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TW TSIN

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Content

1.Human being in thermal environment

2.Criteria for thermal assessment and measurement methods

3.Case studies

a)Indoor environment (e.g. site office)

b)Construction work in summer

c)Marathon 2010

d)Tunneling work

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1. Man in the environment

- Homiothermic (warmblooded) living form on Earth
- **Human existence** depends on heat energy level balancing with the external environment via heat gain or loss from the body

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Importance of heat balance

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Thermal environments

- **Sun** is the major source of heat energy in outdoor and can affect indoor indirectly
- **Thermal comfort** (ISO 7330, ASHRAE 55-2004)
  - Discomfort likely beyond the range of 18 – 27 ° C
  - Performance drop in either too warm or too cool
- **Extreme heat or cold**
  - Consequence of imbalance conditions
  - Heatstroke or frostbite; Risk of cumulative trauma disorders, etc.
  - Heat stress and strain

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Heat stress & strain

- **Stress:** *The net heat load to which a person may be exposed from the combined contributions of metabolic cost of work, environmental factors and clothing requirements.*
- **Strain:** *The physiological impact of heat stress on the body, as expressed in terms of changes in tissue temperatures (core temperature) and compensatory changes in the activity (response) of physiological systems (sweat rate, heart rate, skin blood flow).*

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Activity, personal factors, and environment

- Nature of work (activity)
  - Work situation (metabolic rate, posture, etc,)
- Personal factors to be considered
  - People/ human factors (body size, etc.) and
  - their clothing – best to maximise convection & evaporation (cooling effect)
- Micro-climatic factors (air temperature, humidity, radiation heat load, air movement, etc.) in the environment

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Heat load in Variation with work activity

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Metabolic Rates for Some Typical Activities/ Tasks

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Combined effects - Human factors & heat stress in an environment for different activities

- Critical issues: Internal & external heat environments
- In assessment consider the activity and clothing together with the work environmental conditions
- The strain is not directly related to external factors

12 ## Feeling of hot environment

- high air temperatures
- high surface temperatures
- high atmospheric humidity
- relatively low air movement

- Hot environment – air temperature over 30° C likely to have complaint on hot environment

13 ## Sensation of heat or cold

- Heat is not temperature
- Surface temperature – all surfaces are made of materials, which conduct heat at varying rates (thermal conductivity).
- Fingertips most sensitive to rate of heat conduction or conductivity of the material – transfer of heat energy
  - steel feels colder than wood at room temperature.

14 ## So it is HOT!!!

- Human cannot sense air temperature directly--what human sense is **temperature** at “skin receptors”.

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- Therefore, it is very difficult to predict a person's sensations of warmth or cold from air temperature
- Air temperature alone is not a good indication of heat causing discomfort or illnesses
- Assessment of other environmental factors is necessary.

16 ## The basic environmental factors

- Factors that affect human perception to heat
  - Air temperature, humidity, radiant heat, air movement (wind action and air current or ventilation)

17 ## 2. Criteria for thermal/ heat stress assessment & methods

- Extreme external environments
- Perception of heat or thermal stress related to (environmental factors)
  - Air temperatures (dry and wet)
  - Air velocity (air movement)
  - Temperature gradient
  - Humidity (relative humidity, RH)
  - Surrounding radiation heat sources
- Personal clothing/ activity factors have to be considered in assessment or with assumptions

18 ## Set up of the basic experiment

- Empirical or direct methods

19 ## Instrument for Environmental monitoring (ISO 7726)

- Dry bulb thermometer for air temperature
- Wet bulb for moisture effect
- Hygrometer for relative humidity
- Kata thermometer for air velocity
- Globe thermometer for Radiant heat exchange

20 ☐ Methods for assessment of thermal environment in workplaces (1)

- ☐ Mercury/ alcohol in bulb thermometer – air temperatures (dry bulb or wet bulb)
  - ■ Guideline from Labour Department – Occupational Hygiene guideline
  - ■ Comfort chart from ASHARE 55-2004
  - ■ Humidex from Canada
- ☐ Effective temperature, ET (and corrected effective temperature, CET) for comfort
  - ■ ET Chart after Elliot FP for sedentary work

21 ☐ Methods for assessment of thermal environment in workplaces (2)

- ☐ Wet bulb and globe temperature, WBGT
  - ■ TLV of ACGIH for workplaces, or
  - ■ ISO 7243 for indoor & outdoor estimation
- ☐ Wet bulb temperature, WB
  - ■ Standard for tunnelling work
  - ■ ILO recommended standard for underground mining application

22 ☐ Choice of Instrumentation

23 ☐ Case studies in construction

1. Site office
2. Construction work in summer
3. Marathon 2010 (An analogy)
4. Tunnelling work

24 ☐ a) Working in the site office

- ☐ Sedentary/ office work in the site office
  - ■ Computer work
  - ■ Photocopying
  - ■ Meeting and discussion
  - ■ Presentation & briefing
- ☐ Normal dressing
- ☐ Occasional site inspection outdoors for some staff

25 ☐ Designing for Thermal Comfort – Cooling system provided

Recommendations for a typical Office Cooling Values

- ☐ Air temperature (24 ˚C)
- ☐ Humidity (50% RH)
- ☐ Metabolic rate (1 met)
- ☐ Radiant temperature (24 ˚C)
- ☐ ***Clothing insulation*** (0.5 to 1.0 clo)
- ☐ ***Air speed*** (0.20m/s or less)

26 ☐ General guidelines for indoors or site office

General Recommendations for thermal conditions in buildings

- ☐ Labour Department:
  - ■ Air temperature (20° C to 26° C)
  - ■ summer time (23 – 26° C) & winter time (20 - 24° C)
- ☐ 25.5˚C for IAQ setting & energy saving
- ☐ Comfort chart from ASHARE 55-2004

27 ☐ Assessment with Thermal Comfort chart after **ASHRAE 55-2004**

28 ☐ b) Construction work in summer time

- Activity – variable from light to very heavy (Met = 2 to 4)
- Clothing - 0.3 to 1.0 clo
- Typical summer weather
  - Air = 32 ± 2º C
  - T_{globe} = 45 ± 3º C
  - RH = 60 ± 3%
  - T_{wb} = 24° C

29 ## Assessment with Thermal Comfort chart after **ASHRAE 55-2004**

30 ## ET/ CET chart

31

32 ## WBGT Guide

on work/ rest schedule; (after EN 27243: 1993)

- WBGT = 32.5° C based on hourly data
- High heat stress
- Rest & activity break

33 ## c) Marathon 2010 on 28.2.2010

- 52,000 participants
- Over 1149 got sick: heat exhaustion, heat cramp, fatigue
- 55 persons hospitalized
- 3 critical; and luckily no fatality
- Suggestions
  1. To hold it at night;
  2. In a cooler day of the year

34 ## Nature of activity

- Walking, running or standing
  - Workload from medium to very high
- Demanding activity – normally 8 – 9 Mets
- Personal factors
  - Variable ages, sex, sizes, body built and health status
  - Clothing from 0.2 to 0.5 clo

35 ## The best estimate for the event

- Reported weather conditions
  - **Air temperature at 24 º C, and**
  - **RH = 93% or**
  - **Wet bulb** equivalent = 23.7º C
- Which is the best indicator ??
  - Thermal comfort chart
  - Humidex
  - Effective temperature
  - WBGT ...

36 ## Thermal comfort chart

after **ASHRAE 55-2004**

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38 ☐ CET/ ET chart

39 ☐ Assessment by WBGT meter

- ☐ Select your formula:
  - ■ WBGT = 0.7 T_{nwb} + 0.3 T_g, (indoor), and
  - ■ WBGT = 0.7 T_{nwb} + 0.2 T_g + 0.1 T_{db} (outdoor).
- ☐ **Wet bulb** equivalent = 23.7º C
- ☐ Calculated **WBGT index** = 23.8º C

40 ☐ d) Thermal stress & tunnelling

- ☐ Confined space activity
  - ■ Tunnel boring/ rock drilling, welding, shotcreting and concrete forming, wearing of heavy personal protective gears
- ☐ Identify if there are major heat sources and its radiant energy distribution
- ☐ Ascertain the ventilation distribution, supply and exhaust system
- ☐ Which is the best indicator ??

41 ☐ When no asymmetric radiant heat – Apply WB temperature.

- ☐ Consider the Recommended standard based on wet bulb temperatures from ILO
  - ☐ (ILO Encyclopedia 2005)
  - ■ Slight variation with different ventilation rates
  - ■ Optimum temperatures (WB) between 27.5 to 28.5 º C
  - ■ Normally no work to be continued at (WB) 32.5 º C & above.

42 ☐ Interpretation and comment on #1

- ☐ Comfort chart from ASHARE 55-2004
- ☐ Valid for air conditioning spaces for people with suitable clothing, sedentary (office) work
- ☐ HVAC is for people, requirements are for occupants, not buildings.
- ☐ Goal should be to focus on making people comfortable and for the purposes, but not simply installation of buildings or for decoration.

43 ☐ Interpretation and comment on #2

- ☐ Majority of people might feel discomfort to very discomfort
- ☐ WBGT index predicts exposure to extreme conditions
- ☐ Preventive measures for heat stroke would be essential when work has to be continued, and
- ☐ Physiological monitoring?

44 ☐ Interpretation and comment on #3

- ☐ Which one is better?
  - ■ Humidex?
  - ■ Thermal comfort chart? after **ASHRAE 55-2004**
  - ■ MET value has to be considered
  - ■ Issue of internal heat imbalance
- ☐ Better suggestion for the next Marathon?
  - ■ Option 1 or 2 or ?
- ☐ Less humid day of the year
- ☐ Do not work like in Marathon at construction sites

45 ☐ Interpretation and comment on #4

- ☐ What is the best choice for workplace assessment of heat stress on workers?
  - ■ Effective temperature
  - ■ Thermal comfort
  - ■ Humidex,
  - ■ WBGT

- WB index

☐Consideration of major activities - manual or mechanised work? Ventilation system, work schedules and ...

46 ## Revision of the six parameters

47 ## Conclusion

☐Define purpose of assessment
- Trigger the preventive measures by stages for protection of workers' health
- Prevent heat stroke at extreme heat environment

☐Careful selection of instrumentation
- Over 60 methods
- Physiological monitoring for work in extreme heat environment

☐Preventive measures for work to be continued
- Training and promotion of awareness to workers
- Drinking water supply; shelter from direct heat; rest break schedules ...

48 ## **END**

49 ## Clothing unit and energy saving

☐ 0 – 5 clo = naked (at 30 ºC/ 50% RH) to fully clothed
☐ 1 clo = typical winter clothing (at 21 ºC/ 50% RH)
☐ 0.5 clo = typical summer clothing with short sleeves shirt (0.09) and light trousers (0.25) + ...

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