SPACE PLANNING

The space required to house HVAC equipment and associated pipe and duct shafts can amount to over 10 percent of the building floor area, depending upon the building application and type of HVAC system used. Heavy structural loads of central equipment will also affect the building's structural system design. Location of the mechanical equipment can influence building aesthetics and the acoustical environment in occupied areas. The spatial layout of the HVAC system needs to be programmed early in the design phase and coordinated with all other building elements.

The first step in planning the HVAC system layout is to identify the location and configuration of the central equipment. In large buildings using central systems, this often includes three types of equipment rooms:

- a central plant equipment space (usually one location in the building, housing central chillers, boilers, and related equipment),
- a rooftop location for cooling towers, and
- equipment room(s) for large central air-handling units.

Central plant equipment rooms are often located at the top of a building to:

- minimize the piping distance to connect the chillers to the rooftop cooling towers.
- minimize the length of expensive boiler flues that typically extend well above rooftop heights.
- may also be located on the lowest floor of the building.
- or the boilers and chillers may be located in two different locations.

The nomograph shown in Fig. 8 in conjunction with Table 7 provide a simple technique for approximating the sizes of the main air-conditioning system components, the space required to house them, and associated duct sizes.
Fig. 8. Space and duct sizing nomograph.

Table 7. Air-conditioning and air quantities for various building types

<table>
<thead>
<tr>
<th></th>
<th>Air Conditioning Load (SF/ton)</th>
<th>Air Quantities (CFM/SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Apartments, Hi Rise</td>
<td>500</td>
<td>425</td>
</tr>
<tr>
<td>Auditoriums, Churches, Theaters</td>
<td>400</td>
<td>300</td>
</tr>
</tbody>
</table>
### Educational Facilities

<table>
<thead>
<tr>
<th></th>
<th>400</th>
<th>300</th>
<th>200</th>
<th>0.8</th>
<th>1.2</th>
<th>1.8</th>
</tr>
</thead>
</table>

### Factories

- **Light Manufacturing**
  - 350
  - 250
  - 150
  - 1.2
  - 1.6
  - 2.0

- **Heaving Manufacturing**
  - 150
  - 100
  - 75
  - 2.5
  - 3.5
  - 4.5

### Hospitals

- **Patient Rooms**
  - 350
  - 250
  - 180
  - 0.5
  - 0.75
  - 0.9

- **Public Areas**
  - 300
  - 250
  - 150
  - 0.8
  - 1.0
  - 1.1

- **Hotels, Motels, Dormitories**
  - 500
  - 400
  - 300
  - 0.9
  - 1.2
  - 1.4

- **Libraries & Museums**
  - 400
  - 350
  - 300
  - 0.9
  - 1.0
  - 1.1

- **Office Buildings**
  - 500
  - 400
  - 300
  - 0.7
  - 0.9
  - 1.2

### Residential

- **Large, Single Family**
  - 800
  - 600
  - 400
  - 0.5
  - 0.7
  - 1.0

- **Medium, Single Family**
  - 800
  - 700
  - 600
  - 0.5
  - 0.7
  - 1.0

### Shopping Centers

- **Beauty & Barber Shops**
  - 300
  - 250
  - 200
  - 0.9
  - 1.3
  - 2.0

- **Department Stores**
  - 500
  - 400
  - 300
  - 0.9
  - 1.4
  - 2.0

- **Drug Stores**
  - 250
  - 200
  - 150
  - 0.7
  - 1.0
  - 1.3

- **Shoe Stores**
  - 400
  - 300
  - 200
  - 0.8
  - 1.0
  - 1.2

- **Malls**
  - 450
  - 350
  - 250
  - 1.1
  - 1.6
  - 2.0

---

**System sizing nomograph: an example**

The nomograph is used by entering with total building area on bar (A). To use an example:

- Consider a 300,000 sq ft office building. In Table 7, the data for an office building indicates a medium air-conditioning load of 400 sq ft per ton and medium air quantity of 0.9 CFM/sq ft.
  - Entering the nomograph with a building area of 300,000 sq ft and proceeding vertically up to (B), and the sloped line representing 400 sq ft/ton on bar (C), the air-conditioner size can be approximated as 750 tons.
  - Continuing horizontally to the right to the 45° turning line, we proceed vertically down to bar (D) and vertically up to bar (E). On bar (D) we read the mechanical equipment room volume as 45,000 cu ft.
  - On bar (E), the cooling tower area would be read as 900 sq ft.
  - Going back to bar (A) and proceeding vertically downward to (F) and turning to the 1 CFM/sq ft line, we read on bar (G) that the total air volume is 300,000 CFM.

- The above narrative on air-handling equipment indicates that the largest commercially available units (not custom) are about 40,000 CFM. We know that this office building will require several air handlers. For design estimating purposes, assume we are designing a 10-story office building with 30,000 sq ft per floor and that we will have one 30,000 CFM air handler on each floor.
  - Enter bar (A) with 30,000 sq ft.
  - Bar (G) shows 30,000 CFM.
Bar (H) shows 12,500 cu ft. If we have a clear height of 12 ft in the fan room, it would have a floor area of 1041 sq ft.

- Typical air-handling unit data (e.g., Sweet's catalog manufacturer's literature) indicate (let us assume) an approximate unit size of 14 × 11 × 7.6 ft. This should fit comfortably within a room of 25 × 40 ft and have space for all associated ductwork and servicing. Proceeding from 3 on bar (G) horizontally to the branch duct and supply duct turning lines:
  - We read on bar (I), a supply duct total area of 25 sq ft.
  - We read 33 sq ft of branch duct area.
  - We now know we have a supply air duct of approximately 36 × 100 in, leaving the fan room before it begins to branch to smaller sizes to serve various areas of the floor. Note that the sum of the branch duct area is larger than the total supply duct area. This is due to a lower air velocity being used in the branches.
  - Remember that return air ductwork with the same area as the branch ductwork will be required for return air back to the fan room to complete the system ducting.
  - Bear in mind that cooling towers can range in height from 12 to over 40 ft and should be located far away from building openings (such as windows and outside air intakes) to avoid the possibility of any carryover of moist, and possibly contaminated, air back into occupied areas.

Central equipment room planning
Central equipment rooms housing boilers, chillers, and large pumps should have between 12 to 16 ft clear height available, from the finished floor to underside of structure, to allow for adequate clearance above the main equipment for accessories and large piping crossovers. Long narrow rooms—with an aspect ratio (width to length) of approximately 1 to 2—usually allow for the most flexible and efficient layout of equipment. The equipment room sizes given in the nomograph above should provide adequate space for typical equipment accessories, clearances around equipment for servicing and replacement, and “tube-pull” clearances. Equipment such as chillers and shell-and-tube heat exchangers require clear space equal to the length of the equipment in order to pull the heat exchange tubes for servicing. Often a “back-to-back” arrangement of equipment minimizes the total floor area required to accommodate such needs.

Provide proper vibration isolation for large equipment, particularly rotating equipment, such as chillers and pumps. In addition to planning the location and configuration of equipment rooms, access to these rooms is an important consideration. Adequate equipment room doors and routes to freight elevators and/or the building exterior should be planned such that the largest piece of equipment can be easily installed (and possibly removed in future).

Air-handling equipment planning
The number and location of central air-handling unit equipment rooms (commonly called “fan rooms”) are critical to a successful HVAC system. As noted above, the nomograph in Fig. 8 indicates an estimate of the CFM requirements for the building. Since the largest central fans typically used in commercial applications are approximately 40,000 CFM in capacity, dividing the building CFM by 40,000 yields the minimum number of air handlers required to serve the building. (If self-contained equipment, such as rooftop units, is to be used, a maximum size of 10,000 CFM per air handler is best.)

Once the number of air-handling units is determined, the next decision is how (or whether) they are to be grouped together in separate rooms. The more “centered” or centrally located within the building, the more efficient and less costly will be the distribution systems. However, other planning considerations may dictate a more beneficial arrangement. The following discussion summarizes typical air-handling unit equipment room arrangement approaches:
“Scattered” or separated units

- often used in low-rise buildings employing rooftop equipment.
- air handlers are simply located as centrally as possible to the separate zones they serve (and are thus scattered throughout the building as a function of its separate zones).
- results in the most efficient fan sizing and minimal duct sizes.
- because air handlers will be located directly above occupied areas, noise and vibration isolation are critical factors.

“Central core” placement

- all air-handling unit rooms are located together near the building core often on multiple floors in high-rise buildings.
- tends to yield the most efficient equipment room layout and duct distribution layout if one air handler can serve an entire floor.
- horizontal or vertical ducting is required to admit and reject fresh outside air and to exhaust spent air.
- air-handling unit rooms placed in the central core can take advantage of other service elements such as elevator shafts and rest-rooms to buffer noise.
- no equipment room wall should be located immediately adjacent to an occupied space, and equipment rooms are best stacked vertically to minimize piping and airshaft space requirements.
- at least two and preferably three sides of the equipment room are free of vertical obstructions so that supply and return ductwork can pass through them to serve the occupied areas.
- because floor-to-ceiling height is limited to the typical building floor height, the supply/return mains tend to be dimensioned “flatter” than desired for optimal airflow efficiency and noise control.
- often results in excessive fan noise and high velocity duct noise from the mains.
- place exiting ducts to pass over low occupancy service spaces, such as closets and restrooms, and also to include a duct turn above these spaces to reduce duct-transmitted noise.

“Perimeter” rooms

- minimizes the ducting required for outside air and exhaust air.
- can reduce the efficiency of the supply/return duct system, unless multiple units are required for each floor.
- potential lost use of premium perimeter floor areas.
- potential negative aesthetic impact of large air intake/exhaust louvers on the exterior.
- proximity of potentially noisy equipment close to occupied areas of the building.

“Detached” rooms

- moves the equipment room outside the main building, such as an adjacent protruding service shaft.
- sometimes allows for maximum space utilization and flexibility within the main floor plate of the building it serves.
System summaries
The descriptions that follow in tabular form (Tables 8 to 16) summarize the operating characteristics and key design considerations for the HVAC systems described above.

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