Table 2 .... Comparison of Internal Loads

Sq Ft Floor/Person.....		20	40	60	80	100
Watts* /Sq Ft	Cfm per Sq Ft or Tons per 1000 Sq Ft					
3	15° T.D. cfm/sq ft	1.23	0.93	0.82	0.78	0.75
	Total Tons/1000 sq ft	4.17	3.0	2.72	2.58	2.34
6	20° T.D. cfm/sq ft	1.40	1.16	1.08	1.05	1.03
	Total Tons/1000 sq ft	5.0	3.83	3.55	3.41	3.17
9	22° T. D. cfm/sq ft	1.68	1.47	1.38	1.36	1.34
	Total Tons/1000 sq ft	5.73	4.60	4.32	4.18	3.94
12	25° T.D. cfm/sq ft	1.85	1.67	1.60	1.58	1.56
	Total Tons/1000 sq ft	6.67	5.50	5.22	5.08	4.85
15	25° T.D. cfm/sq ft	2.22	2.04	1.98	1.95	1.92
	Total Tons/1000 sq ft	7.5	6.33	6.05	5.90	5.66

* Liberated in conditioned space.

An important load, frequently overlooked in apartment buildings, is heat gain from piping for hot water services.

Occupancy will vary considerably. In accounting or other sections where clerical work is done, the maximum density is approximately one person per 50 sq ft of floor area. Where there are private offices, density may be as little as one person per 200 sq ft. The most serious cases, however, are the occasional waiting rooms, conference rooms, or directors' rooms where the occupancy may be as high as one person per 20 sq ft.

Ventilation Requirements

There has been much variation in the rate at which outdoor air has been introduced for *ventilation*, a term that may mean make-up for exhaust, smoke-removal, odor-control, pressurization (against inleakage), etc. Past designs were sometimes based on cfm per expected occupant (an acceptable basis for cafeterias and other short-time use), sometimes on a stated percentage of total air circulated, and frequently on cfm per square foot of floor (the usual present basis for office buildings). Standards have improved as air-conditioning uses grew; 10 years ago, 0.25 cfm per sq ft would have been as well-accepted as a present rate 50 percent higher. Now 0.35 to 0.45 cfm per sq ft may be considered as good present day practice. As it happens, this corresponds quite well with the quantities of *primary* air required, typically, for the operation of many modern *induction* air-conditioning units and corresponds also with the 65 cfm, plus or minus, required to pressurize a typical hotel room which has interior bathroom exhaust.

An important economy consideration for interior zones with *all-air* conditioning, and also for peripheral zones with double-duct systems, is to arrange for increasing the proportion of outdoor air, up to 100 percent of the total circulated, whenever this will afford sufficient cooling *without* the use of refrigeration. This is frequently the case in spring and fall.

An example will demonstrate the large effects, even on interior zone demands, caused by heavy concentrations either of population, or of lighting (or other electric) heat sources. The tabulation presented is based on the following reasonable assumptions:

1. Minimum desirable *total* air supply	0.75 cfm/sq ft
2. Sensible heat per person (average)	200 Btuh
3. Latent heat per person (average)	200 Btuh
4. Desirable *outdoor* air	0.4 cfm/sq ft
5. Outdoor air to be at least	10.0 cfm/person
6. Outdoor air conditioning	40 Btuh/cfm
7. Desirable temperature difference between *maintained* and *entering* air temperatures (for economical refrigeration) (75 F outdoor and 64 F indoor wet-bulb)	20 F deg, or less
8. Maximum permissible temperature difference	25 deg

Table 2 shows some interesting comparisons between internal loads, excluding solar loads.

COOLING LOAD DISTRIBUTION

The *proportions* of total cooling demand chargeable to different factors will be instructive. An evaluation may be based on any desired set of assumptions. The following are for an office building:

Floor area	100 sq ft/person
Electric heat	6 watts/sq ft
Outdoor air	0.4 cfm/sq ft
Outdoor air conditioning	40 Btuh/cfm
Glass in facades (with good inside Venetian blinds, or equivalent)	25, 50, and 75%

On these assumptions, people and lights will give out per square foot of floor about 22.5 Btuh of sensible heat, and 2.5 Btuh of latent heat. Conditioning of outdoor air brought in for *ventilation* and *pressurizing* will absorb about 16 Btuh of total heat per square foot floor. For the peripheral zone directly exposed to sunshine (assumed to extend 14 ft *inward*) the heat through glass will approximate 20, 40, or 60 Btuh per sq ft of floor, for the three glass-percentages stated, respectively.

With average walls, wall conduction will approximate 3, 2, or 1 percent of the total in the 3 cases. Miscellaneous allowances (for fan-heat, duct heat pick-up, and safety factors) will approximate not over 12 percent of the total.

For a sunlit facade (with blinds drawn), the load analysis is given in Table 3 for conditions of 25, 50, and 75 percent glass in facade.

Table 3 deals only with peak cooling *demand*. As window solar heat loads grow larger, the type of air-handling scheme that will be most economical may also change.

Table 3 .... Proportional Distribution of Cooling Load in Relation to Percentage of Glass in Sunlit Facade[a,b]

Glass in Facade	%	25	50	75
People, Lights & Office Equipment	%	36	27	22
Window Heat Input (max.)	%	26	43	53
Conditioning Outdoor Air	%	23	17	14
Conduction through Walls	%	3	2	1
Miscellaneous	%	12	11	10
Total	%	100	100	100

[a] With drawn Venetian blinds.
[b] For peak cooling demand.

INSTALLATION COSTS

The installation costs of air-conditioning buildings of the multiroom type fall under three main heads:

1. *Central Refrigerating Plant.* A reasonable present-day cost figure would be $450 to $500 per ton of refrigeration.
2. *Floor Work or Distributing Systems.* This includes fans and drives, cooling and heating coils and connections, under-window units (where used), ducts, filters, outlets, automatic controls, exhaust ventilation, pipe connections (also thermal and acoustic insulation).
3. *Other Trades Work.* Electric power supply and wiring, drainage and fresh-water connections, sill-enclosures, and the like.

Basis for Cost Analysis

For a multistory office building, under typical metropolitan conditions, an attempt to analyze the cost of installation has been based on the following *four schemes*, as affected by *relative* proportion of sensible heat load from windows:

I. A *double-duct* all-air system, with controlled mixing boxes under windows for peripheral zones, plus a single-duct system with zone reheat for inside zones.
II. Metal *radiant* and acoustic *ceilings* for cooling and heating peripheral zones, plus a single-duct system for all parts of the floor, zoned by floors, and by peripheral and interior zones.
III. *Fan-coil units* under windows for peripheral zones, plus a single-duct system with zone reheat for interior zones.
IV. *Induction units* under windows for peripheral zones, plus the same single-duct system for interior zones.

In all but the Scheme I, piping is separately zoned for each major facade, and an average of one thermostat to each two units.

Estimated costs are shown in Tables 4, 5, and 6 for a tall building, about 300 × 80 ft in plan with principal exposures north and south. Peripheral zone areas would amount to about 10,000 and the interior zone areas to about 8000 net sq ft per floor (for the four systems Schemes I, II, III, and IV considered).

Table 4 .... Estimated Cost for Air Conditioning Systems
Schemes I, II, III and IV—25% Glass

Scheme		I	II	III	IV
Per Floor					
Peripheral AC	Tons	43	40	40	40
Interior AC	Tons	26	26	26	26
Ducted (S&R)	Cfm	60,000	32,000	26,000	27,000
Central Plant Cost	$	31,000	30,000	30,000	30,000
Peripheral AC System Cost	$	43,000	43,000	40,000	43,500
Interior AC System Cost	$	12,000	12,000	12,000	12,000
Electric, Plumbing, & Miscel.	$	13,000	9,000	16,500	10,000
Overall Cost	$	99,000	94,000	98,500	95,500
Cost per Sq Ft	$	5.50	5.22	5.48	5.30

Note A—Double-Duct CFM includes 100% *cold-deck* and 60% *hot-deck* duct capacities.
Note B—All *ducted CFM* figures include appropriate return air systems.
Note C—Radiant Ceiling costs have been credited with value of standard acoustic ceiling, that might be added to other schemes.
Note D—Scheme III (under "Misc.") includes drainage and electric connections for units.
Note E—Unit enclosures are included under Miscellaneous in Schemes I, III and IV.
Note F—With moderate-sized windows, it is usually economical to run primary air and secondary water piping vertically at outside walls, close to units, etc. With very large windows this is usually impossible—and, consequently the extra cost of horizontal cross-overs in ceilings (in such cases) becomes an added cost factor.
Note G—It must be understood that these values will vary with different proportion and orientations of buildings, as well as with locality, type, and quality; they should be considered comparative, only.

Table 5 .... Estimated Cost for Air Conditioning Systems
Schemes I, II, III and IV—50% Glass

Scheme		I	II	III	IV
Per Floor					
Peripheral AC	Tons	57	52	52	52
Interior AC	Tons	26	26	26	26
Ducted (S&R)	Cfm	75,000	45,000	26,000	29,000
Central Plant Cost	$	36,000	34,000	34,000	34,000
Peripheral AC System Cost	$	51,000	51,000	42,000	45,500
Interior AC System Cost	$	12,000	12,000	12,000	12,000
Electric, Plumbing, & Miscel.	$	15,000	10,000	17,500	11,000
Overall Cost	$	114,000	107,000	105,500	102,500
Cost per Sq Ft	$	6.35	5.95	5.86	5.70

See footnotes under Table 4.

Owning and Operating Cost

The estimated costs presented refer to initial costs only, but annual owning or operating costs will vary in a somewhat parallel manner:

1. Operating labor will be a fairly definite quantity for a given building.
2. Fixed charges will of course bear a definite ratio to investment.
3. For a given location and climate, operating costs for refrigeration (itself) will be in proportion to hours of use and tonnage—not maximum *installed* tons, but *average* tons in use.
4. Operating costs for cooling towers, filters, pumps, etc., will be about in proportion to capacity of plant and hours of use.
5. Operating costs for fans will be in proportion to cfm, fan static pressures, and hours of use; a double-duct system, for example, with its relatively high pressures and much greater cfm of ducted air will use considerably more power than an induction system. Radiant ceiling systems, generally, will be lowest in electric consumption.

The foregoing analysis was worked out primarily for office

Table 6 .... Estimated Cost for Air Conditioning Systems
Schemes I, II, III and IV—75% Glass

Scheme		I	II	III	IV
Per Floor					
Peripheral AC	Tons	74	68	68	68
Interior AC	Tons	26	26	26	26
Ducted (S&R)	Cfm	91,000	53,000	26,000	31,000
Central Plant Cost	$	44,000	41,000	41,000	41,000
Peripheral AC System Cost	$	59,000	55,000	59,000	50,000
Interior AC System Cost	$	12,000	12,000	12,000	12,000
Electric, Plumbing, & Miscel.	$	17,000	12,000	18,000	12,000
Overall Cost	$	132,000	120,000	120,000	115,000
Cost per Sq Ft	$	7.35	6.68	6.68	6.38

See footnotes under Table 4.