Temperature and Work

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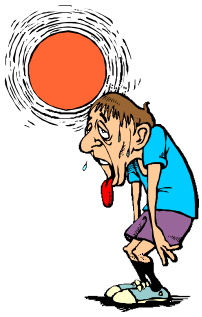
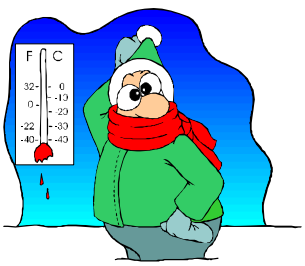
Temperature and Work

Heat stress



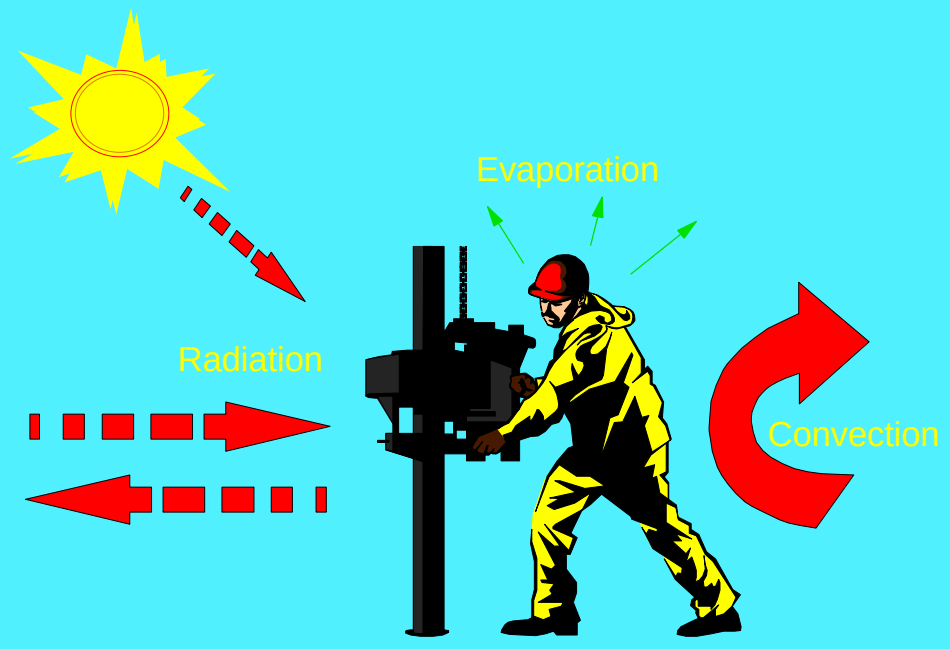
Cold stress



Thermal comfort

Metabolic Heat Production

Activity	Watts
Resting	120
Light	180
Moderate	300
High	410
Very High	520



Heat Balance Equation

$$S = (M-W) \pm C_{sk} \pm C_{res} \pm R \pm K - E_{sk} - E_{res}$$

Factors Influencing Heat Stress

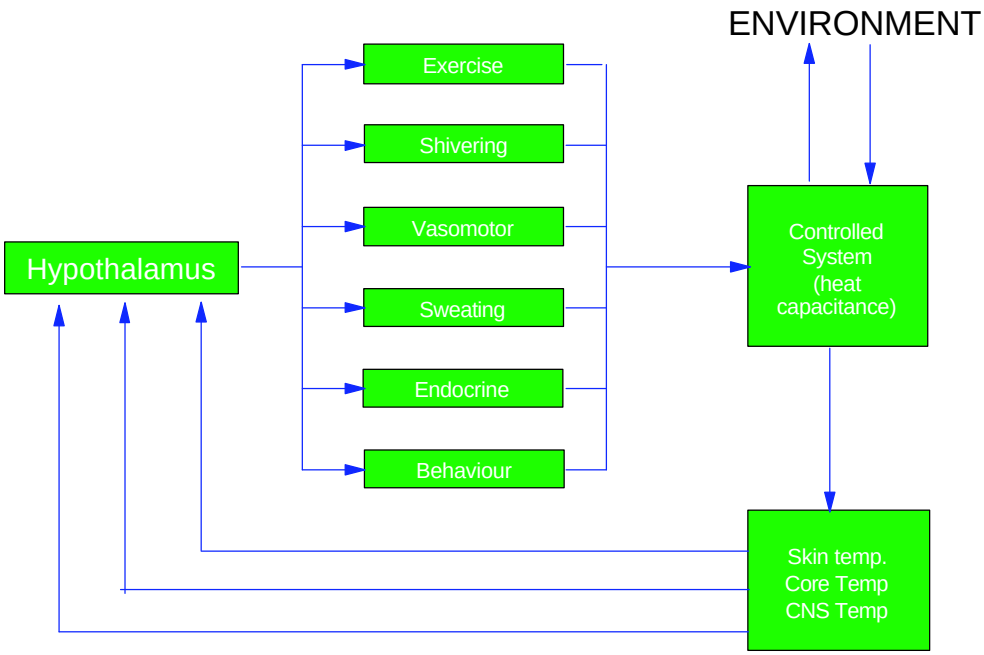
- Metabolic rate
- Air temperature
- Mean radiant temperature
- Air velocity
- Humidity
- Clothing
- Other personal factors

Factors Influencing Cold Stress

- Air temperature
- Air velocity
- Wet clothing

Physiology

- Humans are homeotherms
- Core temperature maintained at around 37^{0}C
- Skin temperature varies



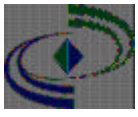
> 43	Tissue damage - Death
40 - 43	Failure of sweating mechanism
38 - 40	Limit set by WHO for avoidance of physiological strain
36.4 - 37.6	Normal core temperature
34 - 36.4	Shivering, decreased efficiency, confusion
30 - 34	Drowsiness, irregular heart rate, cramp
26 - 30	Loss of consciousness, severe impairment of respiratory and cardiac functions
< 26	Death

Acclimatisation

- Physiological adaption to heat
- Can develop after 10 to 14 days exposure to hot conditions
- Results in :
  - increased sweat rate
  - reduced skin temperature
  - reduced core temperature

Harmful Effects - Heat Stress

- Heat Rash (Prickly heat)
- Heat cramps
- Fainting (Heat syncope)
- Heat exhaustion
- Heat stroke



Harmful Effects - Cold

- Trench foot
- Chilblains
- Frost bite
- Hypothermia

Thermal Comfort - Definition

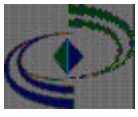
'that condition of mind which expresses satisfaction with the thermal environment'

Factors Influencing Thermal Comfort

- Metabolic rate
- Air temperature
- Mean radiant temperature
- Air velocity
- Clothing
- Psychological factors

Evaluation of Heat Stress / Strain

- Physiological methods
  - core temperature
  - ear canal temperature
  - heart rate
  - recovery heart rate (Brouha's guide)
- Environmental assessment



Evaluation of Heat Stress

- Environmental Factors
  - air temperature
  - radiant heat
  - humidity
  - air velocity
- Human Factors
  - work rate
  - clothing
  - fitness / susceptibility

Measurement

- Air temperature
  - standard thermometer
- Radiant heat
  - globe thermometer
- Humidity
  - whirling hygrometer
- Air velocity
  - kata thermometer

Measurement

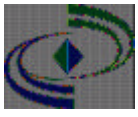
Whirling Hygrometer

Thermal Stress Indices

- Empirical
  - ET / CET
  - WBGT
  - Predicted 4 hour sweat rate (P4SR)
- Rational
  - Heat Stress Index (HSI)
  - Required Sweat Rate

ISO Standards

7243	Estimation of heat stress using WBGT
7730	Evaluation of moderate thermal environments using PMV and PPD
7933	Analytical determination of heat stress using the Required Sweat Rate Index
7726	Instruments and methods
8996	Physiological methods



The WBGT Index

Indoors

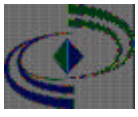
$$WBGT = 0.7\ T_{nwb} + 0.3 T_g$$

Outdoors

$$WBGT = 0.7\ T_{nwb} + 0.2\ T_g + 0.1 T_a$$

WBGT

- Quick and easy to use
- But limited applicability
- Standards available based on the index
  - ISO 7243
  - ACGIH Threshold Limit Values



ACGIH TLVs for Heat Stress

- determine the WBGT
- decide on whether a clothing correction needs to be applied
- compare the WBGT with the screening criteria
- if the corrected WBGT value is within the screening criteria, work can be continued
- if the corrected WBGT value is outside the screening criteria, then a more detailed assessment of heat stress or strain should be undertaken

ACGIH TLVs Screening Criteria Unacclimatised Workers

	Workload			
	Light	Moderate	Heavy	V.Heavy
Continuous Work	27.5	25	22.5	-
75% work / 25% rest	29	26.5	24.5	-
50% work / 50% rest	30	28	26.5	25
25% work / 75% rest	31	29	28	26.5

Values in degrees C

ACGIH TLVs Screening Criteria
Acclimatised Workers

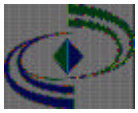
	Workload			
	Light	Moderate	Heavy	V.Heavy
Continuous Work	29.5	27.5	26	-
75% work / 25% rest	30.5	28.5	27.5	-
50% work / 50% rest	31.5	29.5	28.5	27.5
25% work / 75% rest	32.5	31	30	29.5

Values in degrees C

Clothing Corrections

- Summer work uniform 0
- Cloth (woven material) overalls + 3.5
- Double cloth overalls + 5

Values not provided for encapsulating or impervious suits



ACGIH TLVs - Guidelines for limiting heat strain

Discontinue work if:

- sustained (several minutes) heart rate in excess of 180 bpm minus the individual's age in years, for individuals with assessed normal cardiac performance; or
- body core temperature is greater than 38.5 C for medically selected and acclimatised personnel, or 38 C in unselected, unacclimatised workers; or
- recovery heart rate at one minute after peak work effort is greater than 110 bpm; or
- there are symptoms of sudden and severe fatigue, nausea, dizziness or light headedness.

WBGT Reference Values from ISO 7243

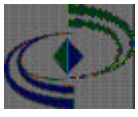
Metabolic Rate Class	Metabolic Rate W/m²	Reference Value of WBGT (C)	
		Acclimatised	*Non-acclimatised*
0	<65	33	32
1	65 - 130	30	29
2	130 - 200	28	28
3	200 - 260	no air movement 25 with air movement 26	no air movement 22 with air movement 23
4	>260	no air movement 23 with air movement 25	no air movement 18 with air movement 20

Required Sweat Rate Index

- Complex!
- Based on heat balance equation
- Utilises required skin wetedness

Required Sweat Rate - Interpretation

- Establishes "danger" and "warning" criteria based on
  - maximum skin wetedness (w_{max})
  - maximum sweat rate (SW_{max})
  - maximum heat storage (Q_{max} in watt hours per square metre of body surface)
  - maximum water loss (D_{max} in grams)
- For both acclimatised and unacclimatised workers



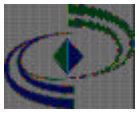
Required Sweat Rate Index - Criteria from ISO 7933

	Unacclimatised		Acclimatised	
	Alarm	Danger	Alarm	Danger
Maximum allowed core temperature increase (C)	0.8	1.0	0.8	1.0
w_{max} maximum skin wetedness	0.85	0.85	1.0	1.0
SW_{max} (g / h) maximum sweat rate	520	650	780	1040
Q_{max} (W.h / m2) maximum heat storage	50	60	50	60
D_{max} (g) maximum water loss	2600	3250	3900	5200

Duration limited exposure time (DLE)

$DLE1 = 60\ Q_{max} / (E_{req} - E_p)$ minutes

$DLE2 = 60\ D_{max} / SW_p$ minutes

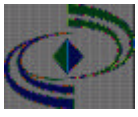


Evaluating Cold Stress

- Air temperature
- Air velocity
- Clothing

TLVs - Cold Stress

Air Temperature - Sunny Sky		No Noticeable Wind		5 mph Wind		10 mph Wind		15 mph Wind		20 mph Wind	
°C (approx)	°F (approx)	Max. work Period	No. of Breaks**	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks	Max. Work Period	No. of Breaks
-26° to -28°	-15° to -19°	(Norm breaks) 1		(Norm breaks) 1		75 min.	2	55 min.	3	40 min.	4
-29°to -31°	-20°to -24°	(Norm breaks) 1		75 min.	2	55 min.	3	40 min.	4	30 min.	5
-32° to -34°	-25°to -29°	75 min.	2	55 min.	3	40 min.	4	30 min.	5	Non-emergency work should cease	
-35° to -37°	-30° to -34°	55 min.	3	40 min.	4	30 min.	5	Non-emergency work should cease			
-38° to -39°	-35° to -39°	40 min.	4	30 min.	5	Non-emergency work should cease					
-40° to -42°	-40°to -44°	30 min.	5	Non-emergency work should cease							
-43° & below	-45° & below	Non-emergency work should cease									



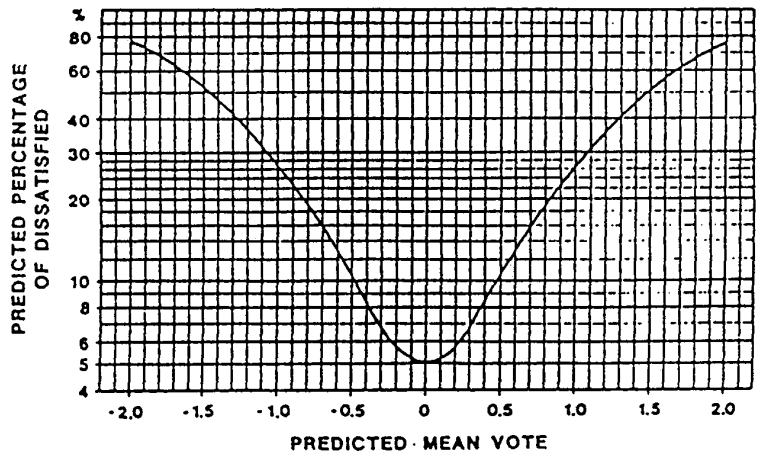
Fanger's PMV:PPD Index

- Based on extensive research
- Concluded that thermal comfort determined by :
  - mean skin temperature
  - sweat loss

Fanger's Voting Scale

+3 - hot
+2 - warm
+1 - slightly warm
0 - neutral
- 1 - slightly cool
- 2 - cool
- 3 - cold

$$PMV = (0{,}303\, e^{-0{,}036\,M} + 0{,}028)\ \{ (M - W) - 3{,}05 \times 10^{-3} \times [5\,733 - 6{,}99\,(M - W) - p_a] - 0{,}42 \times [(M - W) - 58{,}15] - 1{,}7 \times 10^{-5} M (5\,867 - p_a) - 0{,}001\,4 M\,(34 - t_a) - 3{,}96 \times 10^{-8} f_{cl} \times [(t_{cl} + 273)^4 - (\bar{t}_r + 273)^4] - f_{cl} h_c (t_{cl} - t_a)\ \}$$



Controlling Heat Stress

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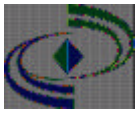
Controlling Heat Stress

- Eliminate source / process
- Engineering controls
- Administrative controls
- Personal protective equipment



Controlling Heat Stress

- Reduce metabolic rate
- Modify thermal environment

Radiant Heat

- Minimise size / intensity of source
- Reduce surface temperature
  - insulation
  - direct or indirect cooling
- Minimise emissivity
- Shielding

Convective Heat

- Insulate heat sources
- Extract hot air
- General ventilation
- Local cooling
- Increase air movement

Hot and Humid Environments

- Can be difficult to control
- Extraction
  - remove water vapour
- Increase air movement

Administrative measures

- Worker selection
- Acclimatisation
- Provide fluids
- Health surveillance
- Education and training

Protective Clothing

- Insulation

Protective Clothing

- Insulation
- Reflection
- Active cooling
- Hands / feet / face
- Respiratory protection

Controlling Cold Stress

- Local heating
- Wind shields
- Shelters
- Work : rest regimes
- Clothing
- Education & training

Clothing in Cold Environments

- Layering
  - outer layer - windproof, waterproof, permeable
  - middle layer - insulating
  - inner layer - wicking
- Protect head, hands and feet
- Ventilation