BUILDING MECHANICAL SYSTEMS FOR MULTI-RESIDENTIAL BUILDINGS

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Single-family developments have a less efficient heat loss form-factor (the ratio between the outside surface area of the thermal insulation in the building envelope and the heated volume) when compared to a multi-residential developments.

Naturally, in cold climates the impact of the factor is larger than in mild climates (Prof. Kimmo Lylykangas, *Shape Factor as an Indicator of Heating Energy Demand*).

Additional factors directing architectural design towards multi-residential buildings are related to natural resources conservation.
Mechanical systems provide domestic hot water, heating/cooling and ventilation to the building and this does not change between different building typologies whether single, multi-residential or commercial;

For single family houses packaged mechanical systems incorporating energy recovery, heating, cooling, and domestic hot water are available (hardly on the North American market)

In multi-residential buildings mechanical systems can be developed with a higher level of complexity in order to optimize their energy use efficiency and take advantage of diversity factors.
Thermal comfort is based upon a “perception of satisfaction” of the human body towards the surrounding environment, as such is mostly individual. However, since we share almost the same physiology it has been possible to outline thermal comfort conditions based on statistical researches.

Factors impacting thermal comfort are:
- Activity level
- Clothing insulation
- Air temperature
- Mean radiant temperature
- Surrounding radiant temperatures
- Air speed
- Relative humidity
When describing acoustic requirements, we refer to the concept of noise as an “unwanted and disturbing sound”. Sound is wave phenomenon and it’s measured using through its intensity and frequency.

Because of the specific sensitivity of the human body to different frequencies the sound spectrum is “weighted” and then expressed in dBA.

A similar approach is used to define the Noise Criterion (NC) as environmental noise produced by mechanical equipment. The method is based on a measurement of sound pressures levels and a set of sound pressure criteria curves ranging frequencies from 63 to 8000 Hz.
Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.

ASHRAE specific definition of air quality is “air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction.”

Typical pollutants are:
- Carbon monoxide, Carbon Dioxide
- Formaldehyde;
- Nitrogen Dioxide;
- Ozone, Radon;
- Particles <2.5 \( \mu \text{m} \) MMADd, Particles < 10 \( \mu \text{m} \) MMADd;
- Sulfur dioxide

The allowed concentration in the indoor environment depends mostly on local jurisdictions (see ASHRAE 62.1 Table B.1).
Some of these pollutants are generated inside the indoor environment (i.e. CO2, CO, NO2) and others can enter the building envelope from outside (i.e. Radon).

Usually, indoor air quality is achieved through filtration and dilution, supplying a certain quantity of “clean outdoor air” to the environment while exhausting “the less clean” to the outdoor.

![Table B-1: Comparison of Regulations and Guidelines Pertinent to Indoor Environments](image)
Fundamentals – Energy

- Energy and Power; same thing? Kw or Kwh, BTU or BTH?
- Primary Energy is a source of energy that has not been “converted“, in this extent Electricity as well as Fuel are “Secondary" or, so called, “Energy Carriers".
- “Site Energy” is the amount of end-use energy of all forms consumed at a specified location.
- “Source Energy” is the primary energy required to generate the Site Energy taking into consideration energy lost during transmission, delivery, and conversion. Source Energy provides more information in regards of the system sustainability.
Application – Thermal Comfort

- PH Std. requirements (warm-temperate climate zones):
  - Interior surface temperatures of the standard cross-sections of walls and ceilings as well as the average interior surface temperatures of windows may not be more than 4.2 K below the operative indoor temperature.
  - The temperature of the floor surface may not fall below 19 °C. The requirements will be checked in the PHPP with an indoor temperature of 22 °C and a minimum outdoor temperature taken from the climate data set for the building’s location.
  - PH Std. refers also to ISO 7730 “Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria”

- The National Building Code of Canada when it comes to thermal comfort generally refers ASHRAE Handbooks and Standards (therefore to ASHRAE 55.10 Thermal Environmental Conditions for Human Occupancy).

- As understandable the two approaches while similar are implemented differently.
  - ASHRAE 55 has an approach differentiated according to the different influential factors.
  - ISO 7730 has an approach differentiated per category of occupancy.
Application – Thermal Comfort

ASHRAE 55

ISO 7730
Passive House Standard Requirements:

- The ventilation system must not generate noise in rooms with prolonged occupancy.

Recommended values for the sound level are:

- ≤ 25 dB(A): supply air rooms in residential buildings, and bedrooms and recreational (NC<10)
- ≤ 30 dB(A): rooms in non-residential buildings (except for bedrooms and relaxation rooms) and extract air rooms in residential buildings (NC<20)
Because of its focus on “safety related matters” the Building Code doesn’t directly address the issue of noise produced inside the indoor environment.

However, industry standards are available suggesting the Noise Criterion (NC) level according to the occupancy category.

<table>
<thead>
<tr>
<th>Type of Room - Space Type</th>
<th>Recommended NC Level NC Curve</th>
<th>Equivalent Sound Level $dBA$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment Houses</td>
<td>25-35</td>
<td>35-45</td>
</tr>
<tr>
<td>Private Homes, rural and suburban</td>
<td>20-30</td>
<td>30-38</td>
</tr>
<tr>
<td>Private Homes, urban</td>
<td>25-30</td>
<td>34-42</td>
</tr>
</tbody>
</table>
Passive House Standard requirements:

- The ventilation volume flow rate must be adjustable for the actual demand. In residential buildings the volume flow rate must be user-adjustable for each accommodation unit (three settings are recommended: standard volume flow / standard volume flow +30 % / standard volume flow -30 %).

- All rooms within the thermal building envelope must be directly or indirectly (transferred air) ventilated with a sufficient volume flow rate. This also applies for rooms which are not continuously used by persons provided that the mechanical ventilation of these rooms does not involve disproportionately high expenditure.

- The ventilation system must not cause uncomfortable draughts.

- Outdoor supply air shall be filtered with a F7 filter (MERV 13)
NATIONAL BUILDING CODE REQUIREMENTS

- Housing and small buildings:
  - Principal ventilation system:
  - Supplemental ventilation: 25 L/S in the bathroom (if not provided by the principal ventilation system) and 50 L/S for the kitchen.
Application – Indoor Air Quality

- Other buildings: ASHRAE Std. 61.1-2001 Excluded Annex N

### OUTDOOR AIR REQUIREMENTS FOR VENTILATION (Continued)

<table>
<thead>
<tr>
<th>Applications</th>
<th>Outdoor Requirements</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living areas</td>
<td>0.35 air changes per hour but not less than 15 cfm (7.5 L/s) per person</td>
<td>For calculating the air changes per hour, the volume of the living spaces shall include all areas within the conditioned space. The ventilation is normally satisfied by infiltration and natural ventilation. Dwellings with tight enclosures may require supplemental ventilation supply for fuel-burning appliances, including fireplaces and mechanically exhausted appliances. Occupant loading shall be based on the number of bedrooms as follows: first bedroom, two persons; each additional bedroom, one person. Where higher occupant loadings are known, they shall be used.</td>
</tr>
<tr>
<td>Kitchens&lt;sup&gt;b&lt;/sup&gt;</td>
<td>100 cfm (50 L/s) intermittent or 25 cfm (12 L/s) continuous or operable windows</td>
<td>Installed mechanical exhaust capacity&lt;sup&gt;c&lt;/sup&gt; Climatic conditions may affect choice of the ventilation system.</td>
</tr>
<tr>
<td>Baths, Toilets&lt;sup&gt;b&lt;/sup&gt;</td>
<td>50 cfm (25 L/s) intermittent or 20 cfm (10 L/s) continuous or operable windows</td>
<td>Installed mechanical exhaust capacity&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Garages: Separate for each dwelling unit</td>
<td>100 cfm (50 L/s) per car</td>
<td>Normally satisfied by infiltration or natural ventilation</td>
</tr>
<tr>
<td>Common for several units</td>
<td>1.5 cfm/ft&lt;sup&gt;2&lt;/sup&gt; (7.5 L/s m&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>See “Enclosed parking garages,” Table 2.1</td>
</tr>
</tbody>
</table>

<sup>a</sup> In using this table, the outdoor air is assumed to be acceptable.

<sup>b</sup> Climatic conditions may affect choice of ventilation option chosen.

<sup>c</sup> The air exhausted from kitchens, baths, and toilet rooms may utilize air supplied through adjacent living areas to compensate for the air exhausted. The air supplied shall meet the requirements of exhaust systems as described in 5.8 and be of sufficient quantities to meet the requirements of this table.
Passive House Standard Requirements:

- Heating Demand < 15 [kWh/(m²a)] or Heating Load < 10 [W/m²]
- Cooling Demand < 15 [kWh/(m²a)] + Dehumidification Contribution or Cooling Load < 10 [W/m²]
- Renewable Primary Energy (PER) < 30/60 kWh/(m²a)
- Alternatively, the previous requirement for the non-renewable primary energy demand (PE) of QP ≤ 120 kWh/(m²a) is still available
Mandatory Requirements: A Complex Scenario

- Many Provinces have applied the National Energy Code for Buildings;
- For other is still “work in process”
- British Columbia: Step Code enforced by local AHJ, TEDI and TEUI
Heating and cooling loads are extremely low - (10 W/SQM) many “standard” mechanical systems may be just be too powerful (radiant floor 100 W/SQM Heating, 30 W/SQM Cooling) a tailored approach is suggested.

Traditionally, in PH projects thermal energy is conveyed to the indoor environment through the ventilation system but this is not strictly necessary, separate systems may be a better solution especially for large buildings.

Decentral systems can reduce the amount of materials.

Central systems can be implemented with a higher level of complexity and efficiency.
Application – Mechanical Systems Design

- PHPP has limits when dealing with more complex projects
- Other tools may be more appropriate (DesignPH, OpenStudio, IES) to support the building design process
Application – Mechanical Systems Design

- Balance between Passive House and Code requirements can be challenging:
  - School (Age 5/8): ASHRAE 62.1 requires 8 LPS/Person and a maximum differential CO2 content of 700 PPM
  - Successful Passive project suggest 4 LPS/Person (if system operated properly) maintaining 1500 PPM of CO2
  - Additional "issues" could arise because of other operational requirements i.e. range hoods