



I. Description of Issues

Data sources for the following Residential HVAC Quality Installation performance parameters will be identified. The subcommittee will recommend the most appropriate data source to inform these performance parameters for a workpaper revision.

ID	Evaluated Parameter	General Parameters	Unit	Keyword	Supporting/Informing Documentation
1	Flow Performance	Design full-load power of the supply fan per unit of supply airflow - Fan power; System airflow	kW/CFM	SUPPLY-KW/FLOW	WO32 + DEER + T24
2	Flow capacity	System airflow; system delivery capacity; system (ARI) rated capacity	CFM/Ton	-	WO32 + DEER + T24
3	Duct Leakage	Duct leakage - fraction of the supply air that is lost from the ductwork, thereby reducing the design supply air at the zones	Leakage (%)	DUCT-AIR-LOSS	WO32 + DEER + T24
4	<i>Equipment Sizing</i>	HVAC equipment capacity	Manual J Manual S	COOLING-CAPACITY COOL-SH-CAP	WO32 + ACCA Manual J/ACCA Manual S + ASHRAE 90.1 + eQuest + T24
5	HVAC System basecase HVAC Sub-systems basecase	SEER; duct leakage; duct insulation; flow performance; etc.	-	-	WO32 + Title-24 + DEER
6	Delivery Mechanism	ROB	-	-	Program Requirements
7	System Efficiency	System Efficiency (SEER)	EIR (at ARI rated conditions)	COOLING-EIR	Title-24 / DEER
8	Refrigerant Charge Adjustment (RCA)	-	-	-	WO32 + DEER



References:

1. HVAC Impact Evaluation FINAL Report WO32 HVAC – Volume 1: Report - CPUC, ED - Prepared by DNV GL
2. ACCA - Residential Load Calculation (Manual J)
3. ACCA - Residential Equipment Selection (Manual S)
4. ANSI/ASHRAE/IES Standard 90.1-2013 - Energy Standard for Buildings Except Low-Rise Residential Buildings
5. 2013 RESIDENTIAL COMPLIANCE MANUAL FOR THE 2013 BUILDING ENERGY EFFICIENCY STANDARDS, Title 24, Part



Flow Performance: Title 24 requires 0.58 watts/CFM. Since there are no OEM fan performance tables to engineer a system to comply with this, the installer must instead utilize an ECM or BFM fan motor connected to duct systems with 0.6 inches of water column or less. This value will be difficult to achieve with add-on coils to a furnace or other external air handler, as well as systems with restricted return duct components included return grilles and filters. Title 24 further requires filtration components to have an initial pressure loss of 0.03 inches of water column at 400 CFM. Finally, ECM motors will likely use more power in restricted duct systems – reducing overall savings. It should also be noted that in order to maintain reasonably sized coils, and to also make them more effective, coil fin spacing (density) is often tighter and more complex on higher efficiency coils. These characteristics results in higher pressure drops across the coils, and present another challenge to those trying to engineer systems to comply with this code requirement (as well as OEM fan pressure/CFM requirements).

WO32 did offer a comparison of watts/CFM for both groups, however did not show the correlation to return grille sizing, or duct static pressures or system SEER/EER. WO32 did identify a small difference between the groups. ECM motors may also need to increase RPM at higher altitudes due to the effect of lower air densities. Finally, WO32 did not record the air handling device or fan type for either group, so it is difficult to determine the affect or benefit of this Title 24 requirement which is not a specified requirement of QIV – other than that the QIV standard defined by ACCA/ANSI Standard 5 requires compliance with any local codes.

I would recommend the work paper take the credit provided in WO32 as a delta compared to the Title 24 requirement given WO32 control group was nearly identical to the Title 24 requirement.

Flow Capacity: Title 24 requires at least 350 CFM/ nominal ton. Manual J and S require the Total CFM be based on the SHR and load of the building. This means the CFM requirements with high internal latent loads may need lower CFM/ton requirements than a project with less latent internal loads. High CFM per ton may be desirable in dry climates; however it may also require higher fan energy input, which will negate some or all of the benefits derived from high airflow.

The Title 24 requirements may create a conflict with Manual J and S in some projects given that the Manual S process may require a larger nominal tonnage unit set with a lower CFM setting to meet both the latent and sensible loads for a building.

Given that many California climates are dry-climates, this may not be a big issue, however we need to better define the concept of system capacity. Title 24 refers to nominal tons, however OEM's and ACCA design procedures refers to system capacity at design conditions. Since many of California's dry-climates also have design conditions above 95°F (the AHRI outdoor rating temperature), the actual capacity will likely be lower than nominal and AHRI ratings. This creates a disparity between the engineering CFM per delivered BTUH versus the CFM/ nominal ton.

WO32 does not provide the CFM/Actual Tons at design conditions so it is difficult to interpret the results. My advice is that contractors should use the engineering practices set forth in the various ACCA manuals, therefore Flow Capacity (airflow) should be more about delivered CFM versus design CFM.



Duct Leakage: Title 24 requires duct sealing to 15% for existing and 6% for new.

WO32 compares overall mean duct leakage and does not compare groups based on requirements even though the paper describes this difference. Furthermore, it does not describe or compare duct locations (ie; attic versus crawlspaces) in the populations.

Duct leakage and Duct insulation R-values both have an impact on the building load and the return air entering the evaporator coil which affect system sizing. My recommendation is to try and get the site data or load models used in WO32 and tease the data to better correlate the potential savings. Furthermore, since the referenced version of Title 24 only requires R-6 insulation, that the QIV program considers R-8 for any newly installed ducts located in attics. It should also consider incentives for advanced duct sealing measures in systems with hard to access ducts in attics (ie; Aeorseal).

Equipment Sizing: Title 24 §150.0(h) states equipment sizing is not mandatory. The definition set forth in the previous work paper is flawed or imprecise given that equipment will always be oversized by some percentage of loads – otherwise they will be undersized. It is nearly impossible to exactly match a load with currently available equipment technologies. Furthermore, Work Order 32 (WO32) study did not properly address this issue; first, WO32 did not perform the Manual S procedure on the control group – they used the sensible heat ratio (SHR) value of the load to determine size based on AHRI rating capacity as an absolute value compared to load and they did not replicate this method for the test group (QIV projects) to compare the results of the contractors Manual S procedure to the load SHR. Manual S requires determining the system capacity at design load, not AHRI rating.

The Manual S procedure takes into account outdoor design temperature (the air across the condenser), the air properties entering the evaporator coil (altitude, duct gains and leakage effect on air density and enthalpy) and line-set length (and pipe diameter sizing) in some cases for split systems.

If “Oversizing” is to be used as a metric, then it needs to be properly defined in the work paper as the Adjusted Equipment Capacity at the projects design conditions – so that any comparisons are made based on the local design conditions.

WO32 did not properly address the Manual S procedure to differentiate the process of Manual S equipment selection from the non-participant control group. Furthermore, there is no data to show what was installed at either groups respective project prior to change-outs, so we don’t know the real effects of Manual S in this situation – in other words, did any down-sizing actually occur in either group.

HVAC System Base-case: WO32 admits its population of non-participants does not reflect the market baseline and instead was chosen to better represent a class of consumers that better matched the participant population. WO32 also sites recent studies showing Title 24 compliance at less than 10%. The WO32 report indicates low realization rates because of the program design and/or participant contractor mix being self-selecting.



Although this may be counter-intuitive – this suggests to me that incentives need to be increased to bring in the population of contractors and consumers who can't fathom the benefits because the contractors in this market likely do not own any of the engineering or testing equipment to do so, and are competing on price and availability alone. I would also argue that the real market baseline includes a large number of housing units with significant opportunities for savings.

Since WO32 could not really define a baseline, anecdotal and other studies will be needed to construct this.

Delivery Mechanism: WO32 did not address this issue.

I am certain that most of the replaced systems are in fact operational, and would suggest the program offer an early-retirement bonus incentive - require an existing system efficiency test and claim some early-retirement savings. The underlying argument will revolve around equipment life – typically published as 15 years.

It seems pretty obvious to me that contractors make money at selling new systems whether a customer needs it or not. Furthermore, it could be argued that a properly maintained system (one where a technician just cleans coils and changes filters and never puts gauges on it) would probably last well over 20 years – except in places where there are diurnal temperature extremes and the compressor may be starting under flooded conditions regularly. It would be much more valuable in appliance saturation studies and/or other studies to report if the systems are still operational or a Replace on Failure/Burnout.

Additional anecdotal evidence is the fact that there are systems well over 15 years of age still in operation – in the same areas where other systems have already been changed out.

System Efficiency: I think the real argument here lies with delivered system efficiency, not the rated system efficiency. QIV is about proper engineering and commissioning – meaning there is a performance oriented feedback loop that should reward contractors for making the overall system as efficient as possible. Picking a high-SEER product may mean selecting an evaporator coil with high static losses – and the real in-field performance may be several SEER values lower than its factory name-plate rating would otherwise suggest.

Incentive bonuses should be offered at a tiered rate to contractors who deliver higher overall system efficiencies than those who go through the process of just following the steps. My recommendation would be to pilot an approach that evaluates overall delivered system efficiency testing to get a handle on what the real performance baseline is.

Refrigerant Charge Adjustment (RCA): Refrigerant charge verification is both a component of Title 24 and QIV. My recommendation is that savings should be claimed on any QIV system where the line-set is over 40 feet in equivalent length and/or there is a vertical rise of more than 15 feet. This recognizes that most systems come pre-charged for 15 to 20 feet of line-set – so any system installed up to 40 feet will see little need for charge adjustment or that the benefit is too small to justify in most cases, however



when line-set get longer or there is a significant lift, additional adjustment may be required by the OEM to compensate for addition friction and/or head losses.

There is also one OEM in particular that is noted for shipping partially charged units (basically a holding charge). These units require a contractor to read instructions and properly charge the system. Furthermore there was a study a few years back looking at new packed systems refrigerant charge levels from the factory. I don't have the study handy, but it found concern for trusting OEM charge levels. The OEM's vigorously defended that units are accurately weighed before shipping so the incidence rate should not be what was found in the study. It might be worth tracking contractor refrigerant charge adjustments compared to factory stamped unit charge levels and line-sets for units.

As noted above, "long" line-sets also affect equipment capacity and are a sub-procedure of Manual S.

These conditions were not accounted for in the recent Work Order 32 study. Of particular concern is the rate of Title 24 compliance. I don't think there is significant savings for this measure in most QIV cases because of the market actor mix, but compared to baseline, there probably is savings.