Sustainable Urban Housing
HVAC System Design

Presented by:

Steven T. Taylor
Taylor Engineering LLC
Alameda, CA
http://www.taylor-engineering.com
October 7, 2015
Focus:
- Market rate high rise condominiums
- New construction
- San Francisco

Topics:
- Outdoor Air Ventilation Systems
- Exhaust Air Systems
- HVAC Systems
- Controls
Ventilation System Drivers

- Title 24/CMC requirements
- Standard 62.1 and 62.2 requirements
- SF Health Code Article 38
- “Standard of care” and lawsuits
T-24/CMC requirements

- **Title 24:**

  - **CBC:**

  - **CMC (based on Standard 62.1):**
    - $5 \text{ cfm/p}^*(\text{BR+1}) + 0.06 \text{ cfm/ft}^2*A$

  - **2019 CMC (based on Standard 62.2):**
    - $7.5 \text{ cfm/p}^*(\text{BR+1}) + 0.03 \text{ cfm/ft}^2*A$

  - **Exhaust rate almost always higher**
    - Will drive outdoor air rate if positive pressure desired

---

<table>
<thead>
<tr>
<th>TYPE OF USE</th>
<th>CFM PER SQUARE FOOT OF CONDITIONED FLOOR AREA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto Repair Workshops</td>
<td>1.50</td>
</tr>
<tr>
<td>Barber Shops</td>
<td>0.40</td>
</tr>
<tr>
<td>Bars, cocktail lounges, and casinos</td>
<td>0.20</td>
</tr>
<tr>
<td>Beauty shops</td>
<td>0.40</td>
</tr>
<tr>
<td>Coin-operated dry cleaning</td>
<td>0.30</td>
</tr>
<tr>
<td>Commercial dry cleaning</td>
<td>0.45</td>
</tr>
<tr>
<td>High-rise residential</td>
<td></td>
</tr>
</tbody>
</table>

**SECTION 1203 VENTILATION**

1203.1 **General.** Buildings shall be provided with natural ventilation in accordance with Section 1203.4, or mechanical ventilation in accordance with the *California Mechanical Code.*
Natural Ventilation Limits

CMC (Standard 62.1): 

- **402.2 Natural Ventilation.** Natural ventilation systems shall be designed in accordance with this section and shall include mechanical ventilation systems designed in accordance with Section 403.0 and Section 404.0. 

  **Exceptions:**

  1. An engineered natural ventilation system where approved by the Authority Having Jurisdiction need not comply with Section 402.2. 
  2. A mechanical ventilation system is not required where natural ventilation openings comply with the requirements of Section 402.2 and are permanently open or have controls that prevent the openings from being closed during occupancy. 
  3. A mechanical ventilation system is not required where the zone is not served by heating or cooling equipment.

Standard 62.2:

- **4.1 Ventilation Rate.** A mechanical exhaust system, supply system, or combination thereof shall be installed to operate for each dwelling unit to provide continuous whole-building ventilation with outdoor air at a rate not less than specified in Section 4.1.1.

  **Exceptions:** Whole-building mechanical systems are not required if the authority having jurisdiction determines that window operation is a locally permissible method of providing ventilation and provided that at least one of the following conditions is met:

  a. the building has no mechanical cooling and is in zone 1 or 2 of the climate zone map shown in Figure 9.1 or 
  b. the building is thermally conditioned for human occupancy for less than 876 h per year.
SFHC Article 38

- Required where indicated in Air Pollution Exposure Zone Map
  - Most all areas where high rise res’ being built
- “ventilation system proposed will be capable of achieving the protection from particulate matter (PM2.5) equivalent to that associated with MERV 13 filtration”

https://www.sfdph.org/dph/files/EHSdocs/AirQuality/AirPollutantExposureZoneMap.pdf
Consequences:

- MERV 13 filter at fan-coil or outdoor air AHU (DOAS)
  - Minimum 2” pleat
  - 3” or 4” better – will last about 1 year
- Depressurization designs that use exterior openings (zee-duct, trickle vent) cannot comply unless in-room air-cleaner is provided and run ~24/7
  - Not desirable anyway due to noise, dirt, drafts, rain infiltration
- Maintain positive pressure unless fan/filter runs when condo has a negative pressure
  - Many systems designed for negative pressure when kitchen hood is on
- Mechanical ventilation is required
  - Natural ventilation alone, e.g. from windows, is not possible
  - Required by Standard 62.1 and 62.2 anyway
  - Required by noise ordinances anyway
1. Recirculating Hood plus general kitchen exhaust
   - Rates:
     - Under 62.1 (UMC): 50 cfm (continuous)/100 cfm (on switch)
     - Under 62.2: 5 ACH up to 300 cfm*
   - Advantages
     - Constant exhaust rate so makeup easier to design
     - Lower exhaust rate under current code

2. Exhaust Hood
   - Rates: Per manufacturer (100 to 750 cfm)
   - Advantages
     - They actually work!
     - LBNL Studies show significant health benefits, conclude:
       - Pretty much mandatory with gas cooktops
       - Highly, highly recommended for electric cooktops
     - Lower lawsuit exposure

*300 cfm limit is in pending 62.2 addendum
### Bathroom Exhaust

<table>
<thead>
<tr>
<th></th>
<th>UMC/62.1/62.2</th>
<th>TE Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Continuous</td>
<td>Intermittent</td>
</tr>
<tr>
<td>Toilet room</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>Shower</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Combo shower/toilet</td>
<td>25</td>
<td>50</td>
</tr>
</tbody>
</table>

- **Continuous**
  - Least expensive
  - Makeup air design simpler
  - Smaller shafts on shorter buildings

- **Intermittent**
  - Most energy efficient due to diversity
  - Better short term odor/moisture removal
  - Reasonably stack effect tolerant with push-pull scavenger fan design
  - Shaft sizes may be smaller due to diversity for taller buildings (>20 fl.)
Size Risers and Fan for Diversity

Fig 9: Diversity factor vs. number of dryers served

Used for toilet and kitchen exhaust too
Typical Condo HVAC Design

- Bath/kitchen exhaust fan
- Sub-duct
- 4-pipe fan-coil with ECM
- Outdoor air intake – sized for toilet exhaust plus that needed to prevent low condo pressure when kitchen fan is on
Cooling with Operable Windows

- **Eliminate Mechanical Cooling?**
  - Marketability (for market rate condos)?
  - ASHRAE design conditions out of date?
    - Climate change?
  - Many hours outside ASHRAE 55 comfort window (even with adaptation) in most glass box condos even in SF weather
    - Exposure to lawsuits
  - Not possible in areas with noise ordinance
  - Not possible in areas falling under SF Article 38

- Mechanical cooling effectively required in almost all high rise residential
HVAC System Drivers

- **Title 24-2013**
  - **Envelope**
    - Baseline: ≤40% glass with SHGF≤0.25, VLT≥0.60
    - ~Zero condo projects will meet this
  - **Domestic Hot Water**
    - Baseline: Natural gas with 20% Solar
    - ~Zero high rise condo projects will meet this
  - **Lighting**
    - Baseline: High efficacy and/or controlled by vacancy sensors in kitchen/bath/utility
    - All condos should meet/beat this but not by much
  - **HVAC**
    - Baseline system extremely efficient
    - Must makeup for Envelope and DHW deficiencies!
    - Eliminates many common system types

- **SF Green Building Ordinance - LEED Silver**
Common System Types

- **4-Pipe Fan-Coil (4PFC)**
  - Central chiller plant
  - Central boiler plant
  - This is Title 24 baseline system

- **Hydronic Heat Pump (HHP)**
  - Central cooling tower and boiler plant

- **Hybrid Hydronic Heat Pump (H-HHP)**
  - Same as HHP but with heating coil using CW for heating

- **Variable Refrigerant Flow (VRF)**
  - Usually one condensing unit per floor
  - Water cooled for high rises similar to HHP
  - Liability exposure due to risk of massive refrigerant leak
Issues

- No explicit model for Hybrid HHP
- No explicit model for VRF
- No explicit model for SZVAV 4PFC
- Dedicated outdoor air system cannot be modeled
- Schedules for internal loads are all the same so no accurate accounting for diversity
- Bugs, bugs, and more bugs
# Simulation Results

## Oceanwide Tower 1

In this case, both systems “apparently” comply.

4PFC VAV will garner more LEED points.
Modeling Conclusion

- 4PFC is the only system that can reliably beat baseline in most cases
- If there is significant simultaneous heat/cool (e.g. glass box facing north and south), HHP and VRF may work
  - VRF must be on common condensing unit
  - Real savings reduced if operable windows are used (little heat recovery)
  - Only 5% of operating hours had simultaneous heat/cool for Oceanwide T1
Measures to help beat T-24

- **CHW Plant**
  - In baseline already
    - VFDs on everything except CW pumps
    - Primary-only variable flow
  - Add this
    - “Mag-lev” chillers in hot climates
    - High efficiency cooling towers
    - TES in hot climates

- **Fan-coil**
  - In baseline already
    - Cycling fan
    - Constant unconditioned outdoor air
  - Add this
    - Variable speed fan
    - HRVs in very hot/cold climates zones
    - High ΔT coils

- **HW Plant**
  - In baseline already
    - Primary-only variable flow
  - Add this
    - Condensing boilers
    - VFDs on HW pumps

- **DHW**
  - In baseline already
    - Natural gas
    - 20% solar thermal
  - Add this
    - Condensing water heaters (or tie to HHW plant condensing boilers)
    - Solar thermal if space
Control Options

- **Fan-coil**
  - **Typical: Programmable thermostat**
    - Not possible to control variable speed fan with current electronic thermostats
    - No internet access (available with premium thermostat +$200)
    - No sub-zoning possible except with multiple fan-coils ($$$$$)
    - No feedback of valve position for CHW/HW plant optimization
  - **Use DDC instead**
    - $1000 to $2000 premium
    - Costs likely to fall over time
Subzoning

- Not currently standard of care
- Highly desirable for units with more than one exposure and lots of glass
  - Comfort issue mainly but also small energy savings
- Solves balancing dilemma
  - Balance for heating or cooling airflow?
- Not that pricy if DDC already to be used
  - $1000 per zone
  - Minimal given cost of market rate condos
4PFC VAV VVT with changeover coil

6 row coil with changeover piping:
- Eliminates cost and pressure drop of second coil
- Results in ~20F ΔT on CHW (vs. ~12F for 4-row) and about 70F to 80F ΔT on HW (vs. 40F for 2-row).
- Savings in piping/pumps results in net cost reduction
- Pump and boiler energy savings

Optional window switch & occupancy sensor
Electricity submetering is required by PUC

- But no need to use PG&E meters – can use submeters and monitor/invoice through with BAS

Meter CW, DHW, CHW, HHW, gas??

- Very high cost for metering and (for CW, DHW) repiping to allow a single meter per condo
- Utility costs low relative to other shared costs (amenities, security, parking)
- Gas use for cooking only – definitely not worth metering
- Usually value-engineered out

Unintended consequence of using efficient HVAC and DHW baselines?

- Metering unlikely due to cost and not mandated
- Actual energy use may be higher vs. old electricity based system (HHP and individual electric DHW) due to occupant behavior
Conclusions

- Natural ventilation cannot meet various codes and operational requirements
  - Operable windows still needed as amenity
- Filtered mechanical outdoor air required
  - Size driver is usually exhaust rate
- Title 24-2013 significantly more stringent
  - May limit choice of HVAC system
- DDC is condo control system of choice
  - Subzoning also made practical
- Submetering possible but expensive
  - Very likely to be VE’d out
Questions