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Express Terms Comments

see attached.

Additional submitted attachment is included below.

To: CEC
From: Jeff Stein
Subject: Docket Number: 22-BSTD-01 Express Terms
Date: November 17, 2023

We offer the following comments on the Express Terms:

1. Vestibules. The new requirement on page 258 of 631 is too broad. Vestibules make sense for high-rises in extreme cold climates to mitigate stack effect. For most CA climates, and for any low rise buildings, there will be minimal stack effect and vestibules will not be cost effective. Buildings should be maintained at slight positive pressure so there will be minimal infiltration from main entrances. At a minimum please include this 90.1 exception: "Building entrances in buildings that are located in Climate Zone 3, where the building is less than four stories above grade and less than 10,000 ft2 in gross conditioned floor area." Note that "Climate Zone 3" here refers to ASHRAE Climate Zone 3 which encompasses most California Climate Zones:

2. 140.4(a)3 Office and School Heat Pump Systems (page 306 of 631)

   a. Offices: The list of 3 systems is unnecessarily narrow and leaves out many all-electric systems that can have lower energy and lower LCC such as DFDD, VVT, and TIER. Not to mention new systems that haven't even been developed yet.
      i. Promoting VRF is particularly problematic for the reasons discussed in our previous comments (attached)
   b. School Buildings. The single option for schools is far too restrictive and happens to be a particularly poor choice for most schools. A system with an air economizer, occupied standby, and DCV (like VVT, VAVR or DFDD) will generally be more efficient and lower cost than FPFC/DOAS for a school.
   c. These lists now ban most multi-zone mechanical systems in use today in offices and schools. A detailed lifecycle cost analysis is required documenting that one of the required systems is lower lifecycle cost than each of the banned systems. Please share the details of this analysis.
   d. There are several requirements in here that basically say "comply with the rest of T24", including references to 140.4(a)3D, 140.4(a)3E, and 140.4(q). These are not needed and should be removed.
   e. This makes no sense: "Ventilation systems shall include DCV in all zones". DCV only makes sense in high density zones, where it is already required, so this sentence can be deleted.
   f. Sections C, D, and E are all basically repeats of requirements elsewhere in T24. Any changes that can be LCC justified should be made to those sections.
   g. **Please replace all of 140.4(a)3 with the following:**
      i. **"The heating system serving offices and schools not covered by Section 140.4(a)2 shall be an electric heat pump. Acceptable options include VRF heat pumps and air-source heat pumps."**
   h. Our recommended version meets your goal of banning gas heat without the collateral damage of requiring systems that are not cost effective, banning systems that are more efficient, and stifling innovation. It is also clearer, more concise, and easier to enforce.

3. 140.4(a)2 Single Zone. Why does this section dictate gas furnaces and dual-fuel heat pumps in some cases? Can we not at least allow electric heat pumps in these cases?

4. Computer Room Economizer Exception 2 (page 363 of 631). The proposed revisions to 140.9(a)1 make no sense. Basically exception 2 says you can serve your office server room with a split DX unit if you also serve it with a VAV box off of your main air handler. Section ii says that you need to be able to run the air handler at night to serve the server room and shut off the VAV boxes to the unoccupied office spaces. The proposed change to ii isn't even a full sentence. Exception 2 only applies to economizers serving other spaces within the building so the revised ii is now in conflict with Exception 2. Please undo this proposed revision. I wrote this section in 2013 and revised it in 2019 or 2022. I'd be happy to revise it again if someone can tell me what issue they are trying to address.

EXCEPTION 2 to Section 140.9(a)1: A computer room with an ITE design load less than 20 tons (70 kW) may be served by a second fan system without an economizer if it is also served by a fan system with an economizer that also serves other spaces within the building, provided that all of the following are met:

this is in conflict with this. please undo this change

i. The economizer system is sized to meet the design cooling load of the computer room when the other spaces within the building are at 50 percent of their design load at outside air temperatures of 65°F dry-bulb and below or 50°F wet-bulb and below; and

ii. ~~The~~ An economizer system ~~has the ability to serve~~ serving only the computer rooms. ~~connected to it, e.g., shut off flow to other spaces within the building when unoccupied.~~

To: CEC
From: Jeff Stein
Subject: Docket Number: 22-BSTD-01 (Heat Pump Baselines)
Date: August 9, 2023

We offer the following comments on Docket Number: 22-BSTD-01 (Heat Pump Baselines):

Medium Office Proposal Comments

1. VRF/DOAS is Less Efficient than PVAV
   a. In CBECC world VRF/DOAS may look better but in real life a VRF/DOAS system will use more energy than a minimally code-compliant packaged VAV reheat system.
      i. The CBECC internal load profiles are unrealistically high and monolithic. This favors fixed fan speed options like VRF/DOAS and incorrectly penalizes VAV systems. With realistic load profiles VAV reheat has much lower total fan energy, as illustrated in this analysis that used more realistic load profiles.
         1. ASHRAE RP-1515 was a long term study of many office buildings with thousands of zones. When the VAVR zone minimums were reduced from 30% to 10-15% almost all zones spent almost all their time at the new zone minimums, meaning that real zone loads are rarely more than 10-15% of their design values. See Figure 1 below.
      ii. CBECC does not model demand controlled ventilation (CO2 controls) or occupied standby (OS) controls. Both of these are huge energy savers (particularly now with remote work) and both are installed in all PVAV systems. VRF/DOAS systems are not typically installed with DCV controls or OS controls.
      iii. Not only does VRF/DOAS have higher annual cooling energy (due to the lack of an air economizer), it also has higher peak cooling energy because every zone is provided with its maximum ventilation every hour. With VAVR there will always be some DCV zones and OS zones that are not fully occupied and thus the peak ventilation rates are lower. Furthermore, some space temperature setpoints are setback by OS.
      iv. Most energy models of PVAV do not accurately model zone minimum flow rates, which are now required to be no higher than minimum ventilation (typically about 10% of zone maximums). Most models use minimums of 20% (per T24-2019) or 30%.
      v. Other features of VAVR that are often modeled incorrectly are supply air temperature reset and duct static pressure reset.
   b. Third party testing of VRF equipment by PG&E, Guidehouse, and DOE has shown that the efficiency claims by the AHRI ratings are overstated, particularly in terms of heat recovery efficiency. For, example, Figure 2 shows that the real measured EERs are about half of what the ratings predict, i.e. VRF uses twice the energy expected by CBECC.
   c. The measured energy performance of actual VRF installations at the ASHRAE HQ and elsewhere has been well below expected performance based on AHRI ratings.
2. VRF Refrigerant Issues
   a. Most VRF uses R-410A, which has a global warming potential (GWP) of 2,090 or 1,920. Senate Bill 1206 bans the sale of refrigerants greater than 1,500 GWP starting 1/1/2030. Packaged rooftop units also typically use R-410A but they have several options for new refrigerants like R-454B (GWP = 467) and R-32 (GWP=675). But R-454B and R-32 are not viable options for VRF because they are A2L (flammable) refrigerants which is highly problematic for VRF given the volumes of refrigerant that can enter occupied spaces. There are no viable low GWP and low ODP options for VRF at this time.
   b. Not only is VRF stuck with higher GWP/ODP refrigerants, but VRF has much higher refrigerant volumes and much higher refrigerant leakage rates than packaged rooftops. The higher volumes are unavoidable because refrigerant must be piped throughout the building to every zone. The higher leakage rates are also not surprising given that every VRF system is a one-off, field-built system, as

opposed to RTU refrigerant circuits, which are mass produced in the factory. Per ASHRAE Standard 228, VRF will typically leak 10% of its mass charge per year, compared to 6% for rooftop units. Higher GWP + Higher Volume + Higher Leakage Rates = MUCH more global warming.
    c. We are aware of a couple VRF buildings that have been plagued by slow refrigerant leaks that are very difficult to find and fix given the concealed refrigerant piping.

3. VRF Health and Safety Issues
    a. Even with R-410A there is an elephant in the room with VRF: How exactly do VRF systems comply with ASHRAE Standard 15 given the high volumes of refrigerant that can be dumped into any given room and given the lack of refrigerant monitoring, refrigerant exhaust, etc?
4. Price Gouging / Restraint of Trade
    a. One reason VRF has been so successful is because it shifts much of the HVAC cost from the core & shell phase to the tenant improvement phase. Speculative developers love this because it reduces their costs. One of the consequences of this shift is that future tenants usually must purchase their fan coils from the base building VRF manufacturer. For example, if the base system is Daikin, then the tenants must buy from Daikin and go to Daikin for part/service, and cannot shop around. The base system manufacturer is then free to basically charge whatever they want.
5. DOAS Results in Poorer Indoor Air Quality
    a. Eliminating the air economizer means less outside air is provided to occupied zones. This detailed analysis showed that air economizer systems average about 0.4 cfm/ft2 of outside air, which is far more than the 0.15 cfm/ft2 typically provided by DOAS.
    b. Air economizer systems also have greater flexibility to deal with future pandemics. Most air economizer systems have the ability to provide at least 4 to 6 times as much outside air as DOAS.
    c. Unlike most VAV systems, DOAS systems do not continuously measure ventilation or CO2 at the air handler or zone level, i.e. with VAV you know at any point in time if it is providing proper ventilation but with DOAS you do not know if it ever provided proper ventilation. We have direct experience with a number of DOAS installations that clearly have never provided code minimum ventilation. Ventilation is not needed for a VRF cooling system to work and thus there is an incentive for the owner and contractor to cut corners.
6. DOAS Mandatory Requirements
    a. If Title 24 is to prescriptively require DOAS then we strongly urge you to include the following mandatory language in 120.1.d.4 (or some other obvious place). As described in our CASE Editorial Markups, this is actually a clarification of the existing requirements but will greatly improve compliance and enforcement. Currently most DOAS systems do not meet this requirement because it is not clearly spelled out for designers to follow and for AHJs to enforce. Not only does this solve the DCV/OS loophole described above, it also solves the IAQ monitoring flaw described above.

       Decoupled ventilation systems (e.g., DOAS) serving spaces required to have occupant sensing ventilation controls (such as conference rooms and private offices) shall include modulating pressure independent air valves, or other means of modulating outside air, at all space conditioning zones. This shall be done to disable ventilation to unoccupied zones while maintaining measured outside air ventilation rates to occupied zones within 10 percent of the design minimum outside air ventilation rate per 120.1(f)2, and shall include demand ventilation controls for high density spaces such as K-12 classrooms, per 120.1(d)3.

7. Prescriptive Alternatives
    a. We strongly urge you to expand the prescriptive requirement to allow other all-electric options besides VRF/DOAS. For example, a packaged VAV reheat system with air-source heat pumps (instead of gas boilers) will use less energy than a VRF/DOAS system and solves many of the other VRF/DOAS issues described above such as the refrigerant issues, price gouging, and IAQ. The prescriptive requirement could be as simple as “fossil fuel heating is prohibited”. The performance baseline can still be changed to VRF/DOAS even if it is not prescriptively required.
8. Fix the Modeling Issues
    a. We also urge you to fix the modeling issues identified above, including:

    i. Realistic load profiles (I provided some to Noresco and others in 2011).
    ii. Modeling of DCV/OS, including in the VRF/DOAS baseline.

b. It is imperative that the modeling is at least relatively accurate (e.g. VAVR vs VRF/DOAS) so that it does not incent or force wrong behavior.

Large Office and Large School Proposal Comments

9. We find it very hard to believe that FPFC/DOAS is lower cost than the baseline VAV reheat system. If it is less expensive that why isn't it being done now? In my 28 year career I have seen hundreds of large offices with VAVR and DFDD but have only seen one with FPFC. That one was built in 1965 as a speculative office building with the intent of minimizing the core & shell cost and shifting as much of the cost as possible to future tenants.
10. One unintended consequence of forcing FPFC will be reduced comfort. Today a VAV zone costs about $10,000, while a FPFC zone costs about $35,000. This huge cost premium will force owners to put in fewer zones, ganging more and more rooms per zone.
11. FPFC also has significantly higher maintenance costs given the hundreds of additional fans, control valves, condensate pumps, filters, etc.
12. The FPFC/DOAS modeling suffers from many of the same flaws identified above. Once these are fixed it is possible, perhaps likely, that FPFC/DOAS models will use more energy than VAVR.
13. FPFC/DOAS also suffers from the IAQ issues described above.
14. Our comment above about DOAS Mandatory Requirements applies to this proposal as well. It is imperative for the DOAS system to include air valves if it is to have any chance of matching the real energy performance of a VAV system with an air economizer.
15. Our comment above about Prescriptive Alternatives also applies to this proposal. We agree with the goal of prescriptively requiring an all-electric system. We are willing to suspend our disbelief if the FPFC/DOAS is the vehicle for justifying all-electric. But that doesn't mean the requirement should be FPFC/DOAS. The prescriptive requirement should be "fossil fuel heating is prohibited" because the reality is there are other all-electric options that are lower lifecycle cost. A four-pipe VAV system, for example, also has no reheat but has an economizer and will have lower energy use than a FPFC/DOAS. It will also cost much less than FPFC/DOAS and have far lower maintenance.
16. Our comments above about modeling accuracy apply to this proposal as well. Nearly all large offices go performance now and even more will have to if FPFC is prescriptively required. The modeling must be accurate so that those using the performance approach are not forced to install a much more expensive and less efficient system.

Figures

Figure 1

RP-1515: Measured flow fractions

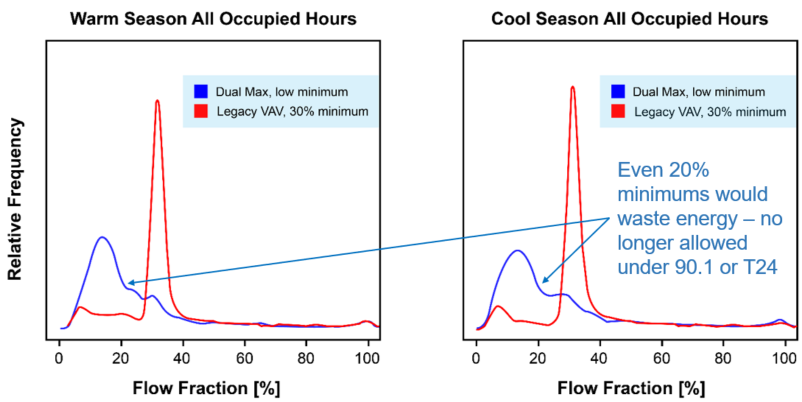
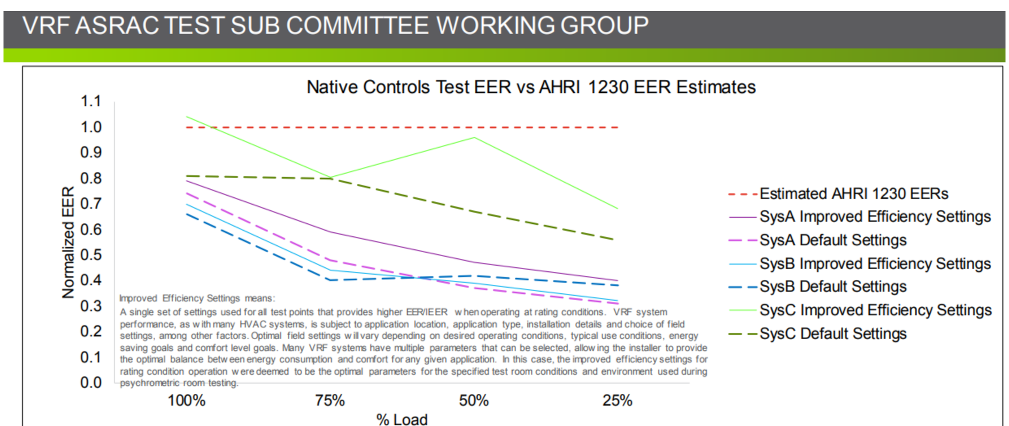


Figure 2



The estimated AHRI 1230 EERs are projected values based on ratings for Standard Rating Test EER at 100% and IEER of each system tested.