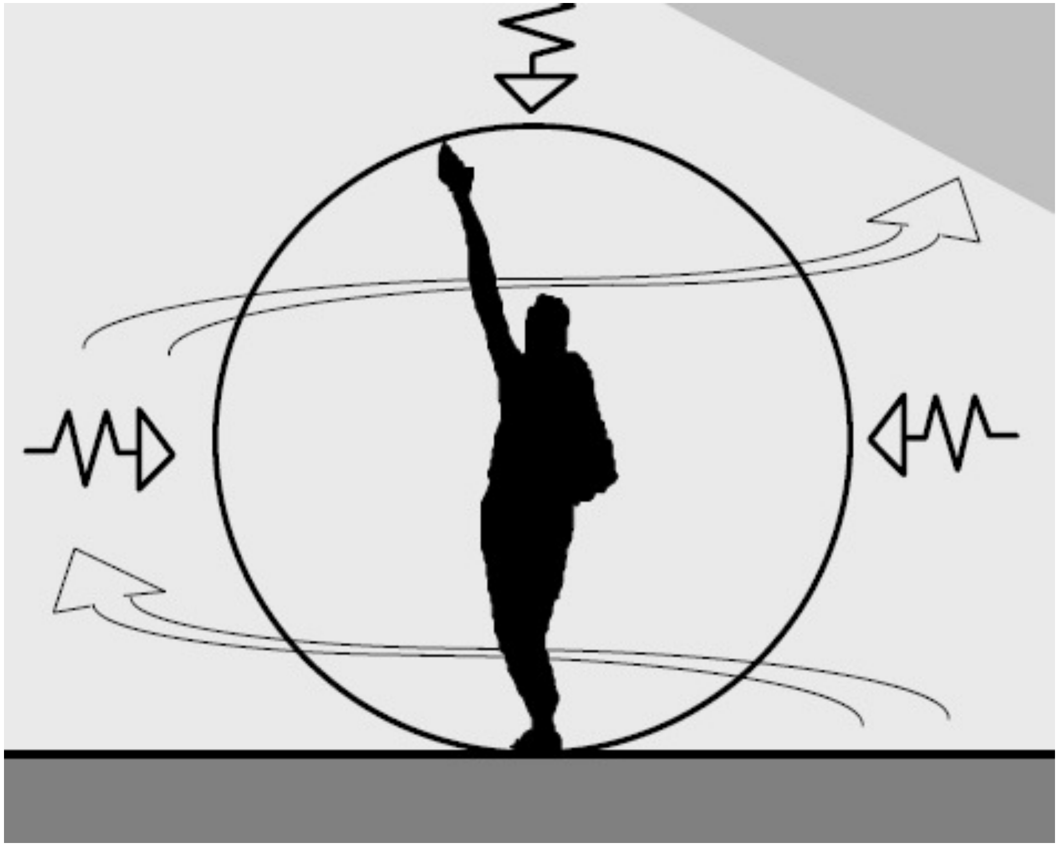
Thermal Comfort

Define

BS EN ISO 7730

'…that condition of mind which expresses satisfaction with the thermal environment.',

ie the condition when someone is not feeling either too hot or too cold.



The Health and Safety Executive suggest that an environment can be said to achieve 'reasonable comfort' when at least 80% of its occupants are thermally comfortable.

This means that thermal comfort can be assessed simply by surveying occupants to find out whether they are dissatisfied with their thermal environment.

Factors influencing thermal

Environmental factors:

Air temperature
Air temperature
Radiant temperature
Relative humidity (RH)

Personal factors:

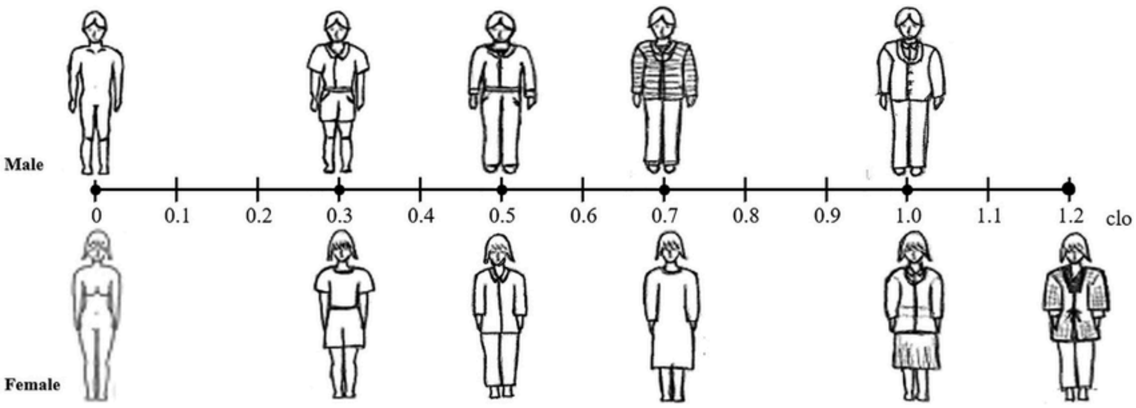
Relative humidity (RH)
Clothing
Metabolic heat
Well being generally and sickness

CBE Thermal Comfort Tool

https://comfort.cbe.berkeley.edu/

Environmental Factors

- *Air temperature.*
    - *The temperature of the air that a person is in contact with, measured by the dry bulb temperature (DBT).*
- *Air velocity.*
    - *The velocity of the air that a person is in contact with (measured in m/s). The faster the air is moving, the greater the exchange of heat between the person and the air (for example, draughts generally make us feel colder).*
- *Radiant temperature.*
    - *The temperature of a persons surroundings (including surfaces, heat generating equipment, the sun and the sky). This is generally expressed as mean radiant temperature (MRT, a weighted average of the temperature of the surfaces surrounding a person, which can be approximated by globe thermometer) and any strong mono-directional radiation such as radiation from the sun.*
- *Relative humidity (RH).*
    - *The ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature, expressed as a percentage. The higher the relative humidity, the more difficult it is to lose heat through the evaporation of sweat.*



Personal Factors

- *Clothing.*
    - *Clothes insulate a person from exchanging heat with the surrounding air and surfaces as well as affecting the loss of heat through the evaporation of sweat. Clothing can be directly controlled by a person (ie they can take off or put on a jacket) whereas environmental factors may be beyond their control.*
- *Metabolic heat.*
    - *The heat we produce through physical activity. A stationary person will tend to feel cooler than a person that is exercising.*
- *Well being generally and sickness,*
    - *such as the common cold or flu which affect our ability to maintain body temperature, 37C at the core.*

Other

- *Sound and noise levels, eg home should be under 45 decibels (dB) offices under 60dB.*
- *Light or illumination levels which have a direct effect on how well we can see, make out colours and reduce glare.*

Controlling

- Environmental monitoring and control (automated or user-controlled systems, active systems such as heating and cooling and passive systems such as shading). NB User-controlled systems require that users are properly trained.
- Adapting or changing clothing. Businesses can allow people to wear different clothing depending on conditions. They can also provide things like cloak rooms or lockers so that people can change clothes or take off and put down coats. The golden rule is layering, generally 3 layers, and use zips and buttons to regulate temperature.
- Allowing flexible working hours, or changing start and finish times.
- Adjusting tasks. For example, allowing breaks or reducing the length of time people are exposed to particular conditions.

Controlling

- Providing information telling people what sort of conditions to expect so that they can dress and behave appropriately.
- Providing or allowing personal equipment such as desk fans.
- Separating people from sources of discomfort. For example putting heat generating equipment such as ICT equipment in separate rooms, insulating pipes, preventing draughts and so on. NB draughts can be caused by high local surface temperature differences even in a space where there is no air infiltration – for example a cold down-draught near a window.
- Providing protective clothing (PPE Personal Protective Equipment). This should be a last resort option.

Predicting

- There are a great number of techniques for estimating likely thermal comfort, including; effective temperature, equivalent temperature, Wet Bulb Globe Temperature (WBGT), resultant temperature and so on, and charts exist showing predicted comfort zones within ranges of conditions. However, BS EN ISO 7730 and BS EN ISO 10551 suggest thermal comfort can be expressed in terms of Predicted Mean Vote (PMV) and Percentage People Dissatisfied (PPD).

Predicting

- PMV and PPD were developed by Professor Ole Fanger based on research undertaken at Kansas State University and the Technical University of Denmark. Research was carried out to find out if people felt comfortable in different conditions and this was used to develop equations that would predict comfort. The equations take into account; air temperature, mean radiant temperature, air movement, humidity, clothing and activity level.

Predicting

- PMV is an index that predicts the mean vote of a group of people voting on how comfortable they are in an environment. PPD is a function of PMV.
- Where non-uniform conditions exist, multiple assessments may be necessary, and in complex environments, Computational Fluid Dynamics (CFD) analysis may be necessary to accurately assess thermal comfort.

Regulation

- Temperatures in the workplace are governed by the Workplace (Health, Safety and Welfare) Regulations 1992, which oblige employers to provide a reasonable temperature in the workplace.
- The Approved Code of Practice (Workplace health, safety and welfare. Workplace (Health, Safety and Welfare) Regulations 1992. Approved Code of Practice) suggests a minimum temperature of 16 degrees Celsius, or 13 degrees Celsius if work involves severe physical effort. However, these are only guidelines.

Regulation

- The Health and Safety Executive (HSE) previously defined thermal comfort in the workplace, as: '…roughly between 13°C (56°F) and 30°C (86°F), with acceptable temperatures for more strenuous work activities concentrated towards the bottom end of the range, and more sedentary activities towards the higher end.' However, the complexity of thermal comfort means that there is really no meaningful maximum guideline temperature, particularly at higher temperatures.
- The Workplace Regulations, the Management of Health and Safety at Work Regulations 1999 require that employers assess the risks to the health and safety of their workers, and take action where necessary and reasonably practicable.

- Comfort in low energy buildings.
- Computational fluid dynamics.
- Dry-bulb temperature.
- Energy targets.
- Globe temperature.
- Heat stress.
- Heating degree days.
- Mean radiant temperature.
- Operative temperature.
- Predicted mean vote.
- Post occupancy evaluation.
- Psychometric charts.
- Sling psychrometer.
- Temperature.
- Thermal indices.
- Wet-bulb temperature.
- Wet-bulb globe temperature.

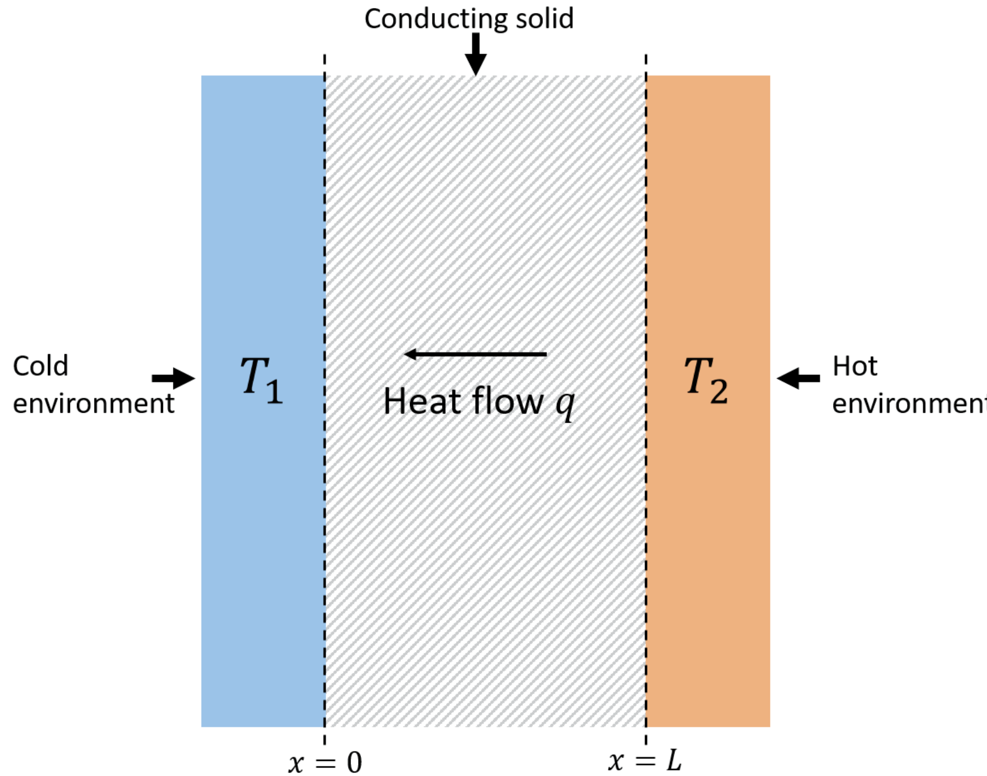
http://www.designingbuildings.co.uk/wiki/Thermal_comfort_in_buildings

보충

열전도율

열전도율?

The **thermal conductivity** of a material is a measure of its ability to conduct heat.



The defining equation for thermal conductivity is , where is the heat flux, is the thermal conductivity, and is the temperature gradient.

- 두께가 1미터인 재료의 열전달 특성
- 단위는 W/mK 혹은 kcal/mh°C
  - 여기서 K=°C
  - W/mK = W/m°C
  - **열전도율÷두께 = 열관류율**

열관류율

Thermal transmittance is the rate of transfer of heat through matter. The thermal transmittance of a material (such as insulation or concrete) or an assembly (such as a wall or window) is expressed as a U-value.

- 특정 두께를 가진 재료의 열전도 특성
- $U = W/m^2K$

Although the concept of U-value (or U-factor) is universal, U-values can be expressed in different units. In most countries, U-value is expressed in SI units, as watts per square metre times Kelvin:

$W/(m^2)(K)$

- 특정 두께를 가진 재료의 열전도 특성
- U = W/㎡K

열저항®

열관류율 역수

물 질	열전도율	비 고
은	0.99	열전도율 최고
구 리	0.92	열배관
알루미늄	0.49	
놋 쇠	0.26	
철	0.17	
콘크리트	0.002	
유 리	0.002	
얼 음	0.005	
석 면	0.0002	단열재
목 재	0.0002	
물	0.0014	
알 코 올	0.0005	
공 기	0.000057	

재료별 열전도율

종류	열전도율(W/mk 20°C)	비고
콘크리트	1.400	밀도 : 2,250(kg/m³)
시멘트벽돌	0.380	밀도 : 1,800(kg/m³)
무근콘크리트	1.630	
기포콘크리트	0.160	
화강석	3.300	
흙벽(황토벽돌)	0.204	
흙(자연상태)	0.580	일반 흙집
ALC블럭	0.092	밀도 : 540(kg/m³)
스티로폼	0.037	
유리섬유	0.044	목조주택 단열재 : 8(kg/m³)
정지공기	0.022	
왕겨숯	0.030	
목재	0.140	
석고보드	0.220	
폴리우레탄폼	0.018	밀도 : 35(kg/m³)
삼나무	0.099	
코르크판	0.040	
물	0.500	

건축전열

전도

열전도율

- **열전도율**(*k*, *λ*, *κ*로 나타냄)은 열전달을 나타내는 물질의 고유한 성질이다.
- 열전도율의 SI 단위는 W/(m·K)
  - 1기압, 293K(=20°C) 조건에서,
    - 공기의 열전도율은 0.025 W/(m·K)
    - 물의 열전도율은 대략 0.5918 W/(m·K)
    - 알코올과 기름은 0.100 W/(m·K)이다.
    - 구리의 열전도율은 약 401 W/(m·K)이다.
- 높은 열전도율을 가지는 물질은 열을 흡수하는데 쓰이고,
- 낮은 열전도율을 가지는 물질은 절연(絕緣)에 쓰인다.
- 물질의 열 전도율은 온도에 의존하며, 같은 물질이라도 온도에 따라 열전도율이 다르다.
- 열 전도율의 역수는 열저항이라고 한다.

열류

열전도율 기본 공식

Q(λ =W/m*K)=k*A(ΔT/L)

Q=열류량(W)

A=시료의 면적(m^2)

L=시료두께(m)

ΔT=온도차(K,° C와 동일)

열류(W/㎡)

Q = λ (t1-t2) / l *A

전도 대류 복사

- Conduction
- Convection
- Radiation

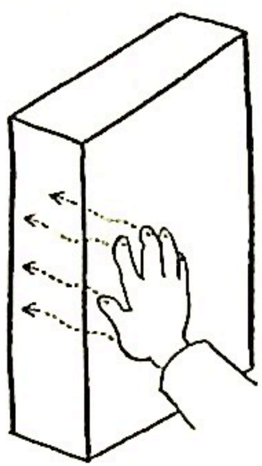


그림 4.12 전도

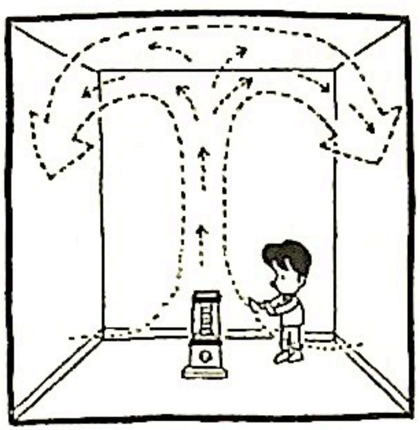


그림 4.13 대류

그림 4.14 복사

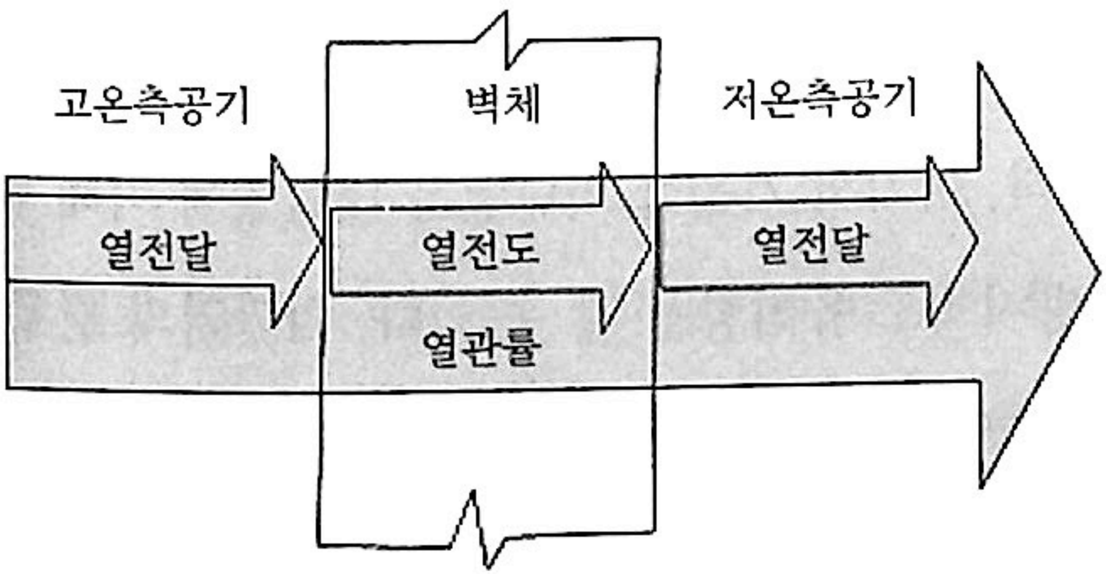


그림 4.15 전열과정

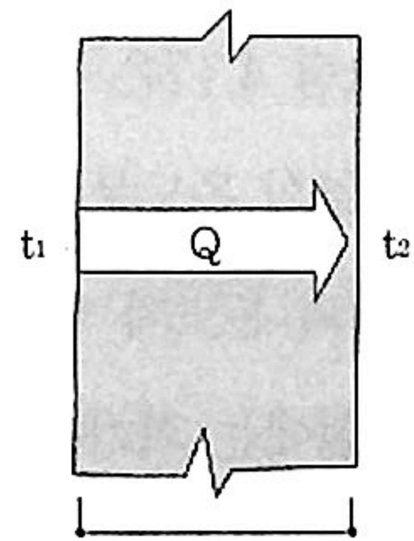


그림 4.16 단층벽열전도

열용량

- 비열
  - 어떤 물질 1kg의 온도를 1K(1°C) 상승시키는데 필요한 열량
  - 물체의 질량과 관계가 있음
- 열용량
  - 질량m(Kg), 비열의c(KJ/Kg·K) 물체 온도를 1K 높이는데 필요한 열량 m·c(Kg/K)
  - 열용량이 큰 물체는 온도를 높이는데 많은 열량을 필요
  -

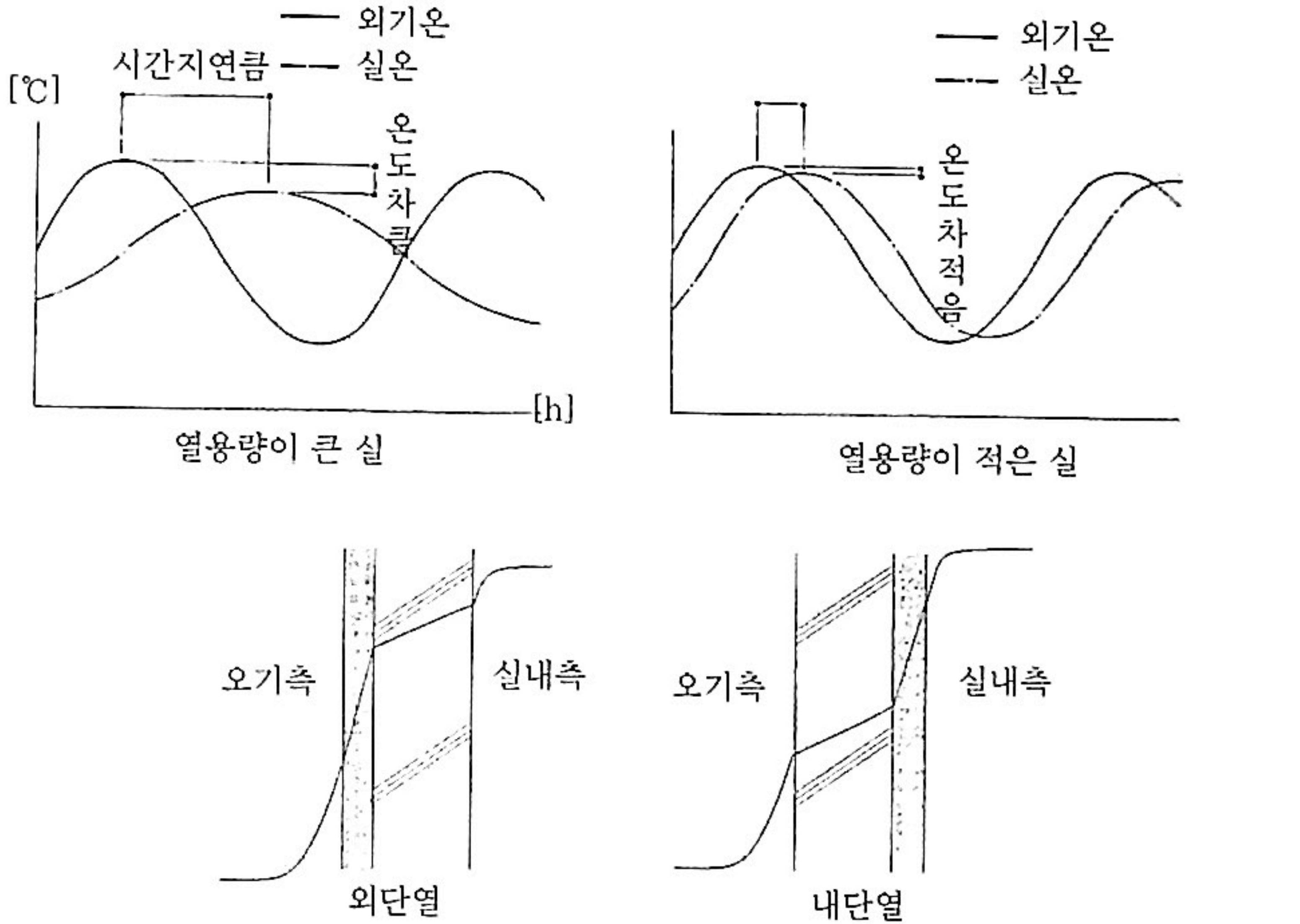
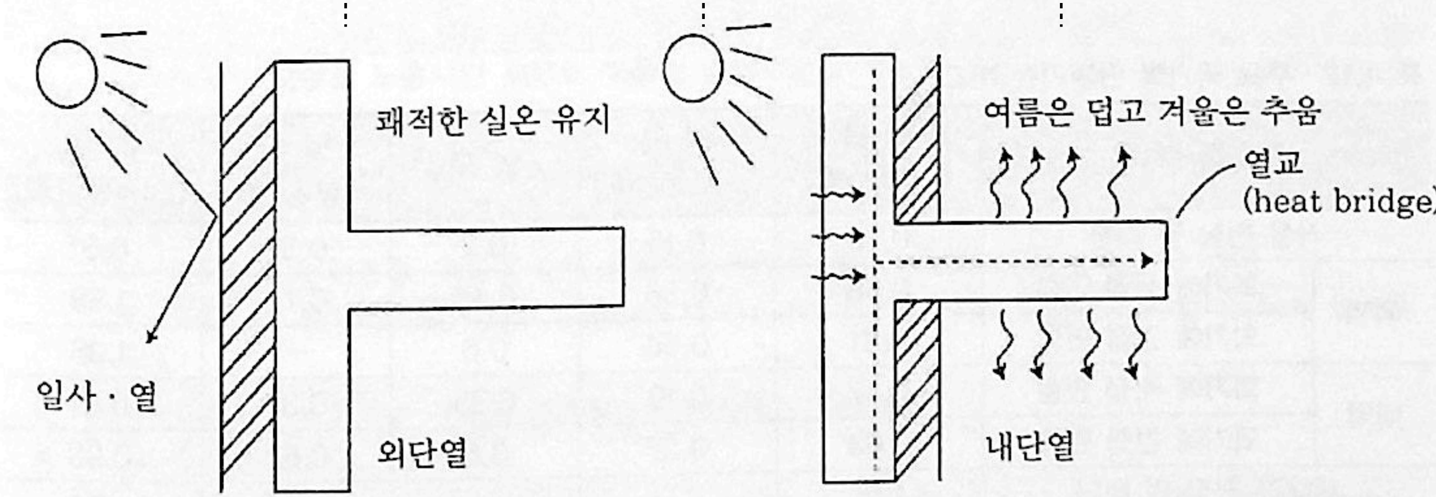


그림 4.17 외단열과 내단열의 열용량 영향

내단열 외단열

구분	무단열	내단열	외단열
벽체온도분포	온도진폭 감쇄 큼	온도진폭 감쇄 보통₩	온도진폭 감쇄 작음
실내측온도 변동	크다	작지만 실온변동 영향 받음	작다
실내쾌감도	불량	양호(실온변동 있으면 불량)	양호
균열발생	크다	크다	작다
결로발생	표면결로 용이	내부결로 용이	매우적다
시공성	용이	용이	외단열공법 용이



결로

결로의 기본 조건	원인 요인	구체적 행위
높은 습도의 공기	기후조건	봄, 하계의 고온 다습한 외기
	난방 방식 및 실내온도	비난방 공간의 온도하강에 의한 상대습도 증가 대류난방시 Cold Draft
	환기의 부족	환기부족에 의한 실내습기의 증가 공간배치의 부적절에 의한 고습 공기의 국부적 정체 겨울철 공간 밀폐
	외피 재료의 사용 특성	방습재의 미사용 및 부적절한 배치 외피 재료의 투습 저항 부족 초기 함습율이 높은 자재의 사용
	건물의 사용 방법	목욕, 세탁, 조리, 관상식물, 광상수조, 가습기의 사용 개방형 난방기의 사용
	건축물의 사용 조건	과도한 재실인원(호흡 및 발한)
차가운 표면	기후조건	혹서 지역의 낮은 외기온의 침투
	건축물의 부위별 결함 (열교 부위의 발생)	모서리, 우각부 등 기본적 결함 창호 및 문의 단열저항 부족 긴결 철물의 구조체 관통 등
	단열시공의 미흡	단열 시공 결함 및 단열재 누락
	일사 수열의 부족	북측 외벽의 내표면의 온도 하강 비난방 무창 건물 등의 바닥면 온도하강
	지중면의 면한 부위	지중에 면한 바닥 부위의 냉각(봄, 여름) 지중에 면한 비단열 벽체의 온도 하강

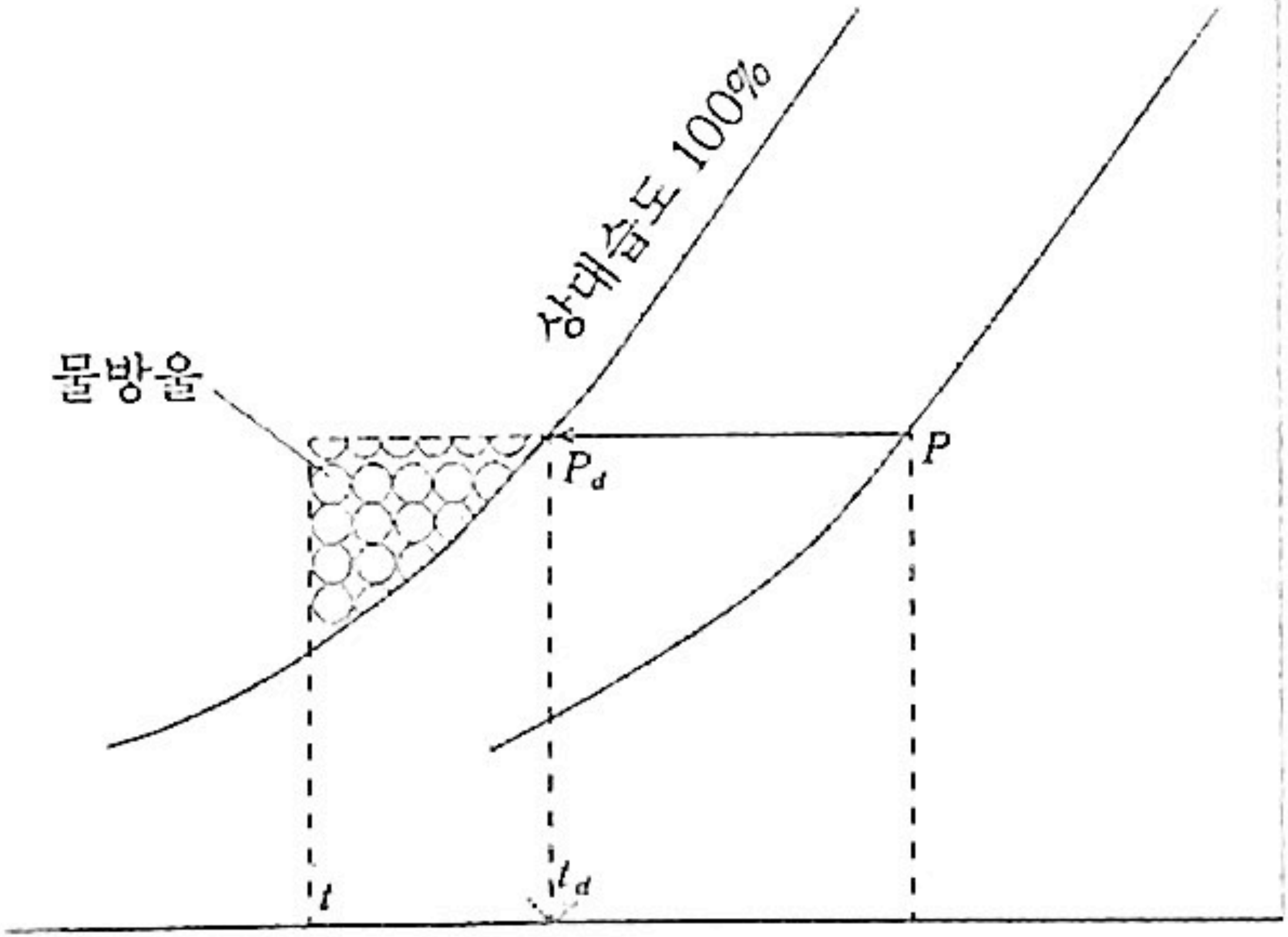


그림 4.35 공기선도상의 결로검토

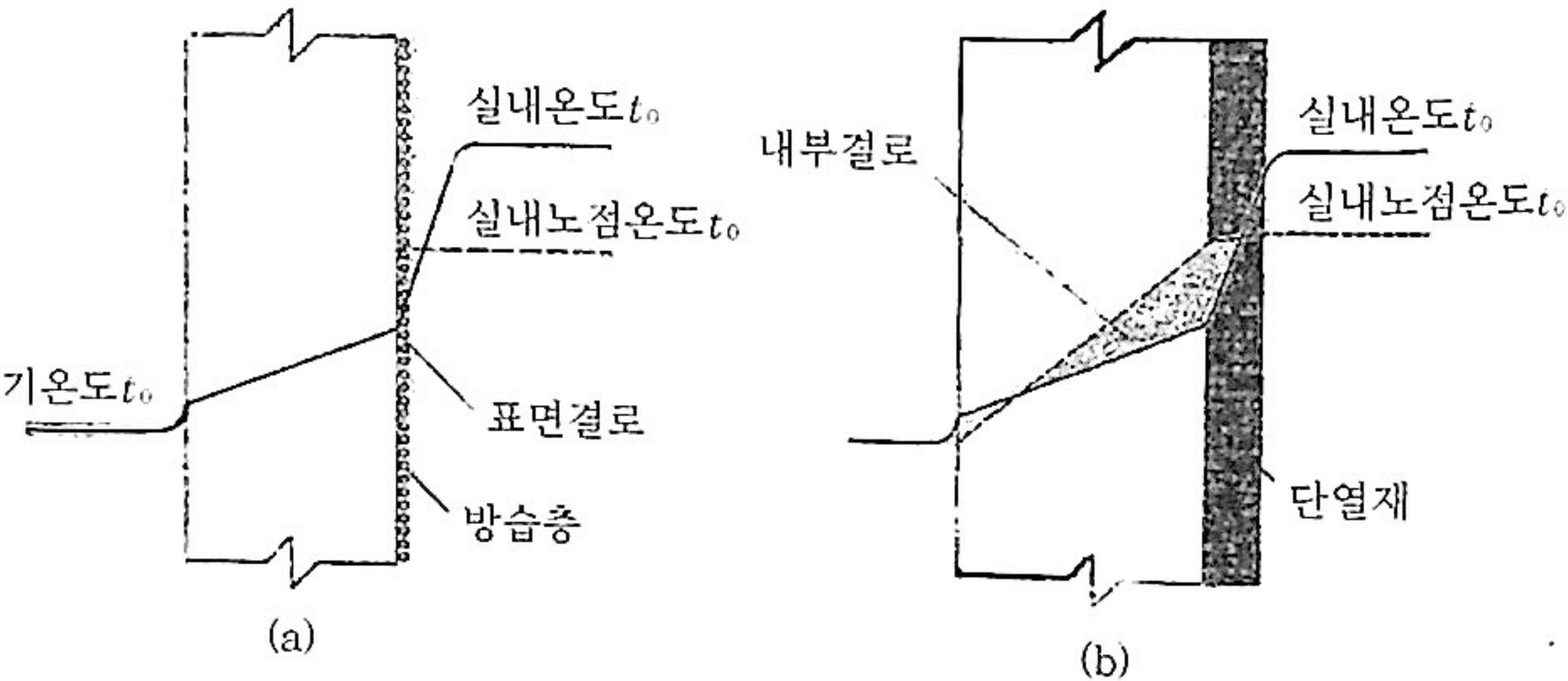


그림 4.36 표면결로와 내부결로

실내공기의 노점온도 낮추는법

- 환기를 이용하여 수증기를 배출한다
- 벽면과 물품 사이에 공간
- 실내 수분 발생 억제
- 실내측 벽표면온도를 실내공기 노점온도보다 높게한다

표면결로방지

- 실내습도 억제
- 벽체 표면온도 저하 방지
- 충분한 단열
- 벽체와 바닥이 만나는 우각부 단열 충분
- 실내 전체 또는 저온부분을 난방 - 실내측 표면온도 높인다
- 열교부분에 단열 처리

내부결로 방지

- 단열 방법과 방습층 설치
- 통기층 설치

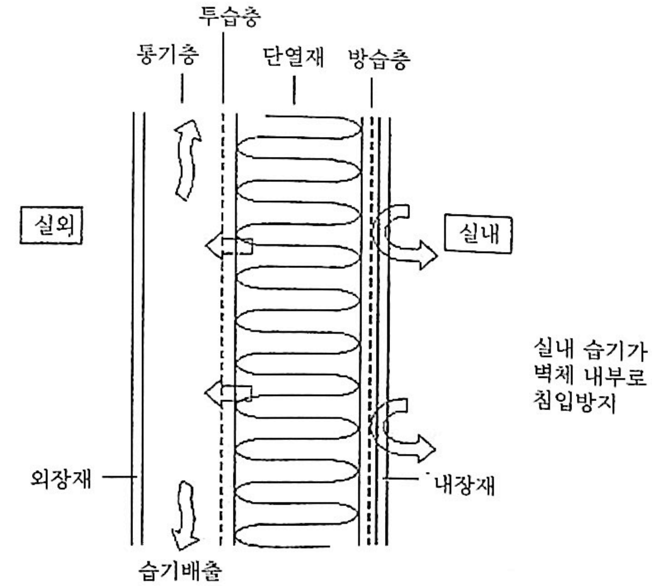
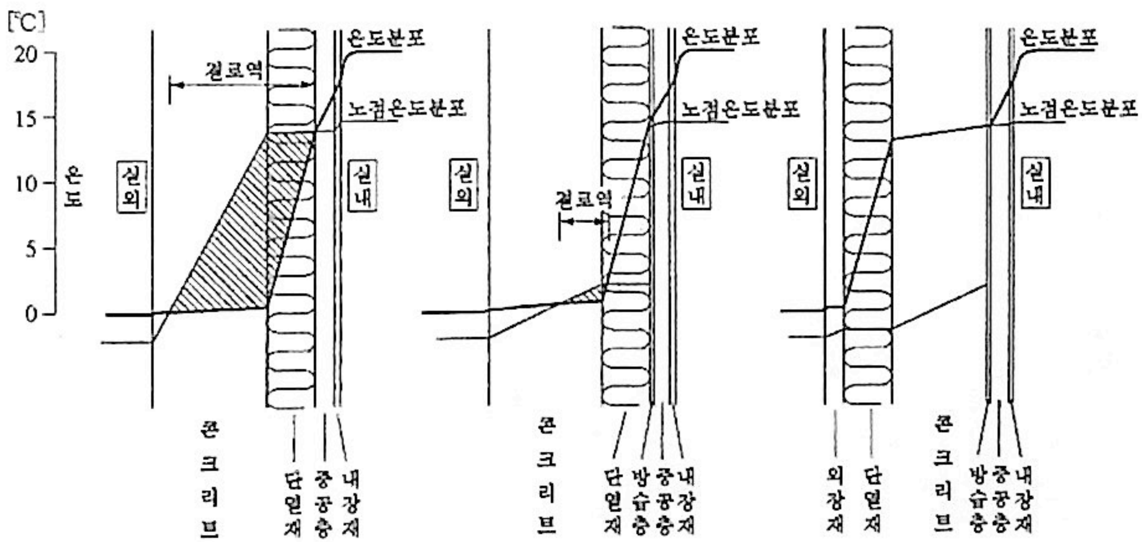


그림 4.41 방습층과 통기층에 의한 내부결로 방지



(a) 내단열 (b) 내단열+방습층 (c) 외단열+방습층

그림 4.40 단열재 위치에 따른 결로 발생정도