A work environment in which the temperature is not properly controlled can be uncomfortable. Extremes of either heat or cold can be more than uncomfortable—they can be dangerous.

- Heat stress, cold stress, and burns are major concerns of modern safety & health professionals.

Temperature, humidity, air distribution, personal preference, and acclimatization are all determinants of comfort in the workplace.

Determining optimum conditions is not a simple process.
**THERMAL COMFORT**

Conduction is the transfer of heat between two bodies that are touching, or from one location to another within a body.

Convection is transfer of heat from one location to another by way of a moving medium (gas or liquid).

Metabolic heat is produced within a body as a result of activity that burns energy.

Environmental heat is produced by external sources.

Radiant heat is the result of electromagnetic nonionizing energy transmitted through space, without the movement of matter within that space.

---

**HEAT STRESS**

Heat stress is the net heat load to which a worker may be exposed from the combined contributions of:

- Metabolic effect of work; clothing requirements,
- Environmental factors,
  - Air temperature, humidity, movement, and radiant heat.

Mild or moderate heat stress may cause discomfort and may adversely affect performance and safety.

As the heat stress approaches human tolerance limits, the risk of heat-related disorders increases.
HEAT STRESS

Widely used heat stress-related terms:

- **Heat exhaustion** - A physical state in which skin becomes clammy & moist and body temperature is still normal, or slightly higher than normal.
  - Results from fluid & salt loss through sweating, that are not properly replaced during exertion.

- **Heatstroke** - Skin becomes hot & dry, there is mental confusion, and may be seizures or convulsions.

- **Heat cramps** - muscle cramps that can occur when workers exert themselves sufficiently to lose fluids & salt through sweating, but replace only fluids by drinking large amounts of water containing no salt.

- **Heat syncope or fainting** - Workers who exert themselves in a hot environment will sometimes faint.
  - Especially those not accustomed to working in the environment.

- **Heat rash** - Workers in a hot environment in which sweat does not evaporate can develop a prickly rash.
  - Periodic rest breaks in a cool environment that allows sweat to evaporate will prevent heat rash.
HEAT STRESS

Widely used heat stress-related terms:

- **Work tolerance time (WTT)** - A formula to determine what steps can be taken to allow a worker to safely perform required tasks, in the environment in question, for the time required.
  - Considers factors such as temperature, humidity, level of energy expended in performing the task, rest periods, and personal protective equipment (PPE).

- **Moisture vapor transfer rate (MVTR)** - A measure of the ability of the fabric used in making PPE to dissipate heat.
  - Even the lightest cotton fabric is less capable of dissipating heat when the unclothed body is used for baseline comparisons.
  - The MVTR of impermeable fabric is zero (because the fabric does not allow the skin to “breathe”).
  - The higher the MVTR, the better in hot environments.

HEAT STRAIN

Heat strain is the overall physiological response resulting from heat stress.

Acclimatization is a gradual physiological adaptation that improves an individual’s ability to tolerate heat stress.
Recognizing Heat Strain

Signs of excessive heat strain:
A sustained rapid heart rate.
  • 180 beats per minute, minus the employee's age in years.
Core body temperature is greater than 38.5 deg C.
Sudden & severe fatigue, nausea, dizziness, or light-headedness.

Employees are at greater risk of excessive heat strain if they experience any of the following:
  Profuse sweating that continues for hours.
  Weight loss of more than 1.5% of body weight during one work shift.
  Urinary sodium excretion of less than 50 moles.
    • Over a 24-hour period.

Clothing

Heat is best removed from the body when there is free movement of cool dry air over the skin surface.
Encapsulating suits and clothing, impermeable or highly resistant to the flow of air & water vapor multiply the potential for heat strain.

The wet bulb globe temperature (WBGT) of working conditions should be increased by 3.5 deg C for employees wearing cloth overalls.
  • WBGT is influenced by air temperature, radiant heat & humidity.
Clothing

**WBGT values can be calculated using this formula:**

<table>
<thead>
<tr>
<th>Situation</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Exposed to Direct Sunlight</td>
<td>[ \text{WBGT} = 0.7 \ T_{nwb} + 0.3 \ T_g ]</td>
</tr>
<tr>
<td>Exposed to Direct Sunlight</td>
<td>[ \text{WBGT} = 0.7 \ T_{nwb} \text{ to } 0.2 \ T_g + 0.1 \ T_{db} ]</td>
</tr>
<tr>
<td>( T_{nwb} )</td>
<td>Natural wet bulb temperature</td>
</tr>
<tr>
<td>( T_g )</td>
<td>Globe temperature</td>
</tr>
<tr>
<td>( T_{db} )</td>
<td>Dry bulb (air) temperature</td>
</tr>
</tbody>
</table>

WBGT must be adjusted for clothing, work demands and acclimatization state—ensure core body does not rise above 38 deg C.

---

**Screening Criteria (°C)**

<table>
<thead>
<tr>
<th>Work Demands</th>
<th>Light Work</th>
<th>Moderate Work</th>
<th>Heavy Work</th>
<th>Very Heavy Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% Work</td>
<td>27.5</td>
<td>25.0</td>
<td>22.5</td>
<td>—</td>
</tr>
<tr>
<td>75% Work</td>
<td>29.0</td>
<td>26.5</td>
<td>24.5</td>
<td>—</td>
</tr>
<tr>
<td>25% Rest</td>
<td>30.0</td>
<td>28.0</td>
<td>26.5</td>
<td>25.0</td>
</tr>
<tr>
<td>50% Work</td>
<td>31.0</td>
<td>29.0</td>
<td>28.0</td>
<td>26.5</td>
</tr>
<tr>
<td>50% Rest</td>
<td>30.0</td>
<td>28.0</td>
<td>26.5</td>
<td>25.0</td>
</tr>
</tbody>
</table>

Once the WBGT has been calculated and adjusted for clothing, the figures may be used for factoring in work demands and acclimatization.
Clothing

Once the WBGT has been calculated and adjusted for clothing, the figures may be used for factoring in work demands and acclimatization.

<table>
<thead>
<tr>
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<th>Light Work</th>
<th>Moderate Work</th>
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<td>29.5</td>
<td>28.5</td>
<td>27.5</td>
</tr>
<tr>
<td>50% Work</td>
<td>32.5</td>
<td>31.0</td>
<td>30.0</td>
<td>29.5</td>
</tr>
<tr>
<td>75% Rest</td>
<td>33.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heat Stress Management - General Controls

ACGIH recommends the following general controls:

- Provide accurate verbal and written instructions, training programs, & information about heat stress and strain.
- Encourage drinking small volumes of cool water about every 20 minutes.
- Permit self-limitation of exposure & encourage coworker observation to detect signs & symptoms of heat strain.
- Counsel & monitor employees who take medications that may compromise normal cardiovascular, blood pressure, body temperature, renal, or sweat gland functions.
  - And those who abuse or who are recovering from the abuse of alcohol and other intoxicants.
- Encourage healthy lifestyles, ideal body weight, and electrolyte balance.
Heat Stress Management - General Controls
ACGIH recommends the following general controls:

- Adjust expectations of those returning to work after absence from heat stress situations and encourage consumption of salty foods.
  - With approval of the employee’s physician, if on a salt-restricted diet.
  - Consider replacement medical screening to identify those susceptible to systemic heat injury.

Heat Stress Management - Specific Controls
ACGIH recommends the following specific controls:

Establish engineering controls that reduce metabolic rate.
  - Provide general air movement; Shield radiant heat sources.

Reduce process heat and water-vapor release.
Consider administrative controls that set acceptable exposure times, allow sufficient recovery & limit physiological strain.
Consider personal protection demonstrated effective for the specific work practices and conditions at the location.
COLD STRESS

Excessive exposure to cold can cause hypothermia, which can be fatal.
Excessive exposure to cold stress can result in impaired judgment, reduced alertness, and poor decision making.
Acute cold stress can cause reduced muscular function, decreased tactile sensitivity, reduced blood flow, and thickening of the synovial fluid.
Chronic cold stress can lead to reduced functioning of the peripheral nervous system.
When work is to be performed in an environment with an air temperature of 4 deg C or less, total body protective clothing is advisable.

COLD STRESS

### Effects of Reducing the Core Body Temperature

<table>
<thead>
<tr>
<th>Core Temperature</th>
<th>°C</th>
<th>°F</th>
<th>Body’s Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.6</td>
<td>99.6</td>
<td>Normal rectal temperature</td>
<td></td>
</tr>
<tr>
<td>36.0</td>
<td>96.8</td>
<td>Metabolic rate increases</td>
<td></td>
</tr>
<tr>
<td>35.0</td>
<td>95.0</td>
<td>Pronounced shivering</td>
<td></td>
</tr>
<tr>
<td>33.0</td>
<td>91.4</td>
<td>Severe hypothermia</td>
<td></td>
</tr>
<tr>
<td>30.0</td>
<td>86.0</td>
<td>Progressive loss of consciousness begins</td>
<td></td>
</tr>
<tr>
<td>24.0</td>
<td>75.2</td>
<td>Pulmonary edema</td>
<td></td>
</tr>
<tr>
<td>20.0</td>
<td>68.0</td>
<td>Cardiac standstill</td>
<td></td>
</tr>
</tbody>
</table>
Preventing Cold Stress

Whether employees are exposed to cold air or are immersed in cold water, wind can magnify the level of cold stress. The phenomenon often referred to as **windchill**.

---

### Cooling Effect of Wind

<table>
<thead>
<tr>
<th>Wind Speed (in mph)</th>
<th>Actual Temperature (°F) and Equivalent Temperatures (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>48</td>
</tr>
<tr>
<td>15</td>
<td>36</td>
</tr>
<tr>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>35</td>
<td>27</td>
</tr>
</tbody>
</table>

---

Preventing Cold Stress

At equivalent air temperatures of 2 deg C employees who are immersed in water or whose clothing gets wet should be treated for hypothermia immediately.

---

### TLVs for a Four-Hour Shift

<table>
<thead>
<tr>
<th>Air Temperature</th>
<th>No Wind</th>
<th>5 mph Wind</th>
<th>10 mph Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>°F</td>
<td>Max Work Time</td>
<td>No. of Breaks</td>
<td>Max Work Time</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>–32 to –34</td>
<td>75 Min.</td>
<td>2</td>
<td>55 Min.</td>
</tr>
<tr>
<td>–35 to –37</td>
<td>55 Min.</td>
<td>3</td>
<td>40 Min.</td>
</tr>
<tr>
<td>–38 to –39</td>
<td>40 Min.</td>
<td>4</td>
<td>30 Min.</td>
</tr>
</tbody>
</table>

Note: This applies to workers properly dressed in dry clothing.
Preventing Cold Stress

Strategies that can decrease hazards of cold stress:

When working in a setting in which wind is a factor, reduce wind effect with a windscreen or wind-breaking clothing.

When working in a cold setting in which clothing may get wet, apply one or more of the following strategies:

- For light work, wear an outer layer of impermeable clothing.
- For heavier work, wear an outer layer that is water-repellent, but not impermeable (change outerwear as it becomes wet).
- Select outer garments that are ventilated to prevent internal wetting from sweat.
- If clothing gets wet before going into the cold environment, change first.
- Change socks daily or more often to keep them dry.
- Use vapor barrier boots to help keep the feet dry.

Preventing Cold Stress

- Strategies that can decrease hazards of cold stress:
  
  When working in a cold setting, use auxiliary heat applied directly to the hands and feet.
  Use facial protection to prevent cold stress to the face and lungs.
  If protective clothing is not available, modify or suspend work until conditions change or clothing is available.
  When work is to be performed in an environment with an air temperature of -12 deg C:
    
    Employees should be under continuous observation.
    Work rate should be paced to avoid sweating.
    When heavy work is necessary, employees should take frequent warming breaks in heated shelters.
Preventing Cold Stress

- Strategies that can decrease hazards of cold stress:
  - If clothing becomes wet—internally or externally—it should be changed during a break.
  - Do not allow new employees to work full time in these conditions without several days to become accustomed to conditions & necessary protective clothing.
  - When determining the required work level for employees, consider the weight and bulkiness of protective clothing.
  - Organize work in cold environments to minimize long periods of sitting or standing still.
  - Never use unprotected metal chairs or seats.
  - Make sure employees working in a cold environment have been trained in safety & health procedures.

Employees should be medically certified as suitable for work in such conditions if routinely exposed to:

Less than 24 deg C, with wind speeds less than 5 mph.

Less than 18 deg C, with wind speeds greater than 5 mph.

Training Checklist for Employees Who Work in a Cold Environment

- ✓ Proper warming procedures
- ✓ Applicable first-aid procedures
- ✓ Protective clothing requirements and proper use of protective clothing
- ✓ Proper eating habits
- ✓ Proper drinking habits (for example, avoid caffeine and other stimulants)
- ✓ Recognizing of cold stress and strain (for example, impending frostbite and impending hypothermia)
- ✓ Safe work processes
BURNS AND THEIR EFFECTS

Human skin is the tough, continuous outer covering of the body, consisting of two main layers:

The outer layer, which is known as the **epidermis**.
The inner layer, known as the **dermis**, or **corium**.

- The dermis is connected to the underlying subcutaneous tissue.
- Burns disrupt the normal functioning of the skin, the deeper the penetration, the more severe the burn.
  - Burn severity of a burn depends on the depth the burn penetrates, location of the burn, age of the victim, and amount of burned area.

**Human Skin**

Protection from fluid loss, water penetration, ultraviolet radiation, and infestation by microorganisms is a major function of the skin.
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Sensory functions of touching, sensing cold, feeling pain & sensing heat involve the skin.

Skin helps regulate body heat through the sweating process.
Human Skin

Protection from fluid loss, water penetration, ultraviolet radiation, and infestation by microorganisms is a major function of the skin. Sensory functions of touching, sensing cold, feeling pain & sensing heat involve the skin. Skin helps regulate body heat through the sweating process. Excreted sweat removes electrolytes and certain toxins.

By giving off minute amounts of carbon dioxide & absorbing small amounts of oxygen, the skin aids slightly in respiration. Burns can disrupt any or all of these functions, depending on their severity.
Severity of Burns

The most widely used method of classifying burns is by degree—first-, second-, or third-degree burns.

First-degree burns are minor, and result only in a mild inflammation of the skin, known as erythema.

- Sunburn is a common form of first-degree burn.

Second-degree burns are easily recognizable from the blisters that form on the skin.

- If superficial, the skin will heal with little or no scarring.
- A deeper burn will form a thin layer of coagulated, dead cells, that feels leathery to the touch.

Third-degree burns are very dangerous and can be fatal.

- Penetrates through both the epidermis and the dermis.
- A deep third-degree burn will penetrate body tissue.

Severity of Burns

Third-degree burns can be caused by both moist and dry hazards.

- Moist hazards—such as steam & hot liquids—cause burns that appear white.
- Dry hazards—such as fire & hot objects/surfaces—cause burns that appear black and charred.
Severity of Burns

Amount of surface area covered is a critical concern. Expressed as a percentage of body surface area (BSA).

Burns covering over 75% of BSA are usually fatal.

<table>
<thead>
<tr>
<th>Body Part</th>
<th>Percentage of BSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right arm</td>
<td>9%</td>
</tr>
<tr>
<td>Left arm</td>
<td>9%</td>
</tr>
<tr>
<td>Head/neck</td>
<td>9%</td>
</tr>
<tr>
<td>Right leg</td>
<td>18%</td>
</tr>
<tr>
<td>Left leg</td>
<td>18%</td>
</tr>
<tr>
<td>Back</td>
<td>18%</td>
</tr>
<tr>
<td>Chest/stomach</td>
<td>18%</td>
</tr>
<tr>
<td>Perineum</td>
<td>1%</td>
</tr>
</tbody>
</table>

Using burn-degree classifications in conjunction with BSA percentages, burns can be classified further as minor, moderate, or critical.

Minor Burns

All first-degree burns are considered minor. Second-degree burns covering less than 15% of the body are considered minor. Third-degree burns can be considered minor provided they cover only 2% or less of BSA.
Moderate Burns

Second-degree burns that penetrate the epidermis and cover 15% or more of BSA are considered moderate.

Those that penetrate the dermis & cover from 15 to 30% of BSA are considered moderate.

Third-degree burns can be considered moderate provided they cover less than 10% of BSA.

And are not on the hands, face, or feet.

Critical Burns

Second-degree burns covering more than 30% percent of BSA or third-degree burns covering over 10% of BSA are considered critical.

Small-area third-degree burns to hands, face, or feet are considered critical due to greater potential for infection to these areas by their nature.

Burns complicated by other injuries (fractures, soft tissue damage, and so on) are considered critical.
CHEMICAL BURNS

Hazards of chemical burns are very similar to those of thermal burns.

They destroy body tissue, and extent of destruction depends on the severity of the burn.

Chemical burns continue to destroy body tissue until the chemicals are washed away completely.

CHEMICAL BURNS

Many concentrated chemical solutions have an affinity for water, and when in contact with body tissue, they withdraw water so rapidly the original chemical composition of the tissue is destroyed.

The more concentrated the solution, the more rapid the destruction.

• Severity of the burn depends on these factors:
  – Corrosive capability of the chemical.
  – Concentration of the chemical.
  – Temperature of the chemical or the solution in which it is dissolved.
  – Duration of contact with the chemical.
Effects of Chemical Burns

Different chemicals have different effects on the body, the primary burn hazards being infection, loss of body fluids, and shock.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Potential Harmful Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>Tissue damage</td>
</tr>
<tr>
<td>Liquid bromide</td>
<td>Corrosive effect on the respiratory system and tissue damage</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Tissue hardening</td>
</tr>
<tr>
<td>Lime</td>
<td>Dermatitis and eye burns</td>
</tr>
<tr>
<td>Methylbromide</td>
<td>Blisters</td>
</tr>
<tr>
<td>Nitric/sulfuric acid mixture</td>
<td>Severe burns and tissue damage</td>
</tr>
<tr>
<td>Oxalic acid</td>
<td>Ulceration and tissue damage</td>
</tr>
<tr>
<td>White phosphorus</td>
<td>Ignites in air causing thermal burns</td>
</tr>
<tr>
<td>Silver nitrate</td>
<td>Corrosive/caustic effect on the skin</td>
</tr>
<tr>
<td>Sodium (metal)</td>
<td>Ignites with moisture causing thermal burns</td>
</tr>
<tr>
<td>Trichloroacetic acid</td>
<td>Tissue damage</td>
</tr>
</tbody>
</table>

Effects of Chemical Burns - Infection/Fluid Loss

The risk of infection is high with chemical burns, as the body’s primary defense against infection-causing microorganisms (the skin) is penetrated.

Infection in a burn wound can cause septicemia (blood poisoning).

• Body fluid loss in second- and third-degree burns can be serious.
  – With second-degree burns, blisters on the skin often fill with fluid seeping out of damaged tissue under the blister.
  – With third-degree burns, fluids are lost internally, and can cause the same complications as a hemorrhage.
    • If these fluids are not replaced properly, the burns can be fatal.
Shock

Shock is a depression of the nervous system, and can be caused by physical or psychological trauma.

In cases of serious burns, it may be caused by the intense pain that can occur when skin is burned away.

- Shock from burns can come in two forms:
  - Primary shock, which is the first stage and results from physical pain or psychological trauma.
  - Secondary shock, which comes later, caused by a loss of fluids and plasma proteins as a result of the burns.

First Aid for Chemical Burns

The proper response to chemical burns is to wash off the chemical by flooding the burned areas with copious amounts of water as quickly as possible.

In the case of chemical burns to eyes, continuous flooding should continue for at least 15 minutes.

Eyelids should be held open to ensure that chemicals are not trapped under them.

If chemicals have saturated the employee’s clothes, they must be removed quickly, while flooding the body or the affected area.

If necessary clothing should be ripped or cut off.
First Aid for Chemical Burns

Health and safety professionals should ensure that special eye wash and shower facilities are available wherever employees handle chemicals.