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Response to Evapco and BAC comments to Title 24 Refrigerated Warehouse proposed Standards
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Evapco, Inc. submitted a letter dated March 8, 2012. Baltimore Aircoil Company followed with a letter dated March 16, which reiterates the Evapco points. ASHRAE TC8.06 notes agreement with Evapco and BAC and does not add additional points.

Response discussed by HMG, PECI, VaCom and with input from Jon McHugh:

1. The comments comparing evap- and air-cooled specific efficiencies are not relevant to the proposed requirements. The two ratings should not be compared and there are no conclusions to be drawn by making these comparisons. The two types of condensers function differently and each has a different basis for calculating specific efficiency, as well as having separately determined economics.
2. The comments regarding ammonia air-cooled condensing are not relevant to the proposed requirements. The intent of the code change is simply to allow ammonia to be used. Since there is no prohibition on halocarbon air-cooled systems (of any size), there is no reason to prohibit a more efficient refrigerant. It was also noted that the industry has reported successful large ammonia air cooled installations (e.g. Wal-Mart 2010 IIAR presentation). Choosing air-cooled condensing can be economically justified on a life-cycle basis if water is very expensive and/or water quality is so poor that condensers become rapidly fouled and must be frequently replaced to maintain performance.
3. The comments did not challenge the cost effectiveness calculations. We believe the specific efficiency requirements are cost-effective: for the subject applications, in California. In addition to the incremental analysis provided in the CASE report, the Savings By Design base case used for incentives for many years is only slightly lower than the proposed Title 24 standards (i.e. for large condensers 330 BTUh/Watt in Savings By Design base case vs. 350 BTUh/Watt in the proposed Standard). Particularly for large condensers, manufacturers can readily propose more efficient condenser selections with lower motor power, so no “retooling” costs are involved.
4. We acknowledge that manufacturers are likely to use actual applied power in determining specific efficiency, particularly on the larger condensers. Fan motors are observed in the field to be less than fully loaded; logically so at the specific efficiency rating conditions, to allow for higher fan and motor loads at lower ambient temperatures. The manufacturers accordingly will be able to reflect higher specific efficiencies for current models than were assumed in CASE analysis, which assumed all motors to be 100% loaded.

General Comments

Air-Cooled vs. Evap-Cooled Specific Efficiency Ratings

The minimum specific efficiency values for air-cooled and evap-cooled condensers cannot be compared. The rating basis for air-cooled is based on a 10°F TD and uses entering dry bulb temperature. The rating basis for evap-cooled is based on 100°F SCT and 70°F entering wet bulb temperature. The fact that evap-cooled specific efficiencies have higher numbers is simply an artifact of these rating basis values, and provides no means of comparing air vs. evap condensers. The proposed minimum specific efficiency is arrived at through hourly analysis of each type of condenser, one of which responds to DBT and the other responding to WBT, which vary differently throughout the year and have different TDV impacts. Also, whereas air-cooled condenser capacity is the same for a given TD regardless of entering DBT (at least with current published ratings) evap-condenser capacity at a given TD varies with entering WBT. Different rating assumptions could have been used to calculate the specific efficiencies, but would never allow a direct comparison between the two types of condensers.

While it has no bearing on the model/size that would represent the cost-effective minimum specific efficiency, it would certainly be possible to change the ambient and SCT temperatures used for the specific efficiency calculations. There is some thought that air-cooled might be better set at 15°F than 10°F, but only concurrent with changes to the ASHRAE or AHRI rating standard to lower the test point from 30°F. For evaporative condensers the 100°F SCT and 70°F WBT values have some history but are somewhat arbitrary. A lower TD and a lower WBT that more closely represents average operating conditions has been argued. The 96.3°F SCT and 78°F WBT rating values from AHRI 490 could be considered, but this WBT is highly unrepresentative of average operating conditions. The general proposition for future code cycles is that attention should be focused on promoting a rating standard used by industry, with capacities and power (and thus specific efficiency) published in accordance with this standard, and presumably with certification of ratings. For evaporative condensers, this could potentially incorporate two test points—one at peak capacity and one at a “typical” operating WBT and SCT, such as 80°F SCT and 70°F WBT. The CEC has noted support for improved rating standards that could be used for testing and published ratings as well as certification.

Air-Cooled Ammonia Condensers

The 2008 standard prohibited use of air-cooled condensers with ammonia. It did not prohibit air-cooled condensers with any other refrigerant. Other than this one instance, the 2008 and proposed 2013 standard do not dictate which type of condensing is used, recognizing there are many reasons to select air-cooled or evap-cooled condensing (or water-cooled condensers) which cannot be defined solely on the basis of energy use, such as water cost, quality and availability, noise and space constraints, etc.

Ammonia is a better refrigerant (in terms of efficiency as well as dramatically so regarding direct GHG impact) than halocarbons. There was no justification in selectively prohibiting ammonia and as a result driving the use of halocarbon refrigerants in instances where air-cooled condensing was desired. Energy analysis shows that in many areas of California air-cooled condensing in lieu of evaporative condensing can be cost effective, so allowing designers who go this route to use ammonia is an important change to the standard. There are a few large recent facilities built with air-cooled ammonia systems (e.g. presentations at IIAR in San Diego by Wal-Mart and others) which show this is more than theoretical. Compressor manufacturers now are making compressors with suitable operating pressures.

We agree there could be high ambient locations where air-cooled condensing would be inefficient, but in California there are also locations with extremely poor water or lack of water where designers may want to use air-cooled. The choice to use air-cooled condensing may still be appropriate and cost-effective if water is very expensive or water conditions result in rapid scaling and frequent condenser replacement. In this instance, the change to the standard allows the most efficient and least expensive refrigerant (ammonia) to be used.

<u>Motor Power and Loading</u>

The evap condenser specific efficiency calculations assumed fan motors and pump motors being 100% loaded. Field measurements show that fan and pump motors are generally not fully loaded, probably for a host of practical reasons, such as sizing for lower winter air temperatures and density, etc. We recognize that manufacturers will be free to use the applied fan BHP and pump applied power and related actual input kW, which may in many instances increase the specific efficiency by 5-10% above the numbers used for the CASE analysis.

Additional responses to Evapco Letter

<u>Comment 1)</u> In the CASE study on the energy use of Refrigerated Warehouses dated October 31, 2011 a chart is published in Section 2, page 8 and 9 for different climate zones. The chart suggests energy savings for each type of condenser and presents data on the energy savings benefits of air cooled condensers compared to indoor evaporative cooled condensers

For example, in Fresno, CA, it is shown that there is a 7680 kWh annual energy savings with an air cooled condenser versus 344 kWh for an indoor evaporative cooled condenser. This appears illogical. Knowing air cooled condenser efficiencies are 75 btuh/watt and centrifugal indoor evaporative condenser efficiencies of 160 btuh/watt. How is this figure achieved?

Response: The condenser specific efficiency measure was evaluated separately for three condenser types: air-cooled, outdoor (axial fan) evaporative-cooled, and indoor (centrifugal fan) evaporative-cooled. The basis of comparison for each evaluation was a Base Case condenser of the same condenser type. In the example presented, the 7,680 kWh savings for the air-cooled condenser and 344 kWh for the indoor evap condenser are not versus a common Base Case. A direct comparison cannot be made between the results for different condenser types.

Regarding the difference in specific efficiency, it should be noted that the rating conditions for air-cooled and evaporative-cooled condensers are not the same. Air-cooled condenser efficiencies are evaluated at a 10F TD (105F SCT, 95F DBT), while evaporative condensers are evaluated at a 30F TD (100F SCT, 70F WBT). Since rating conditions are different and since the performance of the different condenser types are dependent on different ambient conditions (DBT for air-cooled and WBT for evaporative), a direct comparison of efficiencies for different condenser types also cannot be made.

<u>Comment 2</u>) In this same study, EVAPCO agrees with Section 4.4 Allow Air-Cooled Ammonia Condensers by allowing air-cooled condensers for ammonia applications for greater energy savings versus halocarbons. However, the analysis performed in Appendix G to show the attractiveness of air cooled condensers in cool climates contains an overstated water consumption value for evaporative condensers.

EVAPCO performed its own evaluation of water usage for an evaporative condenser using the data for the Prototype Warehouse #1 from "Appendix A: Load Calculations for Fresno" Calculating the total load of this warehouse:

i) The 35°F cooler space of 1,277,384 btuh

ii) The-10°F freezer space of 1,385,001 btuh

iii) The 40°F dock space of 1,107,846 btuh

Total load is 3,770.231 btuh for this 92,000 sf. warehouse.

Using typical design conditions of 96°F condensing and a 73°F wet bulb (not sure why 70°F SCT was utilized in Appendix G) ***[Response: For this analysis, the design conditions were different for each climate zone. Appendix G states that the <u>minimum</u> SCT, not design SCT, was assumed to be 70F with a wetbulb-following control strategy and variable speed fans.]*** , a selection was made utilizing EVAPCO's custom software program which utilizes up to date global climactic data, a typical load profile for refrigerated warehouses provided by Cascade Energy and an increased value of 5 cycles of concentration which is the California average based on the Cooling Tower Water Savings CASE study of October 20II. Note: 2.4 cycles was used in the Refrigerated Warehouse Appendix G study. The EVAPCO ATC-305E-lg evaporative condenser is acceptable for this application and only uses 2,400,000 gallons of water annually. The example illustrated an annual water savings of 4.016.431 gallons of water as shown in Appendix G using air cooled condensers. By the ratio of the specific efficiencies, the air cooled condenser system could consume up to 4.66 times the power of the evaporative system. The additional water consumption required by the power plant to produce this additional power needs to be considered in the evaluation of true water saved. ***[Response: Specific efficiencies for different condenser types are based on different rating conditions, and direct comparisons cannot be made between them.]*** The energy savings realized in cooler climates for air cooled is also confusing, the energy efficiency of evaporative cooled equipment, especially in cooler climates will still exceed air cooled. ***[Response: The study presented in Appendix G considers the energy consumed by the entire refrigeration system, not just the condenser. Therefore, the tradeoff between condenser and compressor energy must be considered. The simulation analysis showed that the lower approach TDs of air-cooled condensers may be advantageous in mild climate zones where the wetbulb and drybulb temperatures are similar for the majority of the time].*** Simply stated, the energy and water saving values in Appendix G are inflated, and give the reader the impression that using air cooled condensers can save both water and energy.

Response: The CASE report does not intend to encourage the use of one type of condenser over another. The study in Appendix G is intended to show that air-cooled condensing may make sense in some climate zones, and therefore a system designer should not be required to use a less efficient (and higher GWP) halocarbon refrigerant if they choose to use an air-cooled condenser.

Comment 3) In Appendix F of the October 31, 2011 Refrigerated Warehouse CASE study, the "Savings by Design" efficiency tables shown in Figure 71: Axial Fan Evaporative-Cooled Ammonia Condenser baseline do not provide a set of design conditions that were used to establish the efficiency levels listed. In addition, the simple average of the values as shown in the table is actually 305 Btuh/Watt, not 350 as shown and used through the entire study.

Response: The specific efficiency rating conditions for this type of condenser is 100F SCT, 70F WBT, which is consistent throughout the report.

The table does not state that the simple average of the Savings By Design specific efficiency database is 350 Btuh/Watt. 350 Btuh/Watt is the calculated efficiency level that was shown to be cost effective using Life Cycle Cost methodology prescribed by the CEC for this evaluation, as described in Section 4.5. The table does state that the average specific efficiency for condensers <u>whose efficiency is less than the prescribed value of 350 Btuh/Watt</u> is 265 Btuh/Watt.