Acoustical Analysis

1. Source, Path and Receiver – a Systems Approach

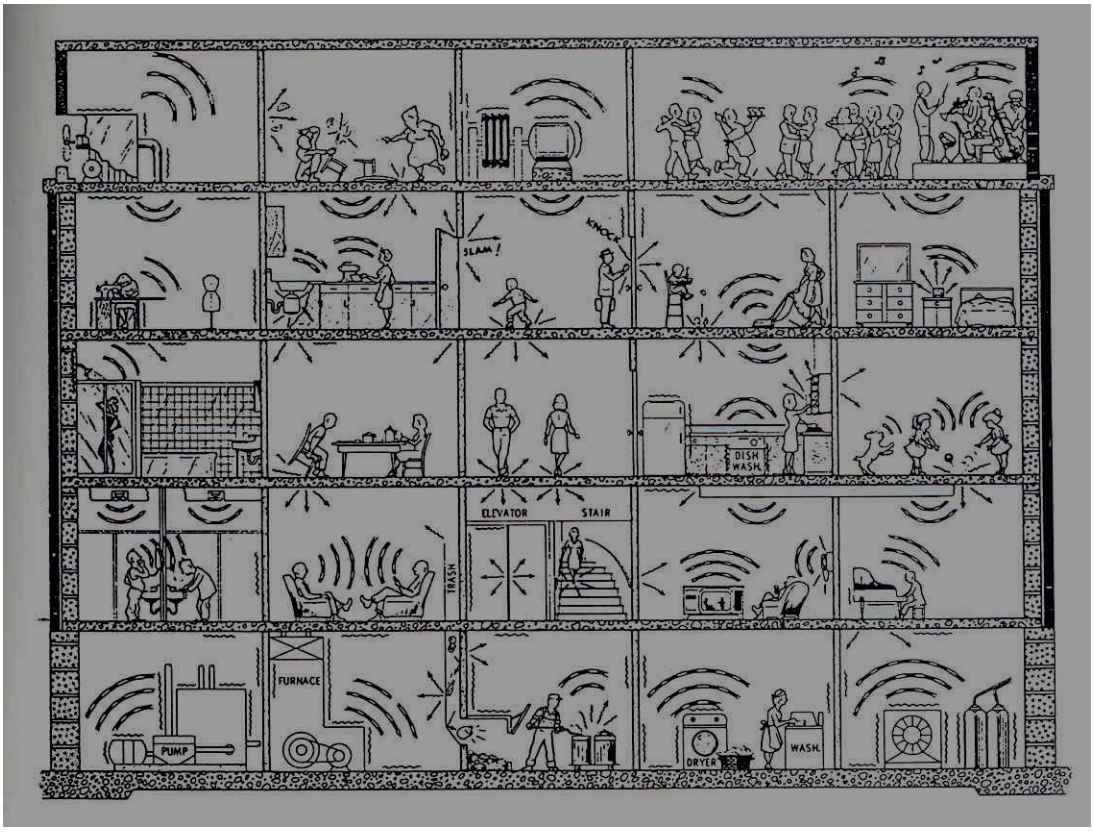
Sources of Noise:

A) Occupant activity

- Footfall
- Door slams
- Voices
- Music
- Appliances (telephones, doorbells, dishwashers, washer/dryer, vacuums, etc.)

B) Operation of building services

- Heating systems
- Air conditioning systems
- Plumbing
- Elevators/escalators



C) External (outside)

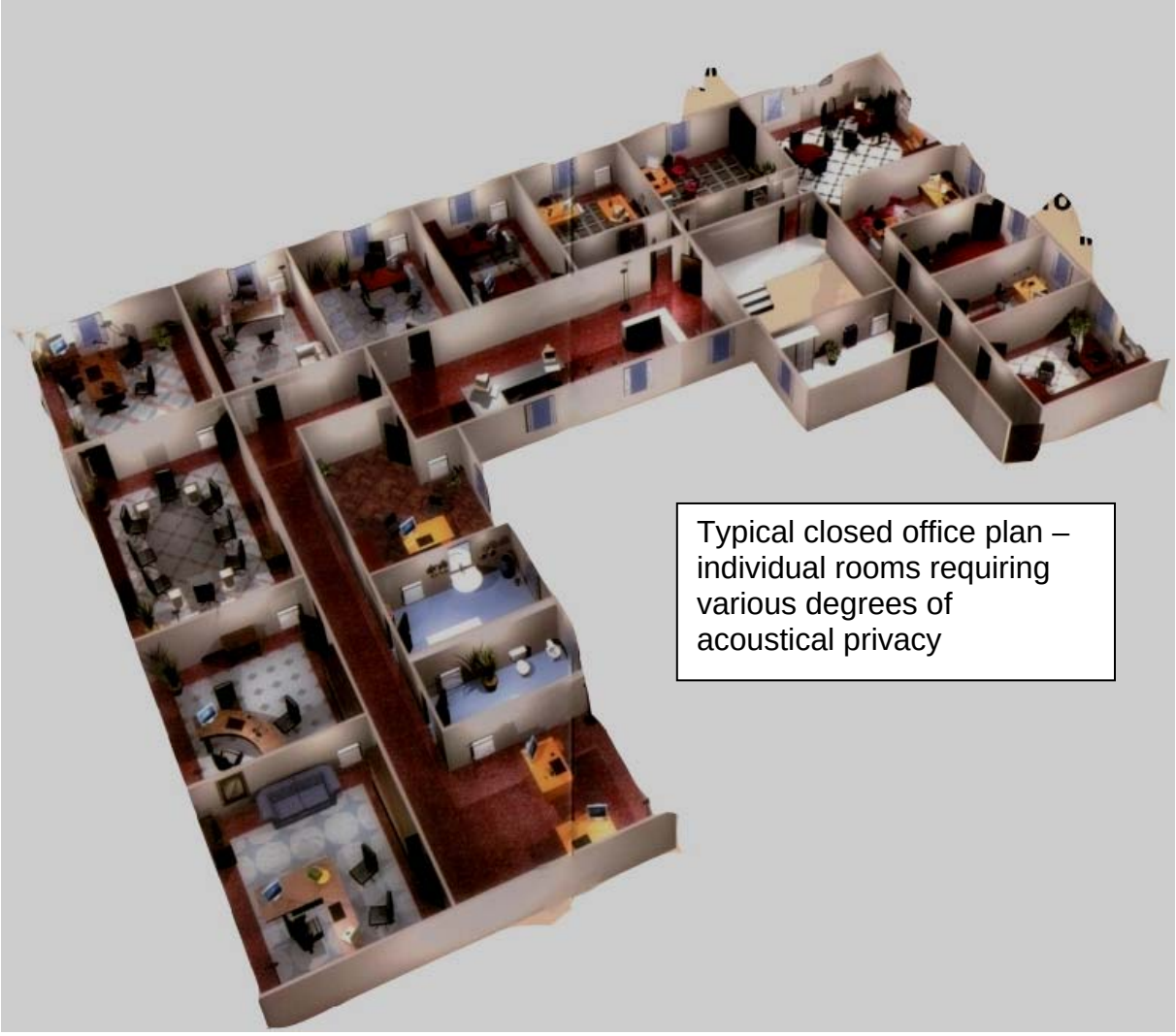
- Traffic (i.e., cars, trucks, buses, motorcycles)
- Pedestrians
- Construction activity
- Airport
- Dog barking

2. Paths of Sound Transmission

Or combined
- Airborne path
- Structureborne path – vibrations transmitted to structure, propagates to large areas making it difficult to discover source

3. Acoustical Privacy Applications

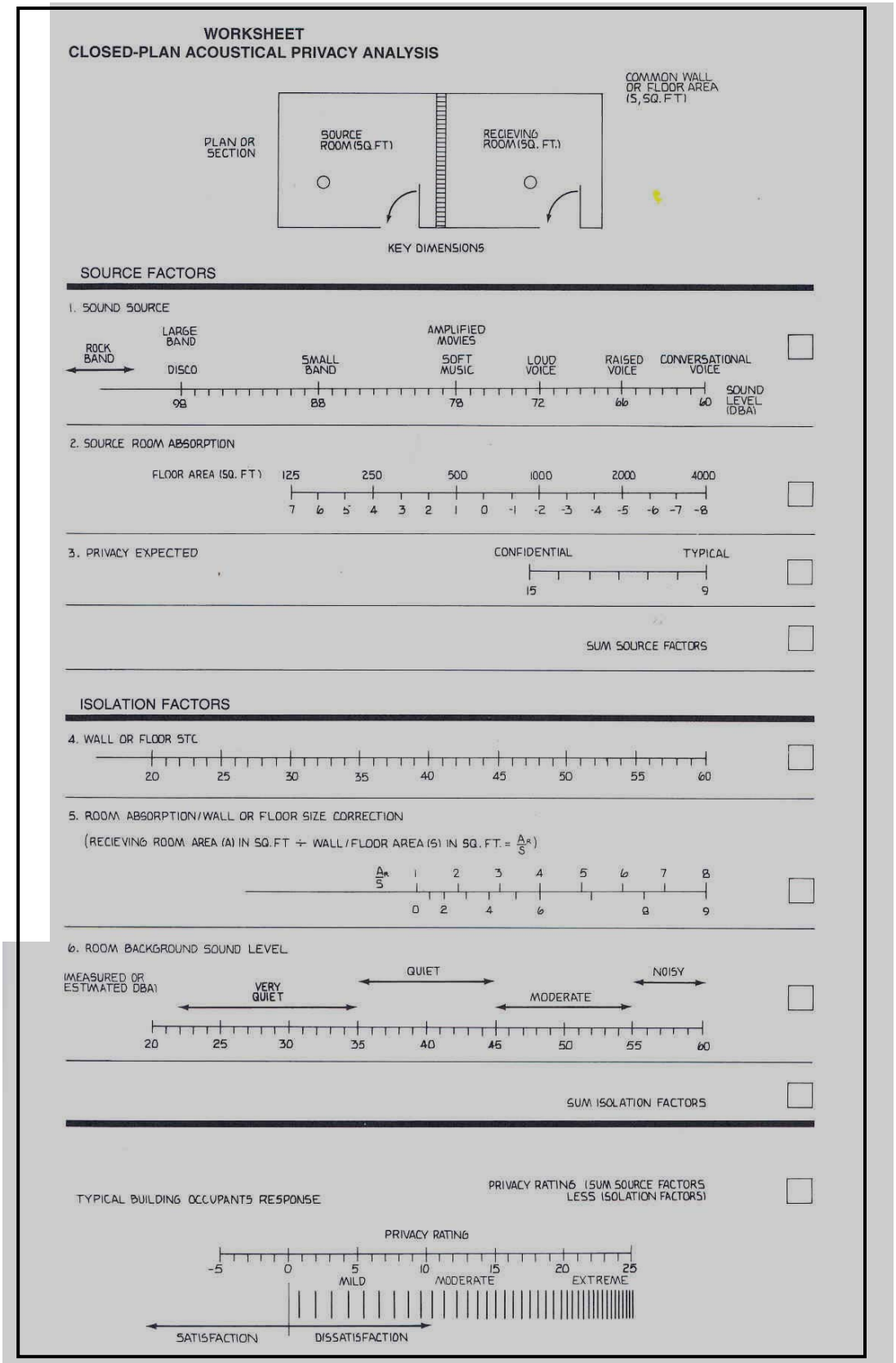
a. Closed Plan Spaces



Typical closed office plan – individual rooms requiring various degrees of acoustical privacy

- **Speech Privacy** – Speech privacy is the opposite of speech intelligibility. Six Factors affecting speech privacy:
    - Background sound level in listener's space (receiving room)
    - Strength of sound source (vocal effort)
    - Amount of sound absorption in receiving room
    - Relative sizes of source and receiving rooms
    - Sound Transmission Class (STC) of mutual walls
    - Required speech privacy (i.e., very private, semi-private, etc.)

Below is a **closed plan worksheet** that can be used to quantify each of the 6 factors noted above. A final single number is calculated, and is thus compared to the "Satisfaction/Dissatisfaction" nomograph at the bottom.



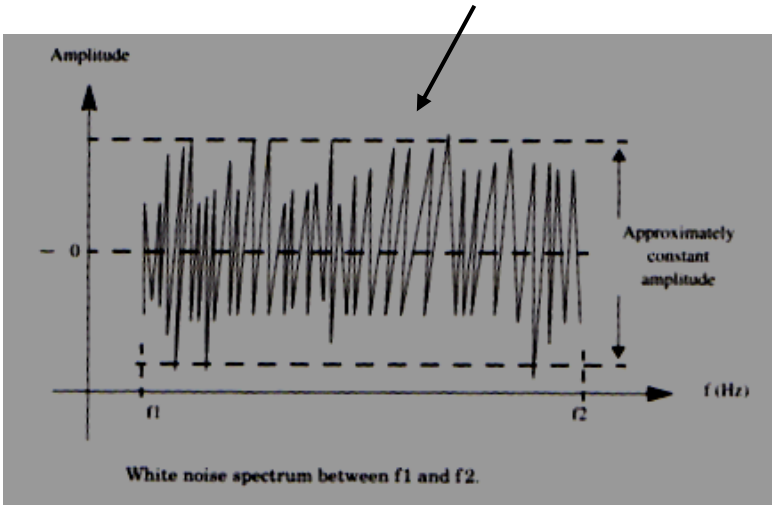
b. Open Plan Spaces

Most new office construction is designed to be "**open plan**" for reasons such as:

- flexibility of space
- team working environment
- ease of movement
- higher density
- cost savings

It appears obvious that an open plan office layout does not provide the same speech privacy as the closed plan layout. However, acceptable speech privacy can be achieved if:

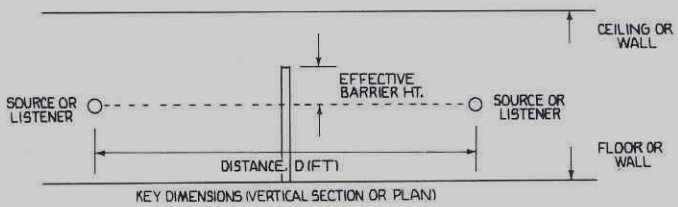
- maximize attenuation of all wall, floor & ceiling surfaces (to reduce reflecting noise)
- provide acoustical partitions that block seated line-of-sight between spaces
- provide masking of sound using continuous background noise (called "**white noise**")



White noise spectrum between f1 and f2.

Below is an **<u>open plan worksheet</u>** that can be used to quantify open-plan acoustical privacy. A final single number is calculated, and is thus compared to the "Satisfaction/Dissatisfaction" nomograph at the bottom.

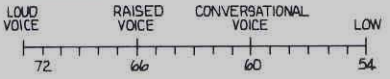
WORKSHEET
OPEN-PLAN ACOUSTICAL PRIVACY ANALYSIS



KEY DIMENSIONS (VERTICAL SECTION OR PLAN)

SOURCE FACTORS

1. SPEECH SOURCE



2. PRIVACY EXPECTED

SUM SOURCE FACTORS ☐

ISOLATION FACTORS

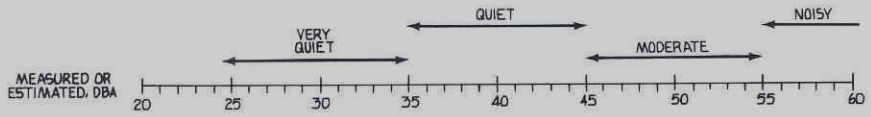
3. SOURCE/LISTENER DISTANCE INDEX

ROOM FINISHES		DISTANCE (FT)				
CEILING (OR WALL)	FLOOR (OR WALL)	3	6	12	24	48
REFLECTING	REFLECTING	0	3	6	9	12
REFLECTING	ABSORBING	0	4	8	12	15
ABSORBING	REFLECTING	0	5	10	15	20
ABSORBING	ABSORBING	0	6	12	18	24

4. BARRIER INDEX

EFFECTIVE BARRIER HEIGHT (FT)	DISTANCE (FT) 3	6	12	24	48
1	11	7	4	2	0
2	14	10	7	4	3
3	15	11	8	5	4
4	18	12	9	6	5
NO BARRIER	0	0	0	0	0

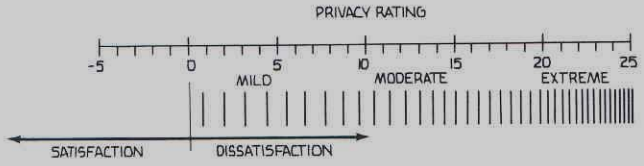
5. ROOM BACKGROUND SOUND LEVEL



SUM ISOLATION FACTORS ☐

PRIVACY RATING (SUM SOURCE FACTORS MINUS SUM ISOLATION FACTORS) ☐

TYPICAL BUILDING OCCUPANTS RESPONSE



Building Noise Criteria

1. Standards and Organizations

a) American Society for Testing and Materials (ASTM) – Developed approx. 50 standards establishing methods for analyzing, measuring and quantifying acoustical properties and systems. Example, ASTM E90 is used to measure sound transmission loss of materials. ASTM E413 is used to classify STC.

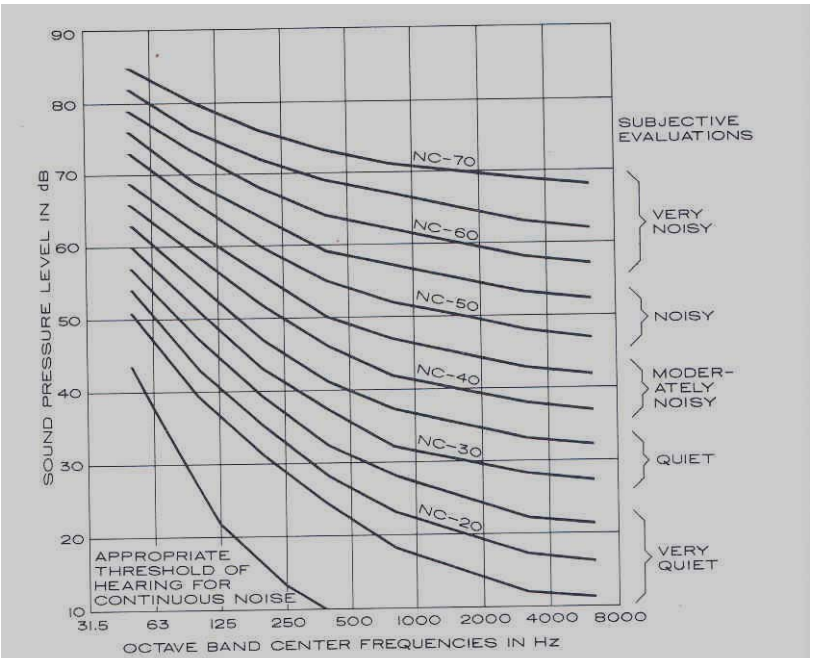
b) American National Standards Institute (ANSI) – More scientific than ASTM, for example, ANSI S12.2 establishes methods and criteria for evaluating sound in rooms.

c) American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) – An organization that develops acceptable design criteria and standards for building HVAC performance. It has a long history of defining recommended sound levels for mechanical systems for buildings and developing Noise Criteria Curves.

2. Noise Criteria Curves

Noise Criteria (NC) curves were developed on the basis of equal loudness contours throughout the range of frequency octaves. These cures are the most widely used means for specifying criteria and evaluating background sound in buildings.

Below is a graph of NC curves:



NOISE CRITERIA SOUND PRESSURE LEVEL TABLE*

NC CURVE	SOUND PRESSURE LEVEL, dB							
	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
NC-70	83	79	75	72	71	70	69	68
NC-65	80	75	71	68	66	64	63	62
NC-60	77	71	67	63	61	59	58	57
NC-55	74	67	62	58	56	54	53	52
NC-50	71	64	58	54	51	49	48	47
NC-45	67	60	54	49	46	44	43	42
NC-40	64	57	50	45	41	39	38	37
NC-35	60	52	45	40	36	34	33	32
NC-30	57	48	41	36	31	29	28	27
NC-25	54	44	37	31	27	24	22	21
NC-20	50	41	33	26	22	19	17	16
NC-15	47	36	29	22	17	14	12	11

*For convenience in using noise criteria data, the table lists the sound pressure levels (SFLs) in decibels for the NC curves from the above chart.

Recommended Background Noise Design Criteria (NC):	
Type of Space:	**Maximum Background Noise Criteria:**
Broadcast studios, concert halls	NC 15 – 25
Theatres, churches (no amplification)	NC 20 – 30
Large conference rooms, small auditoriums, orchestra rehearsal rooms, movie theatres, courtrooms	NC 25 – 30
Bedrooms (residences, apartments, hotels, hospitals)	NC 25 – 35
Small conference rooms, classrooms	NC 30 – 35
Small private offices, libraries	NC 30 – 35
Hospitals, clinics	NC 30 – 45
Restaurants, stores, general offices	NC 35 – 40
Sports arenas (with amplification)	NC 40
Computer rooms	NC 40 – 50

3. Building Codes

a. International Building Code (IBC) – Section 1207 “Sound Transmission”

1207.1 Scope. This section shall apply to common interior walls, partitions and floor/ceiling assemblies between adjacent dwelling units or between dwelling units and adjacent public areas such as halls, corridors, stairs or service areas.

1207.2 Air-borne sound. Walls, partitions and floor/ceiling assemblies separating dwelling units from each other or from public or service areas shall have a sound transmission class (STC) of not less than 50 (45 if field tested) for air-borne noise when tested in accordance with ASTM E 90. Penetrations or openings in construction assemblies for piping; electrical devices; recessed cabinets; bathtubs; soffits; or heating, ventilating or exhaust ducts shall be sealed, lined, insulated or otherwise treated to maintain the required ratings. This requirement shall not apply to dwelling unit entrance doors; however, such doors shall be tight fitting to the frame and sill.

1207.3 Structure-borne sound. Floor/ceiling assemblies between dwelling units or between a dwelling unit and a public or service area within the structure shall have an impact insulation class (IIC) rating of not less than 50 (45 if field tested) when tested in accordance with ASTM E 492.

b. International Residential Code (IRC) – Appendix K "Sound Transmission"

SECTION AK101
GENERAL

AK101.1 General. Wall and floor-ceiling assemblies separating dwelling units including those separating adjacent townhouse units shall provide airborne sound insulation for walls, and both airborne and impact sound insulation for floor-ceiling assemblies.

SECTION AK102
AIRBORNE SOUND

AK102.1 General. Airborne sound insulation for wall and floor-ceiling assemblies shall meet a Sound Transmission Class (STC) rating of 45 when tested in accordance with ASTM E 90. Penetrations or openings in construction assemblies for piping; electrical devices; recessed cabinets; bathtubs; soffits; or heating, ventilating or exhaust ducts shall be sealed, lined, insulated or otherwise treated to maintain the required ratings. Dwelling unit entrance doors, which share a common space, shall be tight fitting to the frame and sill.

SECTION AK103
STRUCTURAL-BORNE SOUND

AK103.1 General. Floor/ceiling assemblies between dwelling units or between a dwelling unit and a public or service area within a structure shall have an Impact Insulation Class (IIC) rating of not less than 45 when tested in accordance with ASTM E 492.

SECTION AK104
REFERENCED STANDARDS

ASTM E90-99 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements AK102

ASTM E 492-90 (1996)e Specification for Laboratory Measurement of Impact Sound Transmission through Floor-ceiling Assemblies Using the Tapping Machine AK103