure 1 illustrates the mixed results from these studies. In four of seven heating cases in heating and four of six cooling cases, the energy consumption increased with the zoning configuration.

Study Author(s)	Energy Use Compared to Not Zoned		Notes
	Heating	**Cooling**	
Kenney & Barbour			
	148% ↑		5°F set up/down in each zone part of the day with basement
	76% ↓	71% ↓	5°F set up/down in each zone part of the day without basement
Oppenheim (from Kenney & Barbour)			
		135% ↑	No temperature set up
Oppenheim/Carrier			
		121% ↑	No temperature set up
		84% ↓	10°F temperature set up in every zone part of the day
Oppenheim/ASHRAE			
	107% ↑		Central with no modulation and 8-hour 12°F setback, zoned with modulating furnace and two additional setback periods on bedroom zones
	88% ↓		Central with no modulation and 8-hour 12°F setback, zoned with modulating furnace and 22 hours of setback on bedroom zones
Leslie & Kazmer			
	112% ↑		With basement conditioned
	99% ↔		No basement, zoning set back 12°F in the bedroom zone for 10 hours a day
Heflin & Keller			
	118% ↑	113% ↑	41% bypass
Temple			
		106% ↑	No bypass, no setback

Figure 1. Energy Consumption Zoned vs. Central System

↑*indicates increase in energy use;* ↓*indicates decrease,* ↔ *indicates no change.*

Kenney & Barbour

This reference was supplied by the AHRI. It discusses a test of the NAHB Laboratory Test House operated with the following characteristics:

- A single speed blower
- An AFUE 91.5 furnace
- A single speed air conditioning condensing unit
- Five zones (two bedroom zones, one first floor living zone, and two basement zones)
- One of the two basement zones was conditioned in this study.
- When operated in the multi-zone mode, the thermostats in the zones were set up 5°F in cooling and down 5°F in heating during “unoccupied

periods." Based on the occupant heat and moisture simulation data, the "unoccupied periods" appear to be: upstairs zone = 14.5 hours, downstairs bedroom zone = 8 hours, downstairs living zone = 11 hours.

- Air returns are present in every zone.

The test showed 34% increase in heating costs when the zoned system was operated with the basement zone conditioned.

The test showed a 29% reduction in cooling energy consumption with zoning and the temperature setpoint adjustments.

The test showed a problem with recovery time when the zones went from unoccupied to occupied (conditioned vs. temperature floating).

The report states:

> "Zoned systems are known to encourage energy conservation. This has resulted in agencies such as the California Energy Commission to provide performance credits for zoned heating and cooling systems."
>
> "Moreover, zoning can cause higher operating costs if thermostat setup/setback is not used; however, the level of comfort is dramatically increased over the central thermostat."
>
> "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... While there is an increase in energy consumption, a zone system does provide more uniform temperatures and better thermal comfort throughout the house than that offered by a central thermostat."
>
> "Zoning can improve thermal comfort, especially in areas that are underheated or ground coupled. However, increased operating cost is required to achieve higher levels of thermal comfort."
>
> "Setback schedules can significantly reduce operating costs, however some degree of thermal discomfort should be expected."
>
> "Only in mild temperatures, outside air greater than 51°F, did the zones recover from the five degree setback. In all other cases, the zones did not recover to 71°F in the allotted two hours."

The cooling savings conclusions of the 1994 study are questionable due to two incongruities in the report. First, there is an unexplained, random distribution of air conditioner efficiency against outdoor temperature for the system operated as a whole house (single zone) system. But in the zoned operation, the study shows a typical air conditioner efficiency pattern against outdoor temperature. The reported efficiency of the unit as a whole house system was substantially lower than when operated as a zoned system in all but the highest temperatures. This is shown in Figure 2 (an overlay of the study's Figures 3.2.2 and 3.2.3).

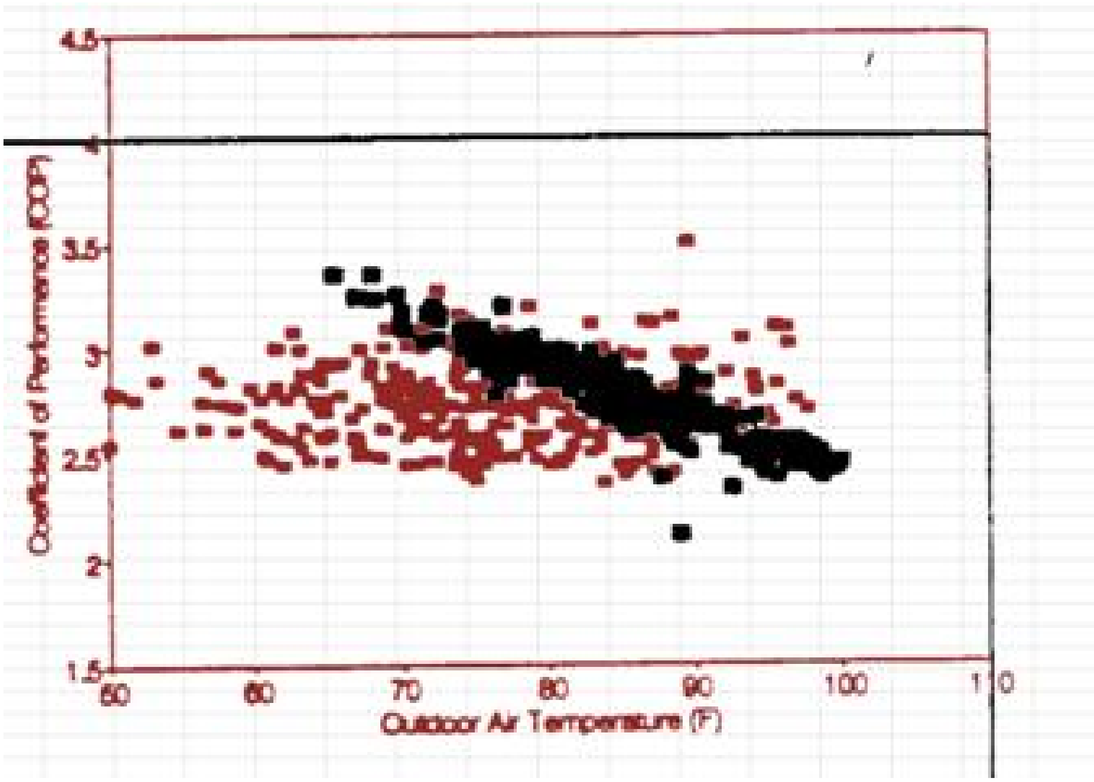

Figure 2. Overlay of AC Efficiency (watts cooling/watts energy consumed) in NAHB study

Whole house single zone operation in red; five zone operation in black

Second, the report states that "both systems experienced approximately the same percentage of hours in each temperature bin." However the graphs in the report show vastly different "Typical Record Year" temperature bins — a statistic that should be identical between the two graphs.

The study reported excess humidity (above 60% Rh) occurring in the zoned configuration twice as often as with the whole house configuration, There were over 400 occurrences in the basement and 130 occurrences in the first-floor bedroom in the multi-zoned configuration compared to 180 and 60 occurrences respectively in the whole house configuration.

Oppenheim

This reference was supplied by the Air-Conditioning, Heating, and Refrigeration Institute (AHRI). It discusses a test of the National Association of Homebuilders (NAHB) Laboratory Test House operated with the following characteristics:

- No bypass duct
- A variable speed blower
- A prototype modulating furnace
- A two-speed air conditioner condensing unit

- Three zones for cooling
- The basement was not conditioned.
- The thermostats in the two bedroom zones were set at a consistent 85°F, 15 hours a day every day (this was a set point temperature increase of 10°F for this unoccupied house).
- The first-floor living zone thermostat was set at a consistent 85°F, 9 hours a day every day.
- There is no mention of the presence of returns in the zones. They are assumed to be present since this is the same test house as was used in the Kenney and Barbour study.

The test showed 21% increase in energy consumption when no temperature setpoint adjustments were used.

The test showed a 16% reduction in energy consumption with the temperature setpoint adjustments.

Leslie & Kazmer

This reference discusses a test at a Laboratory Test House in Chicago, Illinois, operated with the following characteristics:

- No bypass duct
- A variable speed blower
- A modulating (variable capacity) 82% AFUE furnace
- A two-speed air conditioner
- Bedroom, common, and basement zones
- When operated in the heating multi-zone mode, the bedroom thermostats were set down 12°F for 10 daytime hours.
- Also when operated in the heating multi-zone mode, the basement thermostat was set down 12°F for 15 nighttime hours.
- Air returns are present in every zone.

The test showed 12% increase in heating energy consumption when the zoned system was operated with the basement zone conditioned.

The test showed a 1% reduction in heating energy consumption with zoning **and the temperature setpoint adjustments**.

The report states:

> "Zoned heating provided superior comfort compared to central heat, especially in the basement. However, the cost of providing this comfort was high."

> “A test of zoning without basement heat showed energy savings during cold weather but not during moderate weather.”
>
> “Modulating the furnace during central heat reduced energy consumption during moderate weather but not during cold weather.”

Levins

These two papers addressed severe zoning wherein the returns and supplies were fully blocked off and towels were placed under the doors. Levins concluded: “Temperatures in closed-off rooms floated with the outdoor temperature variations, but no savings were observed in the overall heat pump electrical usage or in the house cooling load.”

Heflin & Keller

The authors of this paper were the senior engineer and director for split system development at Carrier Corporation. This paper discusses a series of laboratory tests of zoning bypasses on single speed residential air conditioners and heat pumps. The data from the tests are in Appendix B.

Figure 3 shows the loss of efficiency from recirculating air through a bypass. The left hand axis shows the percentage of efficiency relative to no bypass. The bottom axis displays the percentage airflow providing cooling or heating to the conditioned space. When 50% of the air is bypassed, the efficiency falls to 77% of its full value or a 23% loss in efficiency.

This paper did not present data on the reduction in sensible heat ratio as the amount of bypass increases. It is well known, however, that the recirculation bypass ducts reduce the sensible heat ratio and that the sensible energy efficiency ratio (EER) drops faster than the total EER, as plotted in Figure 3.

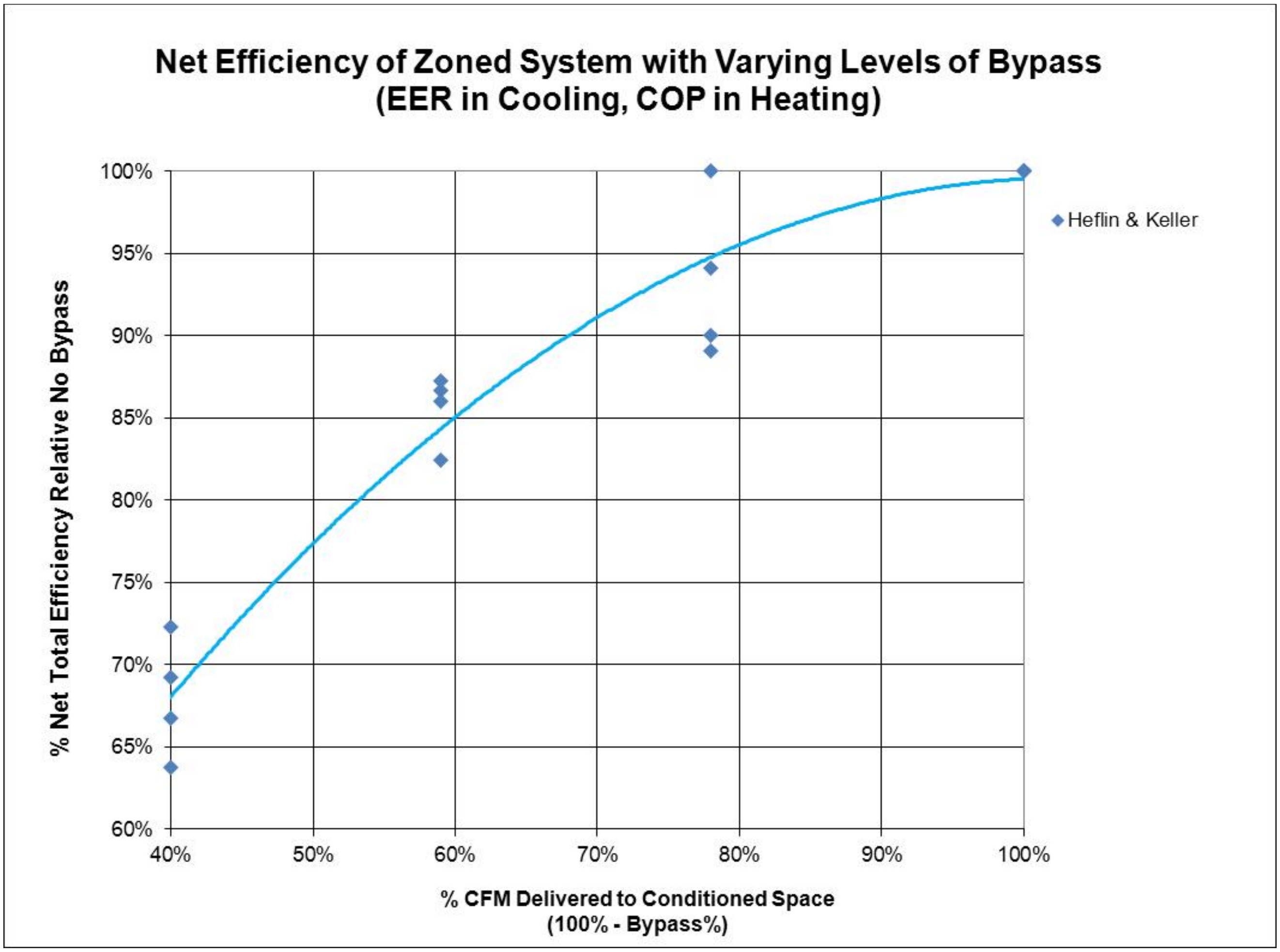

Figure 3. Net Zoned System Efficiency with Bypass (Carrier Lab Data)

This paper states:

> "Capacity and EER drop significantly with increasing air bypass for both the air conditioner and heat pump. The capacity and the EER of the air conditioner decreased 47% and 46% respectively with an increase in bypass from 0% to 79% for DOE A test conditions."

Note that the reduction in capacity produces an almost equal reduction in efficiency. This is because the watt draw of the condensing unit changes very little as the indoor coil gets colder.

Heflin & Keller, commenting on the field studies by Leslie & Kazmer, Levins, and Oppenheim, noted: "None of the studies employed a bypass duct." The report continues, "Moreover, the fact that the homes were unoccupied and zoning 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."

The report states:

> "Without setback/setup schedules, zoned systems typically used more energy than the unzoned systems...."
>
> "Most of the savings resulted from setback/setup."

Temple

This reference discusses a test of a new townhouse in Pittsburg, Pennsylvania, which operated with the following characteristics:

- No bypass duct
- A variable speed blower
- A two-speed air conditioner
- Bedroom, common, and basement zones
- Three zones
- Air returns are present in two zones.

The test showed 6% increase in cooling energy consumption when the system was operated with zoned control.

Rutkowski (ACCA Manual Zr)

Air Conditioning Contractors of America is producing a manual titled "Zoned Comfort Systems for Residential Low-Rise Buildings" (Rutkowski 2011). The manual, which is currently in a public review draft, includes an equation (Figure 4) for estimating the supply dry bulb temperature based on the bypass factor and other operating conditions. The equation assumes a sensible heat ratio of 1.0, which is not achieved in the field. The result is an overestimate of the sensible cooling delivered to the house.

While the equation produces an overly optimistic view of the sensible capacity of an air conditioner operating with a bypass, plotting the results of that equation shows that the reduction in efficiency from a bypass is approximately 31% for a 50% bypass. Figure 5 shows the numbers from that calculation for a 3 ton unit with 1050 CFM through the unit and varying levels of bypass. The results are plotted in Figure 6 and compared to the field data for unit #2.

$$LDB\ (^\circ F) = (-17.0 \times BPF^2 - 10.5 \times BPF + 52.3) + 0.19 \times (OAT - 95) + 0.6^*(EDB_o - 75) + 0.57 \times (28.5 - B/C)$$

Where:
Cooling coil sensible heat ratio = 1.0
LDB = Settled dry-bulb temperature of leaving air
BPF = Bypass factor under investigation
OAT = Outdoor air dry-bulb temperature
EDB_o = Entering dry-bulb temperature, just before the bypass damper opens
B/C = Btuh per blower Cfm for the AHRI rating condition (total Btuh for a specified blower Cfm at 95° F OAT; 80° F EDB and 67° F EWB)

Accuracy

Figure 7-2 and the settled air temperature equation are for a specific piece of 2010 air-cooled equipment. The

Figure 4. ACCA Manual Equation

% CFM to Residence	100%	90%	80%	70%	60%	50%
BPF	0	0.1	0.2	0.3	0.4	0.5
OAT (°F)	95	95	95	95	95	95
EDB (°F)	75	75	75	75	75	75
B/C	32	32	32	32	32	32
LDB (°F)	50.3	49.1	47.5	45.6	43.4	40.8
Temperature Split (°F)	24.7	25.9	27.5	29.4	31.6	34.2
CFM	1050	945	840	735	630	525
CapS (BTUh)	28,004	26,449	24,925	23,318	21,511	19,389
Relative Sensible Capacity	100%	94%	89%	83%	77%	69%

Figure 5. Inputs and Results from ACCA Equation

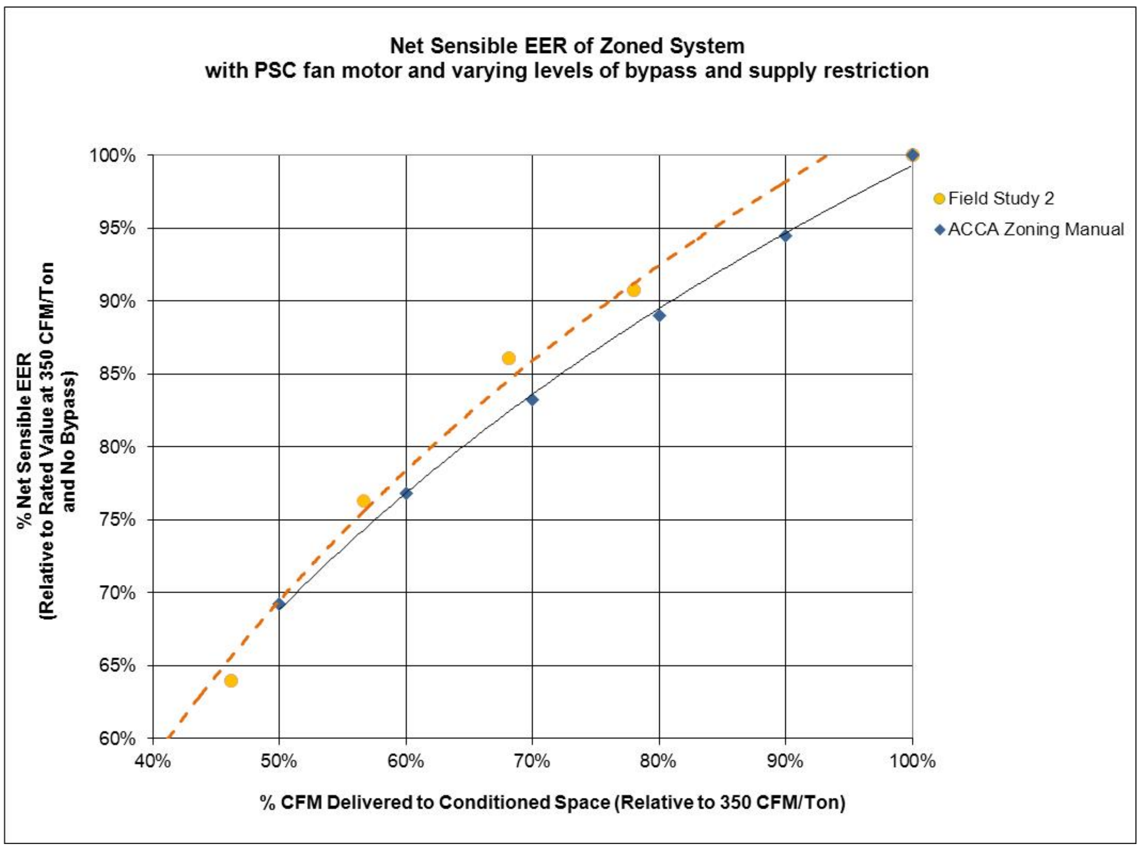

Figure 6. ACCA Manual Z Equation Approximates Field Unit 2

Literature Review Summary

The Heflin and Keller paper illustrates the severe penalty associated with bypass ducts.

From the literature review, it is also clear that **even without a bypass duct or a dump zone** and even with modulating furnaces or air conditioners, the savings from zoned systems are far from certain. In many studied cases the energy consumption increases with the use of the zoned systems.

1.2.2 Field Measured Performance of Zoned AC Systems

Rick Chitwood measured HVAC characteristics of 80 new California homes for the Efficiency Characteristics and Opportunities for New California Homes (ECO) project (Proctor, Chitwood & Wilcox 2011). That randomized survey included 10 dampered multi-zoned systems. Nine of the systems were two-zone systems and one was a three-zone system.

As displayed in Figure 7 and Figure 8, the ECO project found that the multi-zoned systems had significantly lower airflow and higher watt draws than single zoned systems. The differences were always significant at the .05 level. The result of the low airflow and high fan watts is reduced capacity and efficiency (both sensible and total).

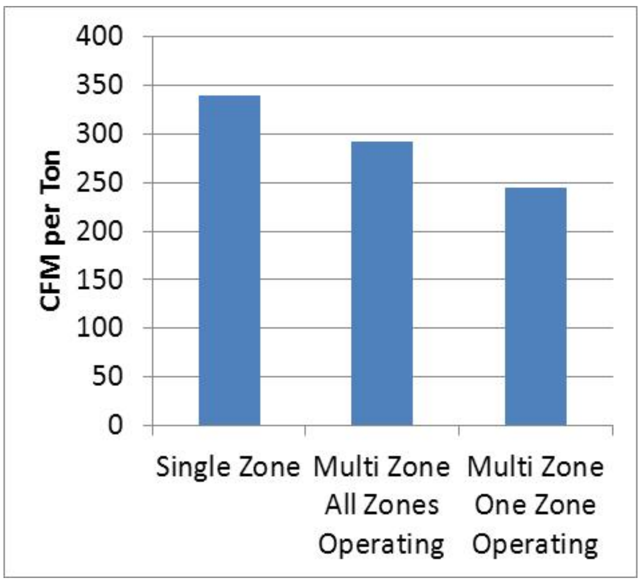

Figure 7. Airflow Reduction with Multi-Zoned HVAC Systems

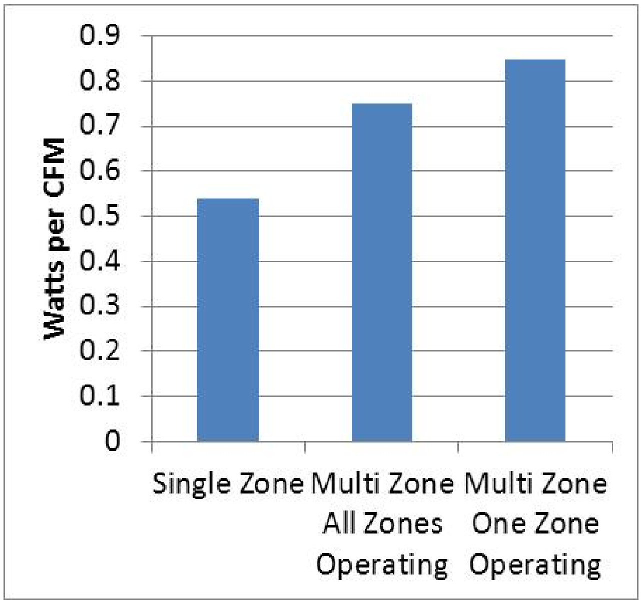

Figure 8. Normalized Fan Watt Draw Increase with Multi-Zoned HVAC Systems

Three of the zoned systems were studied intensively to confirm the energy savings potential. The details of this follow-up investigation are in Section 0.

Analysis and Results

There are two primary methods by which the common multi-zoned dampered system lowers the capacity and efficiency of an air conditioner. These are:

- Lower airflow due to the additional restriction of zoning dampers, and
- Recirculation through the air conditioner due to the use of a bypass duct.

Both of these items lower the evaporator coil temperature, which lowers the capacity and efficiency of the unit.

In Sections 0 through 0 below, these items are examined individually with respect to their effect on system efficiency.

Section **Error! Reference source not found.** summarizes the savings from eliminating the bypass and obtaining airflow in excess of 350 CFM per ton.

The Effect of Lowered Evaporator Coil Temperature

The reverse Carnot cycle establishes a theoretical Coefficient of Performance[2] (COP_C) of a vapor compression air conditioner. That Coefficient of Performance is stated as:

COP_C = Tevap / (Tcond – Tevap)

Where

Tevap is the evaporator (inside coil) temperature and

Tcond is the condenser (outside coil) temperature

The Carnot cycle is a clearly unattainable ideal, but it make two things perfectly clear:

1. Higher condenser temperatures reduce the efficiency of the air conditioner.
2. Lower evaporator temperatures reduce the efficiency of the air conditioner.

Figure 9 graphs the COP_C of a unit with a condenser temperature of 95°F and varying evaporator temperatures.

[2] EER = COP * 3.414

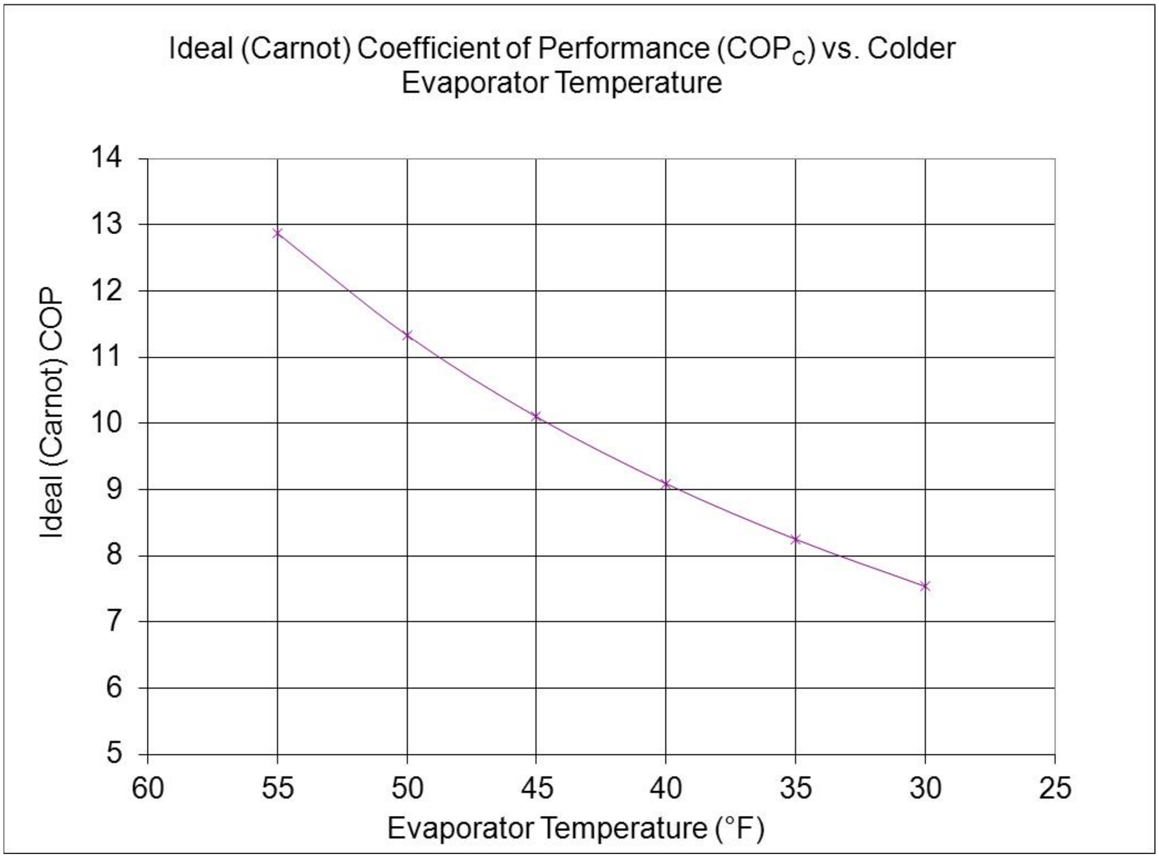

Figure 9. Air Conditioner Efficiency Falls with a Colder Evaporator Coil

Low evaporator coil temperatures are produced when the airflow is low and when cold air is introduced into the return plenum.[3]

Low Airflow and Its Impact

Airflow in the ducted systems tested in the 80-home ECO report was lower than recommended for dry climates such as California. This problem was identified prior to the 2008 Title 24 Standard. In an attempt to deal with this problem, the 2008 Title 24 Standard prescribes a minimum 350 CFM per ton and a maximum 0.58 watts per CFM as the basis for a new home energy budget.

Figure 10 reports the field data in the ECO report. Almost two-thirds of the Whole House Single Zone Ducted systems did not meet those criteria. One hundred percent of the Multi-Zone Ducted systems did not meet those criteria <u>even with all the zone dampers open.</u>

[3] For additional information on the vapor compression cycle, see the online paper, "Design of Vapor-Compression Refrigeration Cycles" (Northwestern University, no date).

Parameter	Whole House Single Zone Meeting Criteria	Whole House Single Zone Not Meeting Criteria	Multi-Zone All Zones Operating	Multi-Zone One Zone Operating
Fan Watts (Mean)	569	572	829	783
Problem Units (Percent with W/CFM >0.58 or CFM/ton < 350)	0%	63%	100%	100%
Fan Watts per CFM (Mean of Problem Units)	0.48	0.57	0.75	0.85
CFM per Ton (Mean if CFM/ton < 350)	407	309	292	244

Figure 10. Single Zone vs. Multi-Zone Airflow and Watt Draw

Laboratory tests at Purdue University (Shen, Braun & Groll 2004) show the efficiency effect of low airflows outside the range normally published in the manufacturers' extended data tables. As displayed in Figure 11, these tests show that the efficiency is reduced to 75% of its full value when the airflow is reduced to 50% of its baseline value.

The data for this graph are in Section **Error! Reference source not found. –** Appendix A.

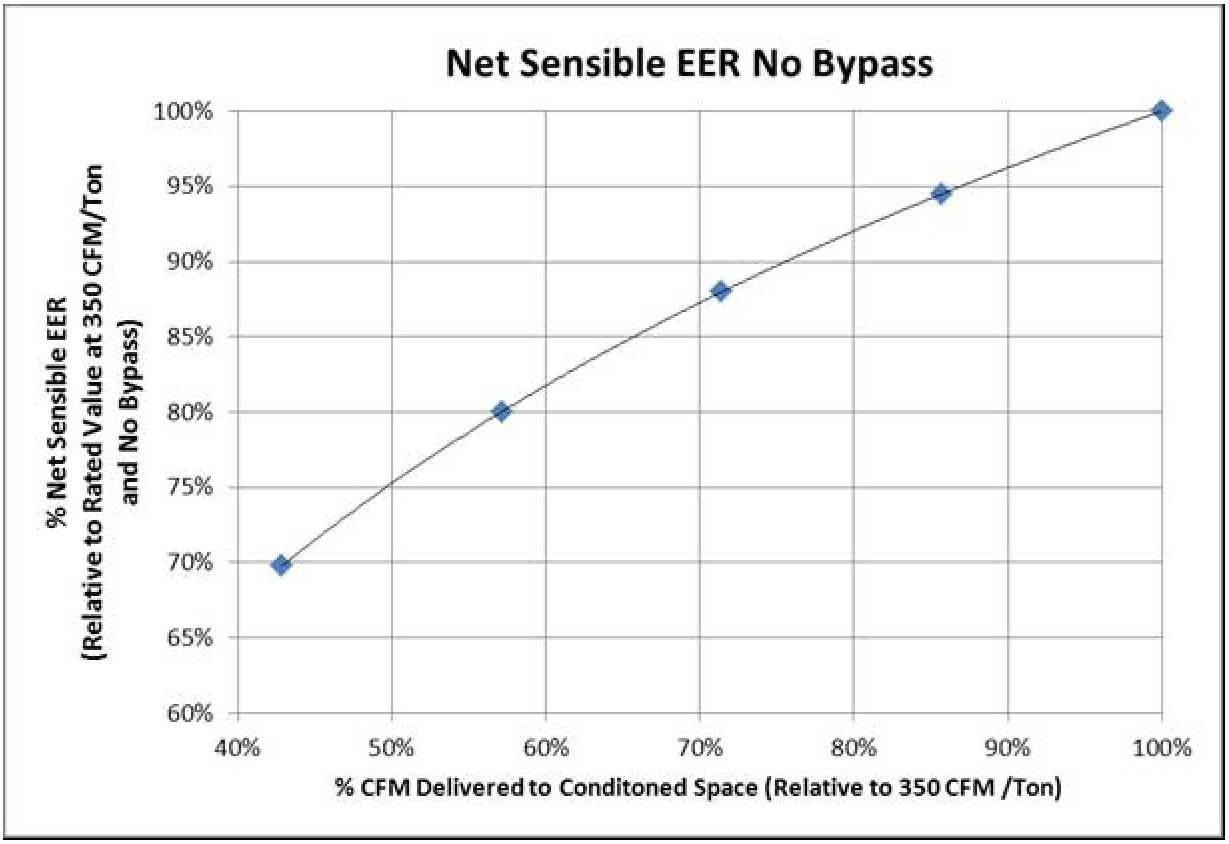

Figure 11. Normalized Sensible EER vs. Supply CFM (laboratory test data)

It is nearly universally accepted that the evaporator airflow for dry climates like California's should exceed 350 CFM per ton. The comments of stakeholders on this matter are quoted in Section 0.

Stakeholder Comments Concerning 350 CFM per Ton Minimum Airflow

Mr. Hourahan of ACCA discussed the 350 CFM per ton minimum airflow:

> "In fact, this is poor practice for most of the country. This is near the lower limit of some OEM equipment, and may be below the low limit for some equipment." (Hourahan 2011)

Mr. Hourahan also concludes:

> "System merit should be based on correct design and installation.
>
> Code should require correct design and installation."
> (ibid)

Mr. Aniruddh Roy of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) wrote a letter discussing some of AHRI's thoughts on zoning. The letter succinctly points out that proper airflow is essential to all systems, particularly zoned systems:

> "When you include zoning on a poorly designed duct system, the poor performance is multiplied."
>
> "Supply airflow must be maintained..."

> "We are sure you will agree that there are many poorly designed and installed duct systems in California."
> (Roy 2011)

Impact of Low Evaporator Airflow

The impact of low evaporator airflow and the savings attributable to improving the airflow are fully developed in Section 7.3 – Appendix C.

In summary:

- The percentage air conditioning savings for improving multi-zoned units with all dampers open from an average 292 CFM per ton to an average 371 CFM per ton is 9.1%
- The percentage gas heating savings for improving airflow through the furnace heat exchanger is 1.9%.

The Bypass

The second problem found with California multi-zone dampered system is the bypass duct. Figure 12 shows the most common California multi-zone dampered HVAC configuration. A single speed air conditioner and furnace supply two zones through dampers. There is a bypass between the supply plenum and the return plenum. The bypass flow is controlled by a bypass damper.

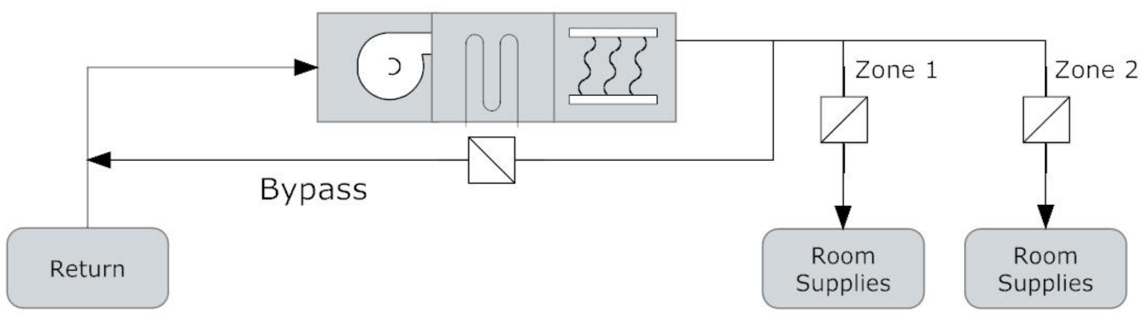

Figure 12. Typical California Zoned HVAC System

Zoned systems throttle the flow to the inoperative zone to reduce the cooling delivered to that zone. The throttling increases the static pressure in the supply plenum and if no other adjustments were made, the air velocity and noise would increase in the operating zone.

In order to avoid the noise, the contractors install a bypass with a damper that opens to relieve the static pressure and maintain nearly the same flow to the operative zone. Bypasses mitigate the increased velocity and noise at the zone calling for heat or cooling.

A "perfect" bypass would bypass all the "excess" air back into the return plenum of the air conditioner/furnace, thereby lowering the evaporator coil temperature in cooling and raising the furnace inlet temperature in heating. This reduces the capacity and efficiency of the air conditioner and furnace.

Mr. Hourahan of ACCA notes that bypass ducts cause a lower cooling coil temperature (Hourahan 2011).

This reduced cooling coil temperature is the major fundamental flaw with bypass ducts. The lower evaporator temperature lowers the total and sensible capacity of the air conditioner.

The Bypass Problem

Figure 13 illustrates the bypass problem by showing an extreme situation.

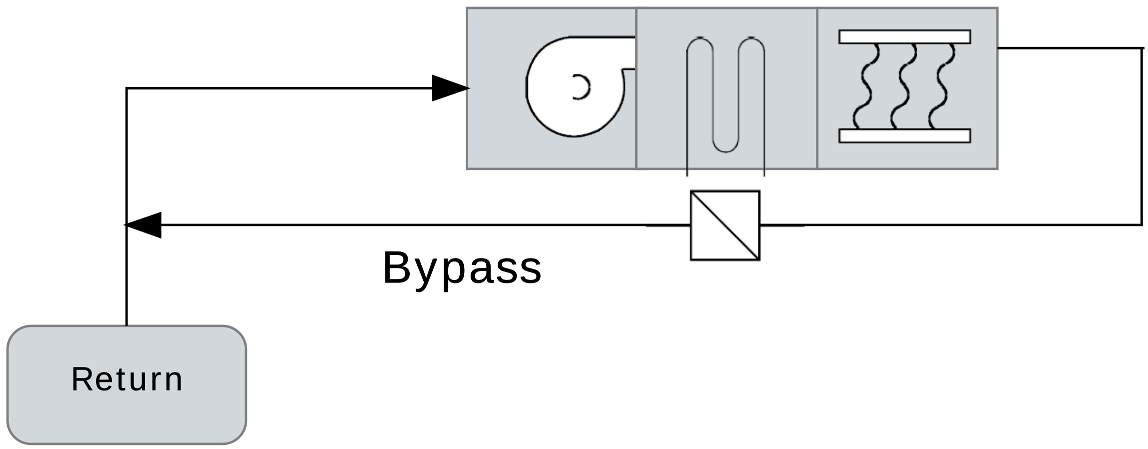

Figure 13. Clarifying the Bypass Problem

In this situation, the return temperature in cooling would fall until the return temperature and the supply temperature were the same and there was no heat transfer across the evaporator coil. As we approach this situation, the watt draw of the compressor, condenser fan, and evaporator fan change very little. The result is an ever-decreasing efficiency.

In heating the same phenomenon applies; the return temperature would rise until the supply temperature and the return temperature were the same and no heat exchange would occur, but the amount of gas burned would remain the same.

In both of these cases, the units normally have safety devices to avoid this extreme situation. Nevertheless, the problem is still with us with any bypass.

The Bypass in the Field Tests

In reality no contractor would build the system illustrated in Figure 13. However, putting the units in the field through varying levels of bypass revealed that some systems come remarkably close to this situation.

In every case the capacity reductions are significant, as shown in Figure 14**Error! Reference source not found.**. The field experiments showed a return plenum temperature reduction in the median case (Field 2) of 11.5°F and a capacity reduction of 25% with a 31% bypass

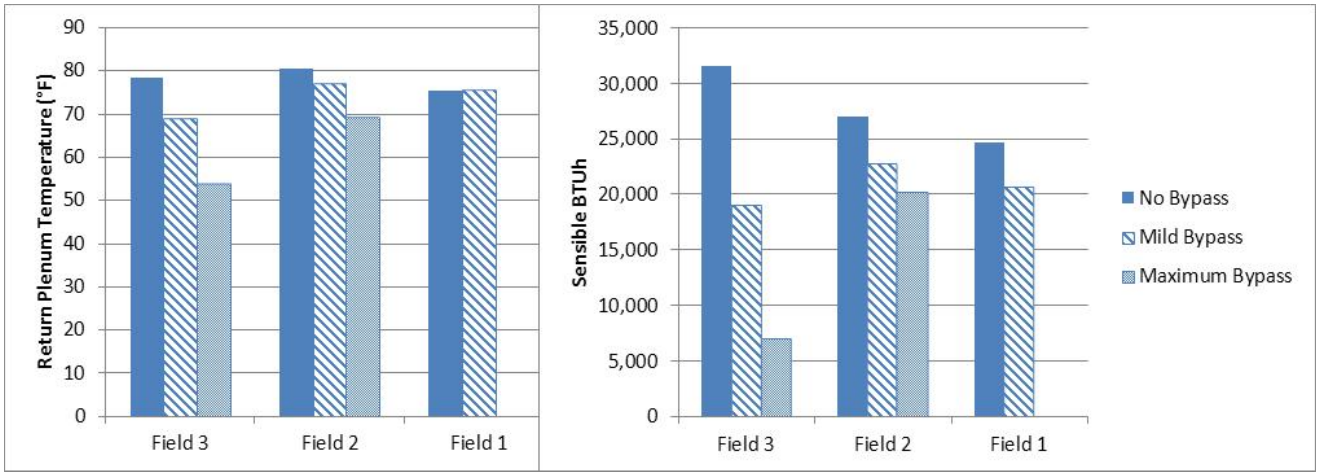

Figure 14. Three Field Units
Operated with Varying Bypass in One Zone Operation
("No Bypass" is all zones open and a closed bypass)

Alternatives to the Bypass

The ACCA Zoning Manual Zr (Rutkowski 2011) lists six strategies as alternatives to the bypass. The elimination of the bypass leaves a number of other options to control airflow including damper stop relief, selective throttling, and most importantly variable airflow/variable capacity air conditioners.

The Oppenheim ASHRAE paper (Oppenheim 1991) is based on an experiment that used physical isolation between zones. The paper notes that any improvement in efficiency is dependent on modulating airflow (a variable speed blower) and modulating refrigerant flow (a variable or multi-speed compressor):

> "Modulating airflow over the indoor cooling coil requires control of the refrigerant flow rate. By effectively controlling both airflow over the evaporator coil and the refrigerant flow, an air conditioner can operate efficiently over a wide range."

Capacity Diversion

One alternative to the bypass is diverting the capacity from one zone to another when the later zone has a higher load. This can be easily accomplished with a design similar to that shown schematically in Figure 15. The design of this type of system would only require minor revisions to the duct design process in ACCA Manual D (Rutkowski 1995). The design process would treat the return system, the dampered supply runs and the undampered supply runs with separate available static pressures.

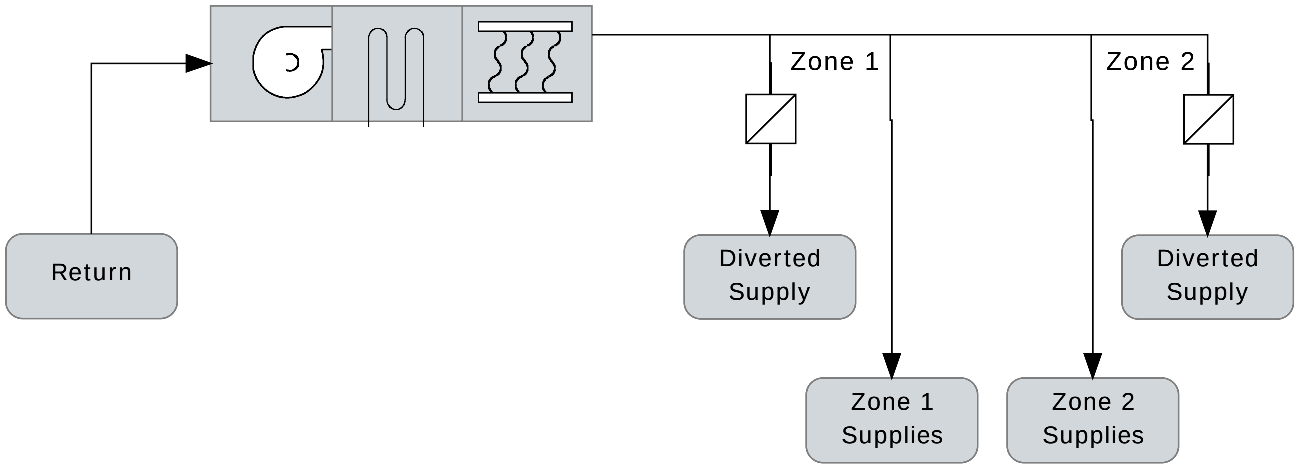

Figure 15. A Two-Zone System with Capacity Diversion