1.0 PURPOSE
The purpose of this Final Report is to document the events leading up to a field study performed by EWC Controls, on behalf of the AHRI Zoning Technology Section. The goal of the field study was to measure and determine the level of impact, upon the energy efficiency ratio of an existing single speed direct expansion cooling system, operated by an air zone system that was designed to comply with ANSI/ACCA 11 Manual Zr, 2012 Residential Zoning Standard, yet also complied with California Title 24, 2013 Building Energy Efficiency Standard. This Final Report documents the results of that field study in full detail.

2.0 INTRODUCTION
The California Energy Commission (CEC) and several utilities, sponsored the Public Interest Energy Research Program (PIER). The PIER program was geared toward identifying best construction methods and practices that may be incorporated into the Title 24, 2013 construction codes and standards, thus improving the efficiency of new homes in the state of California.

2.1 One of the practices identified in the most recent PIER report was the use of a mechanical bypass duct and damper assembly on zoned air conditioning systems, that routes excess conditioned air back into the return duct, in order to control the duct system static pressure at design value. This practice has been in wide use for several decades and is a favored method of managing excess conditioned air amongst contractors who install air zoning systems. In fact, California Title 24, 2008 standard provided a Zonal A/C Performance Credit for those residential air zoned systems that complied with the zoning standard.

2.2 In recent years, the use of a bypass duct that routes excess conditioned air back into the return duct, has been studied. These studies have determined that a high volume of conditioned air routed back into the return duct, may have an adverse affect on the cooling capacity and energy efficiency ratio of a direct expansion cooling system.

2.3 The PIER report stated that in those homes that had a zone system installed, high percentages of bypass air volume resulted in a reduction of the cooling system energy efficiency ratios. However, the PIER report cited numerous system deficiencies in all of the tested homes, such as severely under-sized duct-work, low or high refrigerant charge, contaminated refrigerant, plugged air filters and shoddy workmanship, all of which affect the energy efficiency of any cooling system, whether it is zoned or not. Thus, it becomes necessary to eliminate all potential system deficiencies, in order to accurately determine the singular affect of bypass airflow, on the energy efficiency ratio of a direct expansion (DX) type cooling system.

2.4 Title 24, 2013 was scheduled to go into effect on January 1, 2014 (The CEC recently announced a 6 month delay). The revised Title 24 includes numerous construction related code changes for residential building energy efficiency standards. One of those changes affects the design and the methods, of managing airflow on zoned air conditioning systems. The CEC's original intent was to prohibit routing conditioned air back into the return duct altogether and eliminate the zonal A/C performance compliance credit.

2.5 Due to the efforts of the AHRI Zoning Technology Section who debated with the CEC, the total prohibition of a bypass duct, that routes conditioned air back into the return duct was averted. However, the performance compliance credit for zoned AC systems was eliminated by the CEC.

2.6 Thus, contrary to popular belief, the state of California has not prohibited the use of a bypass duct to route conditioned air back into the return duct of a zoned residential HVAC system. Rather, the state of California has imposed a limit on the volume of air that can flow through the bypass duct, in order to comply with the Title 24 2013, zoning performance standard. The following sections describe the events leading up to this point and the results of the AHRI Zoning Technology field study.
3.0 BACKGROUND
On May 3, 2011, The AHRI Zoning Technology Section reviewed the CEC’s Public Interest Energy Research Program (PIER) Report for the first time. Furthermore, AHRI informed the Zoning Section of the CEC’s decision to prohibit bypassing air back into the return duct and eliminate the zoning performance credit in the revised Title 24, 2013 standard.

3.1 The AHRI Zoning Technology Section was tasked with reviewing the PIER report and evaluate the data regarding these residential HVAC systems and the effect on the energy efficiency of the DX cooling systems in the tested homes. The following data was extracted from the PIER report:

3.1.1 The PIER report documents the results of energy efficiency testing on 80 new or recently built homes.

3.1.2 The PIER report found that 72% of the homes tested, did not comply with the Title 24 2008 standard.

3.1.3 The PIER report cited numerous examples of poorly designed residential DX cooling systems.

3.1.4 The PIER report cited numerous examples of poor mechanical workmanship.

3.1.5 The PIER report listed numerous deficiencies that contributed to efficiency losses in these systems:

3.1.5.1 Incorrect or contaminated refrigerant charge (non-condensibles).
3.1.5.2 Faulty TXV’s.
3.1.5.3 Dirty air filters.
3.1.5.4 Loose insulation blocking airflow.
3.1.5.5 High bypass air volume.

3.1.6 The PIER report cited highly restrictive (under-sized) duct work as the most common problem.

3.1.7 The PIER report data showed that only eight of the 80 homes tested (10%) actually had a zone system with a bypass duct.

3.1.8 The CEC cites the Public Interest Energy Research Program (PIER) Report as the primary justification for the prohibition of bypass ducts and the elimination of the Title 24, 2008 zoning performance credit.

4.0 CLARIFICATION
The PIER report did not attempt to explain the root causes of high volume bypass airflow, nor the field conditions that will result in high volume bypass airflow.

4.1 Installing a zone system on under-sized duct can result in high bypass air volume:

4.1.1 If the existing duct is under-sized, then the system static pressure may be higher than the OEM Mfr’s specified operating range, so the duct system must be corrected prior to installing a zone system.

4.1.2 ACCA Manual D must be performed to confirm the duct is correctly sized for the total volume of air to be delivered by the air-handler, within the OEM Mfr’s specified total static pressure range.

4.1.3 A basic mechanical bypass damper (with limited control range) may open to relieve pressure when all zones are calling, if the system static pressure is in the upper range of the air handler’s blower curve.

4.1.4 The bypass duct-run (including the mechanical bypass damper) has a very low resistance to flow when compared to the resistance value of the sleeping zone duct-run or the living zone duct-run.

4.1.5 When a single zone calls, the typically short bypass duct, will allow more air volume than it was designed for, because the unbalanced bypass duct becomes the path of least resistance.

4.1.6 ACCA Manual Zr specifies that a volume control hand damper must be installed, in order to set the correct resistance to flow (Delta P) across the bypass duct, effectively, balancing the bypass duct.

4.1.7 The lack of a bypass volume control hand damper along with an under-sized duct system and a failure to field balance the zoned duct system, are the primary causes of excessive bypass airflow.
4.2 Title 24 inexplicably prohibits any measurable air leakage into the inactive zone. This increases the amount of excess air that must be managed and results in higher bypass duct airflow:

4.2.1 ACCA Manual Zr recommends leaking a percentage (≤20%) of the zone design airflow.

4.2.2 Leaking air into inactive zones reduces or eliminates air stratification in that zone.

4.2.3 Leaking air into inactive zones can offset the heat gain or heat loss in that zone.

4.2.4 Air volume leaked into the inactive zone, is air volume that does not need to be bypassed.

4.2.5 Modern zone dampers can be adjusted to allow a specific amount of airflow leakage.

4.2.6 If too much damper air leakage results in a zone temperature excursion (over-shoot), the amount of damper leakage can easily be reduced in the field.

4.2.7 Title 24’s prohibition against airflow leaking into the inactive zone(s), complicates the process of managing airflow in a zoned HVAC system and exacerbates the bypass airflow issue.

5.0 EFFORTS TO DEBATE WITH THE CALIFORNIA ENERGY COMMISSION REGARDING THE INTENT TO PROHIBIT THE BYPASS DUCT AND ELIMINATE THE ZONING PERFORMANCE CREDIT

On June 2, 2011, AHRI and the Zoning Technology Section submitted a written memo to the CEC, outlining the zoning section’s concerns about the PIER report and utilizing said study to justify elimination of the Zonal A/C credit. Two separate studies were included that confirmed substantial energy savings were possible, on a properly designed, installed and operated zone system.

5.1 The CEC announced a Building Efficiency Workshop, to be held on July 15, 2011. This workshop was to allow all stakeholders the opportunity to learn about the pending code changes and submit verbal and/or written comments, concerns and viewpoints.

5.2 After the workshop, on August 5, 2011, AHRI submitted another memo stating that the zoning industry concerns were not addressed during the workshop. Furthermore, the memo voiced concerns that when the workshop referred to previous zoning studies, only the negative data from the studies was cited rather than referencing the study in whole including the positive data.

5.3 In that same memo, AHRI formally requests a face to face meeting between the CEC and the AHRI Zoning Technology Section. The CEC agreed to a formal meeting to be held in Sacramento, CA on August 18, 2011.

5.4 The AHRI Zoning Technology Section presented their viewpoints:

5.4.1 High bypass volume is primarily due to severely under-sized duct work, poor bypass design, failure to balance the duct system and shoddy workmanship.

5.4.2 Like other ANSI standards, the CEC should adopt ACCA Manual Zr and adhere to said standard for air zoning and bypass duct design.

5.4.3 Specify that a volume control hand damper must be installed into the bypass duct, which would provide a means of reducing and limiting bypass air volume to a specific value.

5.4.4 Eliminate the current Title 24, 2008 prohibition against airflow leakage into the inactive zone(s), which would result in decreased bypass volume.

5.5 The California Energy Commission presented their viewpoints:

5.5.1 Under-sized duct work would be addressed in the revised Title 24, 2013 standard.

5.5.2 ACCA Manual Zr permits a variable amount of bypass flow based on design load factors and is therefore unacceptable.

5.5.3 A defined means of enforcing a limit on bypass duct air volume did not exist.
5.5.4 Agreed that the prohibition against leaking into the inactive zone may be reconsidered, but that additional studies would be necessary before damper stop leakage would be allowed.

5.6 Basically, the CEC refused to consider the AHRI Zoning Section’s viewpoints as viable reasons to allow the continued use of a bypass duct, that routes conditioned air back into the return duct. The CEC also reiterated their intent to eliminate the zoning performance credit as well.

6.0 ZONING TECHNOLOGY SECTION “Stockton, CA” TEST HOME PROJECT
After these unsuccessful attempts to debate the CEC, the AHRI Zoning Technology Section decided to find a home (in California) that would qualify as a Zoning Test Home. This home would have a zone system installed at the Zoning Section’s expense or already be zoned, and would reflect the ideal zoned home. The CEC would be invited to test this zoned home using the same instruments and methods utilized in the PIER program, thus providing evidence that would support the Zoning Section’s position and viewpoints:

6.1 A single member of the Zoning Technology Section identified an existing home in Stockton, CA as the ideal zoning installation (with bypass) and therefore a viable zoned home to present to the CEC for testing.

6.2 Since the HVAC rooftop system was already zoned, there was zero expense for the Zoning Section.

6.3 Since the home was owned by a member of the HVAC industry who advocated zoning and claimed energy efficient operation, it was assumed that the installation complied with industry standards.

6.4 Other members of the Zoning Technology Section had no opportunity to inspect the zoned rooftop HVAC system prior to inviting the CEC to test the zoned HVAC system.

6.5 An EER impact test date of May 4, 2012 was agreed to by all parties.

6.6 The EER impact testing was performed by Proctor Engineering group and witnessed by members of AHRI and the AHRI Zoning Technology Section.

6.7 The rooftop unit turned out to have under-sized flex-duct that was poorly installed and a 16” diameter bypass duct with a mechanical bypass damper. A bypass duct volume control hand damper did not exist.

6.8 It was observed that with all zone dampers open and the bypass forced closed, the total static pressure reading across the equipment was .78”wc, which proved the duct-work was under-sized.

7.0 A teleconference was scheduled for May 8, 2012 to allow the CEC to present the EER impact test results of the Zoned HVAC system in Stockton, CA.

7.1 The CEC field report found significant bypass airflow occurred during non-zoned operation.

7.2 The CEC field report found high volume bypass airflow occurred during zoned operation.

7.3 The CEC field results revealed a negative effect on the DX cooling system energy efficiency ratio.

7.4 The Zoning Technology Section responded by pointing out the poor condition of the flex-duct system.

7.5 The Zoning Technology Section urged the CEC to adopt Manual Zr and enforce a limit on bypass air volume to perhaps 25% of the total system airflow.

7.6 The CEC stated that perhaps a means of limiting bypass volume could be enforced.

8.0 CALIFORNIA ENERGY COMMISSION ANNOUNCES NEW COMPLIANCE SOFTWARE
Later in May 2012, the CEC informed AHRI and the Zoning Technology Section, that Title 24, 2013 shall include a Point Based Compliance Software package. This new HERS compliance software would operate on a Prescriptive or Performance Point Grading System, and would allow a bypass duct to be installed on a zoned HVAC system albeit with limitations. Selecting “Bypass” in the software shall not result in a grade point loss unless:

8.1 The 350cfm/ton return airflow “Check Box” is not checked, accepting the automatic point loss.
8.2 If the 350cfm/ton “Check Box” is checked, a HERS rater’s field verification is required.

8.3 A field verified return airflow equal to or greater than 350cfm/ton shall not result in a grading point loss.

8.4 This performance compliance approach results in a bypass airflow limit that shall not exceed 12.5% of the total HVAC system airflow. Higher bypass airflow ratios will result in a proportional grading point loss.

8.5 Any grading point loss can be made up, by exceeding the prescriptive requirement on other construction items such as, higher insulation “R” values, higher efficiency windows, appliances, etc.

8.6 The compliance credit for zoned cooling has been removed and shall no longer be permitted.

9.0 ZONING TECHNOLOGY SECTION “Rancho Cordova, CA” TEST HOME PROJECT

Due to the findings of the PIER report, the loss of the zoned cooling credit in the Title 24, 2013 zoning standard, and the poor representation of the Stockton, CA, test home, the AHRI Zoning Technology section decided to find a reputable contractor who could install a zone system into a typical California home that would comply with industry standards, thus creating an independent test home, that would qualify as an ideal zoned home.

9.1 Furthermore, it was determined that EWC Controls, Inc. would design the zone system, manage the project and supply all zone system materials. EWC Controls would provide a complete report to the Zoning Section members upon completion of the project.

9.2 This new zone system would comply with the Manual Zr standard as well as the Performance Zoning standard in Title 24, 2013. This zoned home would qualify as a legitimate test site, to measure and determine the effect on the cooling system’s energy efficiency ratio, as a result of the zone system and bypass airflow.

9.3 In addition to the goal of designing and installing a zone system that fully complied with both standards, EWC Controls decided to engage the services of an independent Professional Engineering firm. After completion of the work, the PE firm would test the performance of the zoned cooling system. The test data would show the effect on the cooling system’s energy efficiency ratio, due to the bypass airflow volume.

9.4 Furthermore, to ensure the resulting data would be acceptable to the California Energy Commission, the independent PE firm would utilize the same testing procedure and instruments, that were relied upon by Proctor Engineering at the Stockton, CA test home and during the PIER program.

9.5 EWC Controls contacted an independent HVAC Distributor in Sacramento, CA, and requested a short list of skilled and reputable contractors servicing the general area. EWC also engaged the services of a local independent Professional Engineering firm as well.

10.0 The CEC was contacted by AHRI and informed of the EWC Controls independent zoning project. A formal e-mail invitation to test the zoned HVAC system, was sent to Proctor Engineering along with a request to cooperate with the independent PE firm, on the use of test instruments and testing methods.

10.1 Proctor Engineering agreed to cooperate and coordinate with the other PE firm and share the method for calculating cooling system EER, in each zoned mode of operation. Proctor Engineering also agreed on the importance of using the same test methods and instruments, in order to obtain reliable test data.

10.2 Through a process of elimination, a single contractor was selected to perform the zoning project and an existing Ranch style home was identified and selected as well:

10.2.1 Project funded by: AHRI Zone Technology Product Section
10.2.2 Project managed by: EWC Controls Inc., Englishtown, NJ.
10.2.3 Zone system designer: EWC Controls Inc., Englishtown, NJ.
10.2.4 Zone equipment supplier: EWC Controls Inc., Englishtown, NJ.
10.2.5 EWC Independent PE firm: Sacramento Engineering Consultants, Sacramento, CA.
10.2.6 HVAC contractor: Dunbar Air Conditioning, Heating & Refrigeration Rancho Cordova, CA.
10.2.7 CEC independent PE firm: Proctor Engineering Group Ltd., San Rafael, CA.
10.2.8 Test Home: 9 year old, 3 Bedroom Ranch, 1910 sq. ft., Rancho Cordova, CA.
10.3 A zone system consisting of two zones was pre-existing in the selected test home, but it did not include a bypass duct. The homeowner was extremely dissatisfied with the performance of the zoned HVAC system and voiced the typical homeowner complaints:

10.3.1 Wide temperature swings throughout the home.
10.3.2 Inability to cool the master bedroom.
10.3.3 Inability to heat the master bedroom.
10.3.4 Loud air noise at the registers.
10.3.5 System never shuts down during Summer.
10.3.6 High electric bills in the Summer.
10.3.7 System short cycles during Winter and house is cold.

11.0 ZONING TECHNOLOGY SECTION “Rancho Cordova, CA” TEST HOME PROJECT DESIGN
Utilizing the “Airflow Management Worksheets” in ACCA Manual Zr, EWC Controls devised a zone strategy for the California test home. The sizing and specification of zone dampers and the bypass would occur after the Manual J and Manual D were completed:

11.1 Manual J was performed on the home which confirmed the existing HVAC system was properly sized.
11.2 Manual D was performed which confirmed that the existing flex-duct system was severely under-sized and would have to replaced, prior to installing the zone system.
11.3 A Manual Zr airflow management worksheet was performed, based on the furnace blower rated Cfm and the creation of two zones with design Cfm values obtained from the Manual J report.
11.4 EWC Controls assumed an OEM low temperature limit of 45°F for the existing DX cooling system.
11.5 At an outdoor design temperature of 101°F, Manual Zr allows a bypass airflow factor at 45% of the total design airflow. This value would not comply with the 12.5% value allowed by Title 24, 2013.
11.6 Using 85°F as an outdoor design temperature resulted in a more conservative 33% bypass airflow factor, which still exceeded the fixed value of 12.5% allowed by Title 24, 2013.
11.7 An outdoor design value of 65°F was utilized to reduce the percentage of bypass airflow to 12.5%, in order to achieve a return airflow value of 350cfm/ton as required by Title 24, 2013.
11.8 A Manual Zr damper stop worksheet was performed specifying 20% leakage into the largest zone.
11.9 Manual Zr allows a maximum of 20% leakage into the largest zone(s) only and no leakage is allowed into the smallest zone. Recall that Title 24 prohibits any measurable leakage into the inactive zone(s).
11.10 But the 20% leakage into the largest zone was insufficient, in order to keep the bypass volume at or below the 12% allowed by Title 24, 2013 zoning performance standard. Additional leakage into the inactive zone would be necessary, as Manual Zr prohibits leaking airflow into the smallest inactive zone.
11.11 Another Manual Zr damper stop worksheet was performed, allowing 35% leakage into the largest inactive zone, which violated ACCA Manual Zr’s 20% allowable leakage value.
11.12 These actions also resulted in an increase in the active zone over-blow value from a conservative 15% to the ACCA Manual Zr allowable 30% of the smallest zone design Cfm.

12.0 ZONING TECHNOLOGY SECTION “Rancho Cordova, CA” TEST HOME PROJECT WORK
Following the Manual D report guidelines, the contractor started the project by first removing the old zone control system and replacing the entire duct system. EWC Controls did not advise the contractor on this phase of the work. Rather, EWC Controls relied upon the skill and expertise of the contractor to perform the duct work correctly and adhere to industry workmanship and quality standards.

12.1 EWC Controls did advise the contractor on the selection of a new zone control panel, compatible with the existing single stage HVAC system, yet capable of multi-stage operation. EWC Controls also advised the contractor on the type of zone control dampers to use and assisted with the bypass duct design as well. After the duct work was replaced, the new bypass system and the new zone dampers were installed.
12.2 EWC Controls instructed the contractor and provided guidance, on how to balance the bypass duct in the field and limit the bypass airflow volume to a value that would achieve compliance with Title 24, 2013.

12.3 The zone control panel, zone dampers and thermostats were wired and the zoned HVAC system was powered up. The contractor balanced the duct system and completed all work on July 1, 2013.

13.0 ZONING TECHNOLOGY SECTION “Rancho Cordova, CA” TEST HOME PROJECT RESULTS
The homeowners gave permission to access the home for testing on July 16 & July 17, 2013. EWC Controls contacted Sacramento Engineering Consultants and scheduled the EER impact testing for July 17, 2013.

13.1 On July 16, 2013, EWC Controls visits the test home for the first time, to evaluate the finished work, confirm the balancing procedure of the bypass duct and take preliminary test readings.

13.2 A minor adjustment was made to the bypass duct volume control damper, in order to effectively limit the bypass airflow and comply with the zoning performance method specified in the Title 24, 2013 standard.

13.3 A minor adjustment was made to the electronic bypass damper to maintain the designed total static pressure of the new duct system in every zoned mode of operation.

13.4 An Alnor™ flow-hood was used to confirm that no substantial airflow (<45cfm) could be measured at any one of the 6 registers serving the largest inactive zone, due to the 35% damper stop leakage value.

13.5 Collectively, the measured cfm leakage values from the 6 registers serving the largest (living) zone added up to 243cfm, when the zone was inactive. The design leakage into that zone was 276cfm.

13.6 The flow-hood was also used to confirm that 350cfm/ton return airflow was measured in every zoned mode of operation, which correlates to a bypass factor (BPF) of 12%.

14.0 On July 17, 2013, Sacramento Engineering Consultants arrived at the test home to perform EER impact testing on the zoned cooling system.

14.1 The zoned cooling system was tested in every zoned mode of operation stipulated by Proctor Engineering Group and the testing was witnessed by EWC Controls.

14.2 Subsequent review of the Sacramento Engineering Consultants collected data, revealed that the return air Cfm readings did not include the required “air filter correction” value.

14.3 As recommended by the manufacturer of the DG700 flow gauge, the measured airflow values from Sacramento Engineering would be rejected. Since each zonal mode test was identical, the measured airflow values to be collected by Proctor Engineering, would be utilized for all performance calculations.

14.4 The zoned cooling system operated within Title 24, 2013 zoning performance standards.

14.5 The collected data revealed no negative impact to the cooling system’s energy efficiency ratio during zoned operation.

14.6 The data revealed a positive influence to the cooling system energy efficiency ratio during zoned operation.

14.7 A mixed return air formula was performed on the collected data, to correct for any possible temperature field measurement inaccuracies. The data continued to reveal a positive influence on system EER.

14.8 The homeowners again gave permission to access the home for testing on July 29, 2013. EWC Controls contacted Proctor Engineering Group and scheduled the EER impact testing for July 29, 2013.

15.0 On July 29, 2013, Proctor Engineering Group arrived at the test home to perform EER impact testing on the zoned cooling system.

15.1 The zoned cooling system was tested in every zoned mode of operation, including one additional mode not performed by Sacramento Engineering Consultants. The testing was witnessed by EWC Controls.
15.2 The zoned cooling system operated within the CEC’s Title 24, 2013 zoning performance standards.

15.3 The collected data revealed no negative impact to the cooling system’s energy efficiency ratio during zoned operation.

15.4 The collected data revealed a positive influence to the cooling system energy efficiency ratio during zoned operation.

15.5 A mixed return air formula was performed on the collected data, to correct for any possible temperature field measurement inaccuracies. The revised data continued to reveal a positive influence on system EER.

15.6 The Homeowners have expressed their extreme satisfaction (via E-mail) with the results of their new Zoned HVAC system, including comments on the comfort level in the home and a perceived energy savings.

16.0 ZONING TECHNOLOGY SECTION “Rancho Cordova, CA” TEST HOME PROJECT CONCLUSIONS

16.1 Based on the collected test data, it is the conclusion of the AHRI Zoning section, that a zone system designed to comply with Manual Zr and California Title 24, 2013, installed on a properly designed HVAC system, has no negative effect on a single speed direct expansion cooling system’s energy efficiency ratio.

16.2 Based on the collected test data, it is the conclusion of the AHRI Zoning section, that it is possible to achieve a positive effect on a single speed direct expansion cooling system’s energy efficiency ratio, when utilizing this particular zone system design.

16.3 Based on the collected test data, it is the conclusion of the AHRI Zoning section, that allowing a prescribed or variable percentage of airflow to leak past the zone damper and into the inactive zone(s), reduces bypass airflow, increases return airflow and helps maintain equipment energy efficiency.

16.4 Given the Homeowner’s assertion that the improved comfort level of the home, includes a realized energy savings, a thorough analysis of past and present utility bills are in order. In addition, a utility monitoring program that will record the zoned HVAC system’s energy consumption, should be implemented.

17.0 ZONING TECHNOLOGY SECTION “Rancho Cordova, CA” TEST HOME PROJECT RECOMMENDATIONS

17.1 Considering the results of this field project, laboratory testing is highly recommended, to determine the dynamics of how this particular zone system design, achieves a positive influence on the cooling system’s energy efficiency ratio during zoned operation.

17.2 The AHRI Zoning section recommends, that further testing be performed to determine precisely how the airflow management techniques of this zone system design can improve sensible BTU capacity and decrease equipment run time.

17.3 The AHRI Zoning section recommends, that further testing be performed to accurately determine, if a prescribed or variable percentage of airflow leaking past the zone damper and into the inactive zone, offsets the heat gain or heat loss in that zone, and reduces or eliminates air stratification in the inactive zone.

17.4 The AHRI Zoning section recommends, that the California Energy Commission revise Title 24, to allow damper leakage into the inactive zone(s), as a means of reducing reliance on bypass airflow.

17.5 The AHRI Zoning section recommends, that further testing be performed to accurately determine the bypass airflow value threshold, at which EER may be negatively affected. That value will be variable when all load factors are considered, and may be higher than Title 24 currently allows.

17.6 True system energy efficiency is measured over time and under all possible load conditions. Additional testing on the zoned HVAC system in the Rancho Cordova test home, and other new zoning installations that adhere to the same design & installation guidelines, should be given serious consideration.

17.8 Given the positive results of the collected data, the California Energy Commission should consider adopting Manual Zr and reinstate the zoning performance credit, when a field verified zoning installation fully complies with Manual Zr and the Title 24, 2013 zoning performance standard.
18.0 CREDITS

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APPENDICES:

Appendix 1 - Proctor, Chitwood & Wilcox 2011 California ECO project, Airflow and sensible capacity comparison of single zone versus multi-zone AC systems.

Appendix 2 - Proctor, Chitwood & Wilcox 2011 Building Energy Efficiency Standards Workshop 2013, NET sensible EER with a PSC motor and varying levels of bypass and supply restriction.

Appendix 3 & 4 - CEC / Proctor Engineering Field Test results on AHRI Zoning Technology Section Zoned Test Home in Stockton, CA. Sensible Capacity with Total Power and Sensible EER charts.

Appendix 5 - ACCA Manual Zr Cooling Excess Air worksheet #1, which specified a 33% bypass factor (BPF) @ 85°F dry bulb outside air temperature and a minimum 45°F dry bulb leaving air temperature. Rancho Cordova project. (Did not comply with Title 24, 2013).

Appendix 6 - ACCA Manual Zr Cooling Excess Air worksheet #2, which specified a 12% bypass factor (BPF) @ 65°F dry bulb outside air temperature and a minimum 45°F dry bulb leaving air temperature. Rancho Cordova project. (Complied with Title 24, 2013).

Appendix 7 - ACCA Manual Zr Bypass Factor Worksheet, which was used to determine the maximum allowable bypass air volume, to achieve compliance with Manual Zr and Title 24, 2013. Rancho Cordova project.

Appendix 8 - ACCA Manual Zr Damper Stop Cfm worksheet #1, which was used to determine the maximum leakage into the largest zone, to achieve compliance with Manual Zr. Rancho Cordova project.

Appendix 9 - ACCA Manual Zr Damper Stop Cfm worksheet #2, which was used to compensate for the 12.5% bypass factor required by Title 24, 2013 compliance software. Rancho Cordova project.

Appendix 10, 11 & 12 - EWC Field Test #1 results on Zoned Test Home in Rancho Cordova, CA. Measured Operational Data, Sensible Capacity with Total Power and Sensible EER charts. (Performed by Sacramento Engineering Consultants and witnessed by EWC Controls)

Appendix 13, 14, 15 & 16 - EWC Final Test #1 results on Zoned Test Home in Rancho Cordova, CA. Measured Operational Data, Sensible Capacity with Total Power and Sensible EER charts. (Corrected by EWC Controls).

Appendix 17, 18 & 19 - EWC Field Test #2 results on Zoned Test Home in Rancho Cordova, CA. Measured Operational Data, Sensible Capacity with Total Power and Sensible EER charts. (Performed by Proctor Engineering Group and witnessed by EWC Controls).

Appendix 20, 21 & 22 - EWC Final Test #2 results on Zoned Test Home in Rancho Cordova, CA. Measured Operational Data, Sensible Capacity with Total Power and Sensible EER charts. (Corrected by EWC Controls).

Appendix 23 - Unsolicited Homeowner e-mail describing their satisfaction with the new zoned HVAC system and a perceived energy savings.

Manual J, D & S reports that confirmed the existing system BTU capacity was sufficient and correct for the test home. Manual D confirmed new duct-work would be required, prior to installing the zone system. Available at EWC Controls, Inc.
The ECO project determined that multi-zoned AC systems averaged lower system airflow versus single zone systems, resulting in reduced sensible capacity and efficiency.
This chart was displayed during the workshop, to show the effect on the sensible energy efficiency ratio of an existing cooling system (with PSC indoor motor) at varying levels of bypass air volume and low supply air volume.
APPENDIX 3 - CEC / Proctor Engineering Group Data Results on the Stockton, CA. test home.

This is the calculated sensible energy efficiency ratio chart based on the data collected by Proctor Engineering on the AHRI zoned test home in Stockton, CA. Note the lower sensible energy efficiency values when the bypass is allowed to operate (free) as designed. An indication of excessive bypass airflow due to high static pressure resulting from under-sized duct along with a poorly designed and unbalanced bypass duct.

Bypass Free = Bypass damper allowed to operate as designed during a test.
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.
This is the calculated sensible capacity and total power chart based on the data collected by Proctor Engineering on the AHRI zoned test home in Stockton, CA. Note the lower sensible capacity values when the bypass is allowed to operate (free) as designed. An indication of excessive bypass airflow due to high static pressure resulting from under-sized duct along with a poorly designed and unbalanced bypass duct.

Bypass Free = Bypass damper allowed to operate as designed during a test.
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.
APPENDIX 5 - Manual Zr Excess Air Worksheet #1 on the Rancho Cordova, CA. test home.

This Manual Zr Worksheet #1 limits bypass volume to 396 Cfm and allows 158 Cfm damper stop leakage into the largest inactive zone. The worksheet allows 60 Cfm residual value, after all airflow management techniques have been utilized. The residual value on this worksheet was 3 Cfm. However, this airflow management design was insufficient to comply with Title 24, 2013 zoning performance standard, which limits bypass volume to 12% of the total system airflow in order to avoid a penalty. See Appendix 6.

<table>
<thead>
<tr>
<th>EXCESS AIR WORKSHEET ACCA MANUAL ZR</th>
<th>Figure 8-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rancho Cordova Project * Ranch Home 2 zones (living &amp; sleeping) Gas Forced Air with A/C 1heat / 1cool</td>
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<tr>
<td>EXCESS AIR CFM</td>
<td>COOLING</td>
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<tr>
<td>Design value for Blower CFM</td>
<td>1200</td>
</tr>
<tr>
<td>Smallest Zone (sleeping 559cfm) design CFM for zone dampers</td>
<td>559</td>
</tr>
<tr>
<td>CFM to spaces that are not zoned</td>
<td>0</td>
</tr>
<tr>
<td>Excess Air CFM (line 1 – line 2 – line 3)</td>
<td>641</td>
</tr>
<tr>
<td>RELIEF MEASURES AND RESIDUAL CFM</td>
<td>COOLING</td>
</tr>
<tr>
<td>Bypass duct CFM for LAT limit 1 (OEM LDB limit = 45°F, OAT 85°F BPF = 0.33)</td>
<td>396*</td>
</tr>
<tr>
<td>Damper stop CFM 2 (leakage into largest (living 788cfm) zone) (0.20 x 788cfm)</td>
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</tr>
<tr>
<td>Dump zone CFM 3</td>
<td>0</td>
</tr>
<tr>
<td>Selective throttling CFM 3</td>
<td>0</td>
</tr>
<tr>
<td>Over blow CFM 4 (15% of the design CFM for the smallest zone)(0.15 x 559)</td>
<td>84</td>
</tr>
<tr>
<td>Residual CFM 5, 6 (Residual limit = 0.05 x 1200 = 60cfm)</td>
<td>3</td>
</tr>
<tr>
<td>Sum of Relief Measures and Residual CFM</td>
<td>641</td>
</tr>
</tbody>
</table>

1) Use the BPF that is compatible with the OEM’s limit for discharge air temperature (Section 7-1 thru 7-7)
2) Total relief CFM from the damper stop worksheet
3) 15% of the maximum value for blower CFM
4) 30% of the design CFM for the smallest zone
5) Excess CFM value – Sum of the relief CFM values
6) Provide capacity control or revise the zoning plan or use both measures, if the residual CFM value is more than 5% of the design value for blower CFM.
7) For staged equipment, perform calculations for each stage.

* 396 bypass cfm = 33% of total CFM. Does not Achieve Compliance with Title 24 2013. (350cfm/ton in every zonal mode)
APPENDIX 6 - Manual Zr Excess Air Worksheet #2 on the Rancho Cordova, CA. test home.

This Manual Zr Worksheet #2 limits bypass volume to 144 Cfm and allows 276 Cfm damper stop leakage into the largest inactive zone. The worksheet allows 60 Cfm residual value, after all airflow management techniques have been utilized. The residual value on this worksheet was 53 Cfm. This airflow management design was sufficient to comply with Title 24, 2013 zoning performance standard, which limits bypass volume to 12% of the total system airflow in order to avoid a penalty. See Appendix 7.

Sheet2

<table>
<thead>
<tr>
<th>EXCESS AIR WORKSHEET ACCA MANUAL ZR</th>
<th>COOLING</th>
<th>HEATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rancho Cordova Project * Ranch Home 2 zones (living &amp; sleeping) Gas Forced Air with A/C 1heat / 1cool</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>EXCESS AIR CFM</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Design value for Blower CFM</td>
<td>1200</td>
<td></td>
</tr>
<tr>
<td>Smallest Zone (sleeping 559cfm) design CFM for zone dampers</td>
<td>559</td>
<td></td>
</tr>
<tr>
<td>CFM to spaces that are not zoned</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Excess Air CFM (line 1 – line 2 – line 3)</td>
<td>641</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RELIEF MEASURES AND RESIDUAL CFM</th>
<th>COOLING</th>
<th>HEATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bypass duct CFM for LAT limit 1 (OEM LDB limit = 45°F, OAT 65°F BPF = 0.12)</td>
<td>144*</td>
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</tr>
<tr>
<td>Damper stop CFM 2 (leakage into largest (living 788cfm) zone) (0.35 x 788cfm)</td>
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<td></td>
</tr>
<tr>
<td>Dump zone CFM 3</td>
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<td></td>
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<tr>
<td>Selective throttling CFM 3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Over blow CFM 4 (30% of the design CFM for the smallest zone)(0.30 x 559)</td>
<td>168</td>
<td></td>
</tr>
<tr>
<td>Residual CFM 5, 6 (Residual limit = 0.05 x 1200 = 60cfm)</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Sum of Relief Measures and Residual CFM</td>
<td>641</td>
<td></td>
</tr>
</tbody>
</table>

1) Use the BPF that is compatible with the OEM’s limit for discharge air temperature (Section 7-1 thru 7-7)
2) Total relief CFM from the damper stop worksheet
3) 15% of the maximum value for blower CFM
4) 30% of the design CFM for the smallest zone
5) Excess CFM value – Sum of the relief CFM values
6) Provide capacity control or revise the zoning plan or use both measures, if the residual CFM value is more than 5% of the design value for blower CFM.
7) For staged equipment, perform calculations for each stage.

* 144 bypass cfm = 12% of total CFM. Achieves Compliance with Title 24 2013. (350cfm/ton in every zonal mode)
Manual Zr calculates a Bypass Factor by determining the OEM low temperature limit versus the design outdoor dry-bulb temperature in that geographic area. At 101°F, the bypass factor of 45% would not comply with Title 24, 2013 zoning performance standard of 12.5%. Using a more conservative outdoor dry-bulb value of 85°F, the bypass factor becomes 33% which still does not comply. An ultra-conservative outdoor dry-bulb value of 65°F was used to achieve a bypass factor of 12% in order to comply with Title 24, 2013 zoning performance standard.

EWC Field Project
Rancho Cordova
Test Home
Bypass Factor
Value Worksheet

**Figure 7-2**

- **Final RC Test Home BPF value**: 0.12
- **Conservative RC Test Home BPF value**: 0.33
- **Design/Allowable RC Test Home BPF value**: 0.45

Selected OEM low temperature limit
Title 24, 2013 zoning standard does not allow any measurable leakage into the inactive zones. ACCA Manual Zr allows a maximum of 20% leakage (largest zone(s) only) as an airflow management technique. However, a damper stop leakage of 20% into the inactive zone was insufficient in order to comply with Title 24, 2013 zoning performance standard. Additional leakage into the largest zone or both zones would be required, in order to effectively limit bypass airflow. See Appendix 9.

<table>
<thead>
<tr>
<th>Zone Damper</th>
<th>Design Cfm (^1)</th>
<th>Stop Setting (^2)</th>
<th>Stop Cfm</th>
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<tr>
<td></td>
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<td>Heating</td>
<td>Cooling</td>
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<tr>
<td>Zone 1</td>
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<td>0.20</td>
<td>0.20</td>
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<tr>
<td>Zone 2</td>
<td>559</td>
<td>N/A(_3)</td>
<td>N/A(_3)</td>
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<tr>
<td>Zone 3</td>
<td></td>
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<td>Zone 4</td>
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<tr>
<td>Zone 5</td>
<td></td>
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<tr>
<td><strong>Total Cfm through damper stops</strong></td>
<td></td>
<td></td>
<td>158</td>
</tr>
</tbody>
</table>

1) The design Cfm for zone damper must be 200 Cfm, or greater.
2) The maximum value for the air relief factor is 0.20.
3) Do not include the stop Cfm for the zone that has the smallest design Cfm value (which may be zero, or greater than zero).
**APPENDIX 9 - Manual Zr Damper Stop Worksheet #2 on the Rancho Cordova, CA. test home.**

Title 24, 2013 does not allow any measurable leakage into the inactive zones. ACCA Manual Zr allows a maximum of 20% leakage (largest zone(s) only) as an airflow management technique. However, in order to comply with Title 24, 2013 zoning performance, which limits the bypass volume to 12.5% of the total system airflow, a damper stop leakage value of 35% was required. An alternative airflow management technique would be to set some percentage of leakage into the smallest (sleeping) zone. But that technique was not acceptable due to the high possibility of a temperature over-shoot (excursion) due to closed bedroom doors.

<table>
<thead>
<tr>
<th>Zone Damper</th>
<th>Design Cfm ¹</th>
<th>Stop Setting ²</th>
<th>Stop Cfm</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Cooling</td>
<td>Heating</td>
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<tr>
<td>Zone 1</td>
<td>788</td>
<td>0.20</td>
<td>0.35</td>
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<tr>
<td>Zone 2</td>
<td>559</td>
<td>N/A ³</td>
<td>N/A ³</td>
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<td>Zone 3</td>
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<td>Zone 4</td>
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<tr>
<td>Zone 5</td>
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<tr>
<td><strong>Total Cfm through damper stops</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) The design Cfm for zone damper must be 200 Cfm, or greater.
2) The maximum value for the air relief factor is 0.20.
3) Do not include the stop Cfm for the zone that has the smallest design Cfm value (which may be zero, or greater than zero).
This is an original data sheet. This is the original collected data before correcting for possible field measurement inaccuracies. Note the slightly high Cfm values due to lack of an “air filter correction factor” and the lack of measured wattage values during each test sequence. Refer to Appendix 13 & 14 for corrected data.

Bypass as Found = Bypass damper allowed to operate as designed during a test.  
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.
APPENDIX 11 - Sacramento Engineering Consultants Original Data Results on the Rancho Cordova, CA. test home.

This is an original data sheet. This is the original sensible energy efficiency ratio chart before correcting for possible field measurement inaccuracies. Note the upward trend in sensible energy efficiency during “zoned” operation versus “all zones”.

Bypass as Found = Bypass damper allowed to operate as designed during a test.  
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.
APPENDIX 12 - Sacramento Engineering Consultants Original Data Results on the Rancho Cordova, CA. test home.

This is an original data sheet. This is the original sensible capacity and total power chart before correcting for possible field measurement inaccuracies. Note the upward trend in sensible capacity during “zoned” operation versus “all zones”.

Bypass as Found = Bypass damper allowed to operate as designed during a test.
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.
APPENDIX 13 - Sacramento Engineering Consultants Corrected Data Results on the Rancho Cordova, CA. test home.

This is a corrected data sheet. Sacramento Engineering Consultants calculated volt amps rather than measured wattage. EWC determined the correct power factor and calculated the correct wattage (total power) value for each test sequence. Watts, VA and Power Factor values are shown in the data sheet below.

Bypass as Found = Bypass damper allowed to operate as designed during a test.
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>MEASURED</th>
<th>TEST 1</th>
<th>TEST 2</th>
<th>TEST 3*</th>
<th>TEST 4</th>
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<th>TEST 6</th>
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<td></td>
<td></td>
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<td>3229</td>
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<td>0.86</td>
<td>0.86</td>
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</tr>
</tbody>
</table>

Sleeping Zone = Smallest Zone
Test 1 = All Zones calling, Bypass as Found
Test 2 = All Zones calling, Bypass Closed
*Test 3* = All Zones calling, Bypass Forced 100% Open (Abnormal Condition)
Test 4 = Sleeping Zone calling, Bypass as Found
Test 5 = Sleeping Zone calling, Bypass Closed
Test 6 = Living Zone calling, Bypass as Found

*Power Factor* calculated values based on measured voltage, current and wattage on both test days
*Watts* values were calculated using measured voltage, current & corrected power factor values
*CFM* readings are high due to lack air filter correction factor. See corrected data on Appendix 15.
This is the final corrected data sheet. Sacramento Engineering Cfm readings did not include the required “air filter correction factor”. Since the test definitions of Test #1 thru Test #5 were identical on each test day, the correct Cfm values from Proctor Engineering were utilized instead. In addition, a mixed return air formula was performed on the original collected data.

Bypass as Found = Bypass damper allowed to operate as designed during a test.
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.

### EWC Controls ZONED TEST HOME * Rancho Cordova, CA

Data captured by Sacramento Engineering Consultants on 07/17/2013 and revised by EWC to find true mixed return air temperature.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>MEASURED</th>
<th>TEST 1</th>
<th>TEST 2</th>
<th><em>TEST 3</em></th>
<th>TEST 4</th>
<th>TEST 5</th>
<th>TEST 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUPPLY AIR VOLUME CFM</td>
<td>ORIGINAL / REVISED</td>
<td>1334 / 1155</td>
<td>1331 / 1155</td>
<td>1334 / 1155</td>
<td>1334 / 1155</td>
<td>1334 / 1155</td>
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<td>1265 / 1086</td>
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<tr>
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<td>0 / 0</td>
<td>20 / 18</td>
<td>9.0 / 6.0</td>
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<tr>
<td>SUPPLY AIR TEMP. Dry Bulb</td>
<td>ORIGINAL / REVISED</td>
<td>55 / 55</td>
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<td>70</td>
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<td>MIXED AIR TEMP. Dry Bulb °F</td>
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<td>70</td>
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<td>15</td>
<td>14</td>
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<tr>
<td>DELTA T Dry Bulb °F MIXED</td>
<td>CALCULATED</td>
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</tbody>
</table>

**Living Zone = Largest Zone**

**Sleeping Zone = Smallest Zone**

Test Definitions: Test 1 = All Zones calling. Bypass as Found
Test Definitions: Test 2 = All Zones calling. Bypass Closed
Test Definitions: *Test 3* = All Zones calling. Bypass Forced 100% Open (Abnormal Condition)
Test Definitions: Test 4 = Sleeping Zone calling. Bypass as Found
Test Definitions: Test 5 = Sleeping Zone calling. Bypass Closed
Test Definitions: Test 6 = Living Zone calling. Bypass as Found

*** Return air volume data from Proctor Engineering test sequences, are utilized to compensate for lack of air filter correction factor on original SEC measurements.

FORMULA TO DETERMINE TRUE MIXED RETURN AIR TEMPERATURE

Return Mixed Air Temperature =

\[
\frac{([\% \text{ bypass air}] \times \text{bypass air temperature}) + ([\% \text{ return air}] \times \text{return air temperature})}{\text{Total Supply CFM}}
\]

Where:

\% bypass air = Bypass CFM / Total Supply CFM
\% return air = Return CFM / Total Supply CFM
This is the final sensible energy efficiency ratio chart. A mixed return air formula was performed on the original collected data. The formula corrects for any possible temperature measurement inaccuracies in the field. Note the upward trend in sensible energy efficiency ratio during “zoned” operations versus “all zones”.

Bypass as Found = Bypass damper allowed to operate as designed during a test.
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.

**Sensible EER**

<table>
<thead>
<tr>
<th>Cooling Capacity over Power</th>
<th>All Zones Calling Bypass as FOUND</th>
<th>All Zones Calling Bypass Forced 100% CLOSED</th>
<th>All Zones Calling Bypass Forced 100% OPEN</th>
<th>Restrictive Zone Calling Bypass as FOUND</th>
<th>Restrictive Zone Calling Bypass Forced 100% CLOSED</th>
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<tr>
<td></td>
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<td>5.15</td>
<td>4.72</td>
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</table>

EWC Controls ZONED TEST HOUSE
(Rancho Cordova, CA) Site work performed by Dunbar HVACR.
Measured Data obtained by Sacramento Engineering Consultants.
and EWC Controls on 07/17/2013
2 Zones (Living and Sleeping) 3 Ton, 1 Heat / 1 Cool
Zone system design by EWC Controls, using ACCA Manual J, D & Zr.
Data revised by EWC using “mixed return air formula” to correct for possible temperature measurement inaccuracies.
This is the final sensible capacity and total power chart. A mixed return air formula was performed on the original collected data. The formula corrects for any possible temperature measurement inaccuracies in the field. Note the upward trend in sensible capacity during “zoned” operation versus “all zones”.

Bypass as Found = Bypass damper allowed to operate as designed during a test.
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.
APPENDIX 17 - Proctor Engineering Group Original Data Results on the Rancho Cordova, CA. test home.

This is the original collected data before correcting for possible field measurement inaccuracies. Note the upward trend in Differential Temperature during "zoned" operations versus all zones. Note additional Test #6 not performed by Sacramento Engineering Consultants.

Bypass as Found = Bypass damper allowed to operate as designed during a test.
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.

<table>
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<tr>
<th>Parameters</th>
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<th>Test 2</th>
<th><em>Test 3</em></th>
<th>Test 4</th>
<th>Test 5</th>
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<td><strong>3131</strong></td>
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<td>53</td>
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<td><strong>Return Air Temp. Dry Bulb</strong></td>
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<td>58</td>
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<td><strong>Delta T Dry Bulb</strong></td>
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</tbody>
</table>

Living Zone = Largest Zone
Sleeping Zone = Smallest Zone

Test Definitions: Test 1 = All Zones calling. Bypass as Found
Test Definitions: Test 2 = All Zones calling. Bypass Closed
Test Definitions: *Test 3* = All Zones calling. Bypass Forced 100% Open (Abnormal Condition)
Test Definitions: Test 4 = Sleeping Zone calling. Bypass as Found
Test Definitions: Test 5 = Sleeping Zone calling. Bypass Closed
Test Definitions: Test 6 = Living Zone calling. Bypass as Found

*Power Factor* calculated values based on measured voltage, current and wattage on both test days
This is the original sensible energy efficiency ratio chart before correcting for possible field measurement inaccuracies. Note the upward trend in sensible energy efficiency ratio during “zoned” operation versus “all zones”.

Bypass as Found = Bypass damper allowed to operate as designed during a test.  
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.
APPENDIX 19 - Proctor Engineering Group Original Data Results on the Rancho Cordova, CA. test home.

This is the original sensible capacity and total power chart before correcting for possible field measurement inaccuracies. Note the upward trend in sensible capacity during “zoned” operation versus “all zones”.

Bypass as Found = Bypass damper allowed to operate as designed during a test.
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.

EWC Controls ZONED TEST HOUSE
(Rancho Cordova, CA) Site work performed by Dunbar HVAC.
Measured Data obtained by Proctor Engineering and EWC Controls on 07/29/2013
2 Zones (Living and Sleeping) 3 Ton, 1 Heat / 1 Cool
Zone system design by EWC Controls, using ACCA Manual J, D & Zr.
This is the final corrected data sheet. A mixed return air formula was performed on the original collected data. The formula corrects for any possible temperature measurement inaccuracies in the field. Note the upward trend in differential temperature (Delta T) during “zoned” operations versus “all zones”.

**APPENDIX 20 - Proctor Engineering Group Final Data Results on the Rancho Cordova, CA. test home.**

**EWC Controls ZONED TEST HOME * Rancho Cordova, CA**

*Data captured by Proctor Engineering on 07/29/2013 and revised by EWC to find true mixed return air temperature.*

<table>
<thead>
<tr>
<th>PARAMETERS</th>
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<th>TEST 1</th>
<th>TEST 2</th>
<th><em>TEST 3</em></th>
<th>TEST 4</th>
<th>TEST 5</th>
<th>TEST 6</th>
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<tr>
<td>RETURN AIR VOLUME CFM</td>
<td>ORIGINAL</td>
<td>1155</td>
<td>1155</td>
<td>947</td>
<td>1086</td>
<td>1086</td>
<td>1062</td>
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<td>BYPASS AIR VOLUME CFM</td>
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<td>0</td>
<td>208</td>
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<td>0</td>
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<td>8</td>
</tr>
<tr>
<td>SUPPLY AIR TEMP, Dry Bulb</td>
<td>ORIGINAL</td>
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<td>57</td>
<td>50</td>
<td>53</td>
<td>53</td>
<td>47</td>
</tr>
<tr>
<td>RETURN AIR TEMP, Dry Bulb</td>
<td>ORIGINAL</td>
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<td>69</td>
<td>70</td>
<td>72</td>
<td>72</td>
<td>71</td>
</tr>
<tr>
<td>MIXED AIR TEMP, Dry Bulb °F.</td>
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<td>66</td>
<td>71</td>
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</tr>
<tr>
<td>DELTA T Dry Bulb °F. RETURN</td>
<td>ORIGINAL</td>
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<td>12</td>
<td>20</td>
<td>19</td>
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<td>24</td>
</tr>
<tr>
<td>DELTA T Dry Bulb °F. MIXED</td>
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<td>SENSIBLE HEAT btu/hr</td>
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*Living Zone = Largest Zone
Sleeping Zone = Smallest Zone
Test Definitions: Test 1 = All Zones calling. Bypass as Found
Test Definitions: Test 2 = All Zones calling. Bypass Closed
Test Definitions: *Test 3* = All Zones calling. Bypass Forced 100% Open (Abnormal Condition)
Test Definitions: Test 4 = Sleeping Zone calling. Bypass as Found
Test Definitions: Test 5 = Sleeping Zone calling. Bypass Closed
Test Definitions: Test 6 = Living Zone calling. Bypass as Found

**FORMULA TO DETERMINE TRUE MIXED RETURN AIR TEMPERATURE**

Return Mixed Air Temperature =

\[
\frac{[\% \text{ bypass air} \times (\text{bypass air temperature})] + [\% \text{ return air} \times (\text{return air temperature})]}{\text{Total Supply CFM}}
\]

Where:

\% bypass air = Bypass CFM / Total Supply CFM
\% return air = Return CFM / Total Supply CFM
APPENDIX 21 - Proctor Engineering Group Final Data Results on the Rancho Cordova, CA. test home.

This is the final sensible energy efficiency ratio chart. A mixed return air formula was performed on the original collected data. The formula corrects for any possible temperature measurement inaccuracies in the field. Note the upward trend in sensible energy efficiency ratio during “zoned” operations versus “all zones”.

Bypass as Found = Bypass damper allowed to operate as designed during a test.
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.

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**Sensible EER**

![Graph showing Sensible EER](image)

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EWC Controls ZONED TEST HOUSE  
(Rancho Cordova, CA) Site work performed by Dunbar HVACR.  
Measured Data obtained by Proctor Engineering and EWC Controls on 07/29/2013  
2 Zones (Living and Sleeping) 3 Ton, 1 Heat / 1 Cool  
Zone system design by EWC Controls, using ACCA Manual J, D & Zr.  
Data revised by EWC using “mixed return air formula” to correct for possible temperature measurement inaccuracies.
This is the final sensible capacity and total power chart. A mixed return air formula was performed on the original collected data. The formula corrects for any possible temperature measurement inaccuracies in the field. Note the upward trend in sensible capacity during “zoned” operation versus “all zones”.

Bypass as Found = Bypass damper allowed to operate as designed during a test.
Bypass Closed / Forced = Bypass damper manually forced open or closed during a test.

EWC Controls ZONED TEST HOUSE
(Rancho Cordova, CA) Site work performed by Dunbar HVAC.
Measured Data obtained by Proctor Engineering and EWC Controls on 07/29/2013
2 Zones (Living and Sleeping) 3 Ton, 1 Heat / 1 Cool
Zone system design by EWC Controls, using ACCA Manual J, D & Zr.
Data revised by EWC using “mixed return air formula” to correct for possible temperature measurement inaccuracies.
APPENDIX 23  Unsolicited Homeowner E-mail concerning their satisfaction with the new zone system, the improved level of comfort and a perceived energy savings.

December 9, 2013

EWC Controls, Inc.

I would like to take a moment to thank you for the fine job you and EWC Controls, Inc. did on our home this last year. The process that was used to increase the energy efficiency of our home was not only completed professionally, but done with the utmost consideration of the homeowners as you and the EWC Controls, Inc. team analyzed the project. We have noticed a marked savings in our energy bills and the house is constantly at a comfortable level. Before this was completed our bedrooms were very uncomfortable most of the year. I would especially like to thank Chris Dunbar and Sherry Mann from Dunbar Air Conditioning for the wonderful work they did. It was a pleasure to work with them and they not only completed the work in a professional way but kept us informed as we went through the entire process.

Thank you again for the fantastic service! If you need any other information or have any other questions, please call us at [redacted]  
With much Appreciation,

[Redacted]

Rancho Cordova, CA 95670