COOLING LOAD

OUTLINE

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V. EXAMPLE PROBLEM

I. COOLING LOAD VERSUS SPACE HEAT GAIN

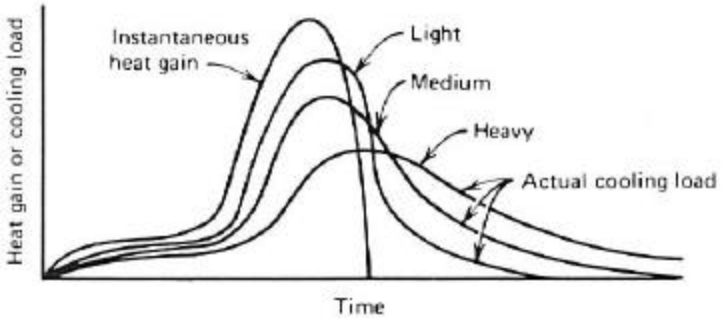
A) **SPACE HEAT GAIN** – RATE AT WHICH HEAT ENTERS BUILDING AND BUILDING STRUCTURE

B) **COOLING LOAD** – RATE AT WHICH HEAT MUST BE REMOVED FROM AIR TO MAINTAIN TEMPERATURE

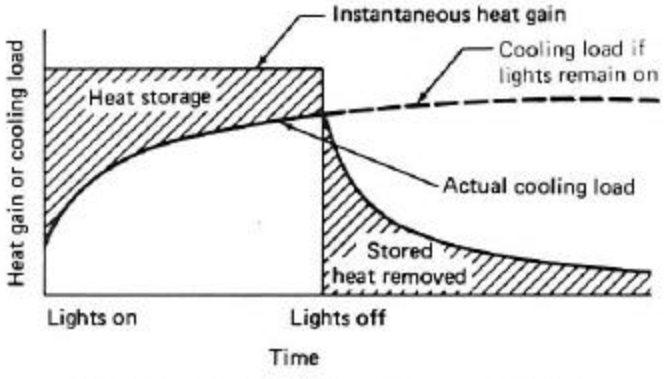
THESE TWO DIFFER DUE TO BUILDING THERMAL CAPACITANCE WHICH INTRODUCES A TIME LAG BETWEEN HEAT GAIN AND COOLING LOAD.

THIS EFFECT HELPS
IN THE SENSE THAT THE PEAK COOLING LOAD IS REDUCED

BUT IT ADDS
AN UNSTEADY COMPONENT TO THE PROBLEM, WHICH MAKES ANALYSIS MORE DIFFICULT.



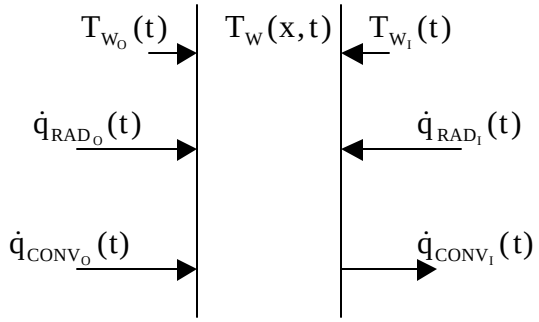
Actual cooling load and solar heat gain for light, medium, and heavy construction.



Actual cooling load from fluorescent lights.

C) DIFFICULTIES IN SOLVING UNSTEADY HEAT CONDUCTION PROBLEM.

LETS LOOK AT A WALL SLAB



$$\rho C_P \frac{\partial T_W}{\partial t} = k \cdot \frac{\partial^2 T_W}{\partial x^2}$$

THIS IS AN UNSTEADY HEAT CONDUCTION PROBLEM THROUGH THE WALL.

DIFFICULTIES ARISE DUE TO TIME VARYING BOUNDARY CONDITIONS.

ALSO, WE ARE INTERESTED IN $\dot{q}^i_{CONV}(t)$ BECAUSE THIS IS THE RATE AT WHICH HEAT IS TRANSFERRED TO THE AIR.

AGAIN, THIS PROBLEM MUST BE SOLVED FOR EVERY BUILDING SURFACE. THIS REQUIRES ACCURATE ESTIMATES OF ρC_P AND k FOR ALL BUILDING MATERIALS.

ALL OF THE ABOVE ARE NOT EASILY DONE TO WITHIN REASONABLE ACCURACY.

REQUIRES COMPUTER-BASED METHOD.

D) SOLUTION METHODS

1) **TRANSFER FUNCTION METHOD** - COMPUTER BASED METHOD, WHICH ATTEMPTS TO SOLVE PROBLEMS ENTIRELY. IT IS THE STATE-OF-THE-ART INDUSTRY STANDARD BUT IT IS TOO COMPLICATED TO TREAT IN THIS COURSE.

   CLTD / SCL/ CLF METHOD – HAND CALCULATION METHOD BASED ON REPRESENTATIVE RESULTS FROM THE TRANSFER FUNCTION (TF) METHOD. SOME TIME AGO, ASHRAE CONDUCTED TF ANALYSIS FOR A VARIETY OF BUILDING STRUCTURES / OCCUPANCY PATTERNS AND HAVE TABULATED THE DATA.

II. REQUIRED DATA FOR COOLING LOAD CALCULATIONS

A. BUILDING LOCATION AND ORIENTATION (ARCHITECTURAL PLANS)
B. BUILDING CONSTRUCTION (ARCHITECTURAL PLANS)
C. OUTDOOR DESIGN CONDITIONS
D. INDOOR DESIGN CONDITIONS
E. OCCUPANCY SCHEDULE
F. LIGHTING
G. EQUIPMENT SCHEDULES
H. INFICTRATION / VENTILATION

III. COOLING LOAD TEMPERATURE DIFFERENCE / SOLAR COOLING LOAD / COOLING LOAD FACTOR METHOD IN BRIEF (CLTD/SCL/CLF).

USES TABULATED RESULTS FROM TRANSFER FUNCTION METHOD SOLUTIONS FOR COMMON BUILDING CONSTRUCTION.
CALCULATION IS BASED ON

$$\dot{q}_i(t) = UA \cdot CLTD_t$$

$$CLTD_t = \frac{\dot{q}_i(t)}{UA}$$

WHERE $CLTD_t$ IS KNOWNN AS THE COOLING LOAD TEMPERATURE DIFFERENCE WHICH IS TABULATED AS A FUNCTION OF TIME.

ALSO USES COOLING LOAD FACTORS (CLF'S) FOR LIGHTS, PEOPLE, AND EQUIPMENT.

$$\dot{q}_t = \dot{q}_i \cdot CLF_t$$

IV. INDIVIDUAL COMPONENTS OF COOLING LOAD USING CLTD/SCL/CLF METHOD.

LOOK AT SUMMARY TABLE ON PAGE 28.40 OF ASHRAE FUNDAMENTALS HANDBOOK OR TEXT TABLE 7-~~19~~32.

A. ROOF

$$\dot{q}_{ROOF} = UA \cdot CLTD_{ROOFC}$$

STEP 1) DETERMINE ROOF CONSTRUCTION AND OVERALL HEAT TRANSFER COEFFICIENT (CHAPTER 5 TEXT, CHAPTER 24 ASHRAE)

2) SELECT ROOF NO. FROM ASHRAE TABLE 31 OR TEXT TABLE 7-~~21~~ 34 WHICH IS CLOSEST TO MATCHING ACTUAL ROOF CONSTRUCTION (NEED TO ALSO USE TABLE 7-36).

3) GO TO ASHRAE TABLE 30 OR TEXT TABLE 7-~~20~~ 33 AND SELECT $CLTD_{ROOF}$ FOR TIME OF INTEREST (TYPICALLY ON AN HOURLY BASIS)

4) CORRECTIONS:
VALUES ON TABLE ARE FOR
4 LATITUDES ON JULY OR AUGUST
INDOOR TEMPERATURE OF 78°F
OUTDOOR MAX TEMPERATURE OF 95°F WITH MEAN DAILY TEMPERATURE OF 85°F AND DAILY RANGE OF 21F
ADDITIONAL GUIDANCE FOR SPECIFIC APPLICATIONS AND TABLES FOR VARIOUS LATITUDES CAN BE FOUND IN MCQUISTON, F. C. AND SPITLER, J. D., 1992, *COOLING AND HEATING LOAD CALCULATION MANUAL*, 2ND ED., ASHRAE

$$CLTD_{ROOFC} = [CLTD_{ROOF} + (78 - T_R) + (T_M - 85)]$$

$(78 - T_R)$ INDOOR DESIGN TEMPERATURE CORRECTION

$(T_M - 85)$ OUTDOOR DESIGN TEMP CORRECTION.

MEAN OUTDOOR TEMP $T_M = T_{MAX} - (\text{DAILY RANGE}) / 2$

T_{MAX} = MAXIMUM OUTDOOR TEMPERATURE

5) CALCULATE AREA FROM PLANS.

6) $\dot{q}_{ROOF} = UA \cdot CLTD_{ROOFC}$

B. WALLS

$$\dot{q}_{WALL} = UA \cdot CLTD_{WALLC}$$

STEP 1) DETERMINE WALL CONSTRUCTION AND OVERALL HEAT TRANSFER COEFFICIENT (CHAPTER 5 TEXT, CHAPTER 24 ASHRAE)

2) SELECT WALL TYPE FROM ASHRAE TABLE 33 OR TEXT TABLE 7-~~24~~ 37 WHICH IS CLOSEST TO MATCHING ACTUAL WALL CONSTRUCTION. PAY ATTENTION TO EFFECT OF MASS DISTRIBUTION (INSIDE INSULATION, OUTSIDE INSULATION OR EVENLY DISTRIBUTED). (NEED TO ALSO USE TABLE 7-36).

3) GO TO ASHRAE TABLE 32 OR TEXT TABLE 7-~~22~~ 35 AND SELECT $CLTD_{WALL}$ FOR TIME OF INTEREST (TYPICALLY ON AN HOURLY BASIS).

4) CORRECTIONS:
VALUES ON TABLE ARE FOR
4 LATITUDES ON JULY OR AUGUST
INDOOR TEMPERATURE OF 78°F
OUTDOOR MAX TEMPERATURE OF 95°F WITH MEAN DAILY TEMPERATURE OF 85°F AND DAILY RANGE OF 21F
ADDITIONAL GUIDANCE FOR SPECIFIC APPLICATIONS AND TABLES FOR VARIOUS LATITUDES CAN BE FOUND IN MCQUISTON, F. C. AND SPITLER, J. D., 1992, *COOLING AND HEATING LOAD CALCULATION MANUAL*, 2ND ED., ASHRAE

$$CLTD_{WALLC}=[CLTD_{WALL}+(78 - T_R)+(T_M - 85)]$$

$(78 - T_R)$ INDOOR DESIGN TEMPERATURE CORRECTION

$(T_M - 85)$ OUTDOOR DESIGN TEMP CORRECTION.

MEAN OUTDOOR TEMP $T_M = T_{MAX} - (\text{DAILY RANGE}) / 2$

T_{MAX} = MAXIMUM OUTDOOR TEMPERATURE

5) CALCULATE AREA FROM PLANS.

6) $\dot{q}_{WALL} = UA \cdot CLTD_{WALLC}$

C. GLASS OR WINDOWS

TWO COMPONENTS CONDUCTIVE: $\dot{q}_{WIN_{CON}} = UA \cdot CLTD_{WINC}$

SOLAR: $\dot{q}_{WIN_{SOL}} = A \cdot (SC) \cdot (SCL)$

CONDUCTIVE:

STEP 1) DETERMINE U VALUE

2) SELECT $CLTD_{WIN}$ FROM ASHRAE TABLE 34 OR TEXT TABLE 7-~~25~~ 38 FOR TIME OF INTEREST (TYPICALLY ON AN HOURLY BASIS).

3) CORRECTIONS

$$CLTD_{WINC}=[CLTD_{WIN}+(78 - T_R)+(T_M - 85)]$$

$(78 - T_R)$ INDOOR DESIGN TEMPERATURE CORRECTION

$(T_M - 85)$ OUTDOOR DESIGN TEMP CORRECTION.

MEAN OUTDOOR TEMP $T_M = T_{MAX} - (DAILY\ RANGE) / 2$

T_{MAX} = MAXIMUM OUTDOOR TEMPERATURE

4) DETERMINE AREA FROM ARCH PLANS

5) $\dot{q}_{WIN_{CON}} = UA \cdot CLTD_{WINC}$

SOLAR:

STEP 1) DETERMINE SHADING COEFFICIENT (SC) FROM ASHRAE TABLES 15 TO 21 (CHAPTER 29) OR TEXT TABLES 7-4 TO 7-11

2) DETERMINE ZONE TYPE FROM ASHRAE TABLE 35B OR TEXT TABLES 7-~~26~~ 39 B,C,D&E

3) DETERMINE SOLAR COOLING LOAD (SCL) FROM ASHRAE TABLE 36 OR TEXT TABLE 7-~~27~~40.

4) DETERMINE AREA FROM ARCHITECTURAL PLANS

5) $\dot{q}_{WIN_{SOL}} = A \cdot (SC) \cdot (SCL)$

D. LIGHTS

$$\dot{q}_{LIGHTS} = (TLW) \cdot (UF) \cdot (SAF) \cdot (CLF)$$

TLW = TOTAL LIGHT WATTAGE

UF = USE FACTOR – FRACTION OF LIGHTS IN USE

SAF = SPECIAL ALLOWANCE (BALLAST) FACTOR – ALLOWANCE FACTOR TO ACCOUNT FOR BALLAST LOSSES (FLUORESCENT ~ 1.2)

CLF = COOLING LOAD FACTOR

STEP 1) DETERMINE TOTAL WATTAGE (ELECTRICAL PLANS)

2) DETERMINE USE FACTOR (BUILDING USAGE)

3) DETERMINE SPECIAL ALLOWANCE FACTOR (INCANDESCENT – 1.0, FLUORESCENT = 1.2)

4) USE ASHRAE TABLES 35A AND 35B OR TEXT TABLES 7-~~26~~ 39 A-E TO DETERMINE ZONE TYPE CLASSIFICATIONS OF LIGHTS

5) USE ASHRAE TABLE 38 OR TEXT TABLE 7-~~29~~ 42 FOR CORRESPONDING ZONE TYPE, TIME, AND NUMBER OF HOURS OF OPERATION OF LIGHTS TO DETERMINE CLF.

6) $\dot{q}_{LIGHTS} = (TLW) \cdot (UF) \cdot (SAF) \cdot (CLF)$

E. PEOPLE

$$\dot{q}_{P_{LAT}} = (NO) \cdot (LHG)$$

$$\dot{q}_{P_{LAT}} = (NO) \cdot (SHG) \cdot (CLF)$$

LATENT LOAD:

STEP 1) ESTIMATE NUMBER OF PEOPLE, (NO)
(BUILDING USAGE)

2) USE ASHRAE TABLE 3 OR TEXT TABLE 7-14 TO DETERMINE THE LATENT HEAT GAIN PER PERSON (LHG)

SENSIBLE LOAD:

STEP 1) ESTIMATE NMBER OF PEOPLE (NO)
(BUILDING USAGE)

2) USE ASHRAE TABLE 3 OR TEXT TABLE 7-14 TO DETERMINE SENSIBLE HEAT GAIN PER PERSON (SENSHG)

3) USE ASHRAE TABLE 35A&B OR TEXT TABLES 7-~~26~~39 A-E TO DETERMINE ZONE TYPE

4) USE ASHRAE TABLE 37 OR TEXT TABLE 7-~~28~~ 41 FOR COOLING LOAD FACTOR (CLF) FOR THE GIVEN ZONE TYPE

F. EQUIPMENT

SENSIBLE HEAT GAINS (SHG)

EQUIPMENT OPERATED BY ELECTRIC MOTORS

PLACEMENT: BOTH EQUIPMENT AND MOTOR ARE IN THE CONDITIONED SPACE:

$$\dot{q}_{EQ_M} = 2545 \cdot (P/E_M) \cdot F_{LM} \cdot F_{UM}$$

PLACEMENT: MOTOR IS OUTSIDE THE CONDITIONED SPACE OR AIRSTREAM, EQUIPMENT ARE INSIDE:

$$\dot{q}_{EQ_M} = 2545 \cdot P \cdot F_{LM} \cdot F_{UM}$$

PLACEMENT: MOTOR IS INSIDE THE CONDITIONED SPACE OR AIRSTREAM, EQUIPMENT ARE OUTSIDE:

$$\dot{q}_{EQ_M} = 2545 \cdot P \cdot (1 - E_M)/E_M \cdot F_{LM} \cdot F_{UM}$$

WHERE, $\dot{q}_{EQ_M}$ IS THE SENSIBLE HEAT GAIN IN BTU/h

STEP

1) DETERMINE MOTOR HORSEPOWER RATING OF EQUIPMENT (P)

2) DETERMINE EFFICIENCY OF THE MOTOR (E_M)

3) DETERMINE FRACTION OF TIME DURING WHICH EQUIPMENT IS IN OPERATION. THIS WILL BE THE MOTOR USE FACTOR (F_{UM})

4) DETERMINE FRACTION OF THE RATED POWER USED WHEN EQUIPMENT IS IN OPERATION. THIS WILL BE THE MOTOR LOAD FACTOR (F_{LM})

5) DETERMINE PLACEMENT OF EQUIPMENT (ARCHITECTURAL AND MECHANICAL DESIGN PLANS)

6) USE APPROPRIATE EQUATION ABOVE OR TEXT TABLE 7-~~15~~ 16 DEPENDING ON THE EQUIPMENT PLACEMENT TO CALCULATE THE SENSIBLE HEAT GAIN.

APPLIANCES (PRIMARILY FOR COOKING APPLIANCES)

$$\dot{q}_{EQ_A} = \dot{q}_I \cdot F_{UA} \cdot F_{RA} / F_{FL}$$

$$\dot{q}_{EQ_A} = \dot{q}_I \cdot F$$

STEP 1) DETERMINE ENERGY SOURCE FOR THE APPLIANCE
CATEGORY 1: ELECTRIC OR STEAM
CATEGORY 2: FUEL FIRED

2) DETERMINE HEAT RATING OF THE APPLIANCE ($\dot{q}_I$) FROM NAMEPLATE, MANUFACTURER'S CATALOGUE OR ~~OR~~ USE TEXT TABLE 7-~~17~~ 18 FOR RESTAURANT EQUIPMENT

3) DETERMINE USAGE FACTOR (FUA) WHICH IS EITHER TAKEN FROM TEXT TABLE 7-~~16~~ 17 OR 50% IF INFORMATION IS INCOMPLETE.

4) DETERMINE RADIATION FACTOR (FRA) FROM TEXT TABLE 7-~~16~~ 17 OR 32% IF INFORMATION IS INCOMPLETE.

5) USE APPROPRIATE EQUATION FROM ABOVE WITH
FFL=1 AND F=0.16 FOR CATEGORY 1
FFL=1.6 AND F=0.10 FOR CATEGORY 2

NOTE: FOR RESTAURANTS HEAT ADDITION PER MEAL SERVED IS 50 BTU/h. 75% OF THIS IS SENSIBLE AND 25% LATENT.

HOSPITAL AND LABORATORY EQUIPMENT

CONSULT CHAPTER 13 FROM ASHRAE APPLICATIONS 1995 AND/OR TEXT TABLES 7-~~18~~19, 20.
TYPICAL VALUES: 15-70 BTU/(h ft^2)

OFFICE APPLIANCES

CONSULT TEXT TABLE 7-~~18~~21 THROUGH 27

LATENT HEAT GAINS (LHG)

LATENT LOAD IS INSTANTANEOUS

LATENT LOAD

$$\dot{q}_{EQ_L} = (LHG)$$

SENSIBLE LOAD

$$\dot{q}_{EQ_S} = (SHG) \cdot (CLF)$$

STEP 1) DETERMINE SENSIBLE HEAT GAIN ACCORDING TO PROCEDURE OUTLINEDABOVE

2) DETERMINE ZONE TYPE FROM ASHRAE TABLE 35A, B OR TEXT TABLE 7-~~26~~ 39 A-E

3) DETERMINE COOLING LOAD FACTOR (CLF) FROM ASHRAE TABLES 37, 39 OR TEXT TABLES 7-~~28~~41, 7-~~30~~43

NOTE: TEXT SAYS SET LATENT HEAT GAIN (LHG) = 0 FOR HOODED APPLIANCES. THIS MAY NOT ALWAYS BE A GOOD ASSUMPTION

G. VENTILATION / INFILTRATION

SENSIBLE

$$\dot{q}_{INF_S} = 1.10 \cdot Q \cdot (T_o - T_i)$$

LATENT

$$\dot{q}_{INF_L} = 4840 \cdot Q \cdot (\omega_o - \omega_i)$$

TOTAL

$$\dot{q}_{INF_{TOT}} = 4.5 \cdot Q \cdot (h_o - h_i)$$

Q	INFILTRATION RATE IN CFM
o	OUTSIDE CONDITION
i	INSIDE CONDITION
h	MOIST AIR ENTHALPY BTU/lbm(dry air)
ω	HUMIDITY RATIO