Heat Stress: Exposure Hazards, Health Effects, and Measurement Protocol

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INTRODUCTION

Define heat stress, heat strain, and heat-related illness.

Overview of a heat stress and strain program/policy (4 major parts)

• Applicability
• Heat Assessment
• Heat Stress Controls
• Awareness Training

CHUBB
Heat Stress: Exposure Hazards, Health Effects, and Measurement Protocol

HEAT STRESS AND STRAIN

**Heat Stress** - the net heat load to which a worker is exposed. Physical exertion, environmental factors, and clothing worn all contribute to heat stress.

**Heat Strain** - The body’s physiological response to heat stress (e.g., sweating).

HEAT-RELATED ILLNESS

- **Heat Stroke** (most serious) – Medical Emergency
- **Heat Exhaustion** (precursor to heat stroke)
- **Heat Cramps**
- **Heat Syncope**
- **Heat Rash** (skin irritation)
HEAT-RELATED ILLNESS

Heat Stroke - Symptoms

• Hot, dry skin OR profuse sweating, flushed skin
• Nausea and vomiting
• Throbbing headache
• High body temperature ≥ 104 °F or 40 °C rectally
• Altered mental state or behavior
• Rapid breathing
• Racing heart rate

Source: Mayo Clinic

HEAT-RELATED ILLNESS

Heat Stroke - What can you do?

If you think a person may be experiencing heatstroke, seek immediate medical help. Call 911 or your local emergency services number.

Take immediate action to cool the overheated person while waiting for emergency treatment.

• Get the person into shade or indoors.
• Remove excess clothing.
• Cool the person with whatever means available — put in a cool tub of water or a cool shower, spray with a garden hose, sponge with cool water, fan while misting with cool water, or place ice packs or cold, wet towels on the person’s head, neck, armpits and groin

Source: Mayo Clinic

Photo Source: Lejeune.marines.mil
Free to use and share, even commercially
HEAT-RELATED ILLNESS

Heat Exhaustion - Symptoms

- Cool, moist skin with goose bumps when in the heat
- Heavy sweating
- Faintness
- Dizziness
- Fatigue
- Weak, rapid pulse
- Low blood pressure upon standing
- Muscle cramps
- Nausea
- Headache

Heat Stroke - Symptoms

- Hot, dry skin OR profuse sweating, flushed skin
- High body temperature ≥ 104 °F or 40 °C rectally
- Altered mental state or behavior
- Rapid breathing
- Racing heart rate
- Nausea and vomiting
- Throbbing headache

Source: Mayo Clinic

HEAT-RELATED ILLNESS

Heat Exhaustion - What Can You Do?

- Stop all activity and rest
- Move to a cooler place
- Drink cool water or sports drinks
- Contact your doctor if your signs or symptoms worsen or if they don't improve within one hour.


- Get the person into shade or indoors.
- Remove excess clothing.
- Cool the person with whatever means available — put in a cool tub of water or a cool shower, spray with a garden hose, sponge with cool water, fan while misting with cool water, or place ice packs or cold, wet towels on the person's head, neck, armpits and groin

Source: Mayo Clinic
HEAT-RELATED ILLNESS

Heat Cramps - Symptoms

Muscles most often affected include those of your
- Calves
- Arms
- Abdominal wall and back,
- Any other muscle group involved in exercise.

Source: Mayo Clinic

Heat Cramps – What Can You Do?

Rest briefly and cool down
Drink clear juice or an electrolyte-containing sports drink
Practice gentle, range-of-motion stretching and gentle massage of the affected muscle group
Don’t resume strenuous activity for several hours or longer after heat cramps go away
Call your doctor if your cramps don’t go away within one hour or so

Source: Mayo Clinic
HEAT-RELATED ILLNESS

Heat Syncope and Exercise-Associated Collapse

Heat syncope is a feeling of lightheadedness or fainting caused by high temperatures
* often occurring after standing for a long period of time, or
* standing quickly after sitting for a long period of time.

Exercise-associated collapse, feeling lightheaded or fainting immediately after exercising.

Source: Mayo Clinic

Photo Source: health.mil
Free to use and share, even commercially

HEAT-RELATED ILLNESS

Heat Rash

Heat Rash = Prickly Heat = Miliaria

Symptoms

Adults usually develop heat rash in skin folds and where clothing causes friction.
In infants, the rash is mainly found on the neck, shoulders and chest. It can also show up in the armpits, elbow creases and groin.

Source: Mayo Clinic

Both Photos Source: commons.wikimedia.org
Free to use and share, even commercially
HEAT-RELATED ILLNESS

Types of Heat Rash

- Miliaria Crystallina – the mildest form of heat rash affects the sweat ducts in the top layer of skin.
- Miliaria Rubra occurs deeper in the skin, is sometimes called prickly heat.
- Miliaria Postulosa – where the fluid-containing sacs (vesicles) of miliaria rubra become inflamed and pus-filled (pustular).
- Miliaria Profunda, a less common form of heat rash, affects the dermis, a deeper layer of skin.

Source: Mayo Clinic

HEAT-RELATED ILLNESS

Heat Rash – When to See a Doctor

- Increased pain, swelling, redness or warmth around the affected area
- Pus draining from the lesions
- Swollen lymph nodes in the armpit, neck or groin
- A fever or chills

Source: Mayo Clinic
HEAT-RELATED ILLNESS

Many risk factors contribute to the risk for heat-related illness.

Management commitment to identify and reduce exposures to heat stress hazards.

Based on environmental conditions:

- Weather
- Indoor
- Temperature and Humidity
- Clothing, and
- Workload.

Should include policies/procedures for controlling heat hazards.
HEAT-RELATED ILLNESS PREVENTION PROGRAM

Applicability
Heat Assessment
Heat Stress Controls
Awareness Training

APPLICABILITY

Where ambient temperatures may exceed the action limit
Federal OSHA – Guidance and the General Duty Clause
State OSHA Regulations
- California, 8 CCR 3395
- Minnesota Rules 5205.0110, General Ventilation and Temperature Requirements
- Washington State, WAC 296-62-095 through 296-62-09560

Action limit = Ambient heat level at 85° F / 29° C (Federal) or 80 ° F / 27 ° C (California) and 1 or more of the following conditions:
- Direct solar / radiant heat load
- 70% relative humidity
- Heavy or strenuous physical exertion or thick inner or outer garments

When the action limit may be exceeded, an assessment shall be conducted and control measures implemented as appropriate.
HEAT ASSESSMENT - METHODS

1. Wet Bulb Globe Temperature (WBGT) using the American Conference of Governmental Industrial Hygienists (ACGIH) criteria, compared to the threshold limit value (TLV) and action limit.

2. Local weather forecast (dry bulb temperature and humidity) when outdoor weather conditions are representative of conditions in the workplace.


WET BULB GLOBE TEMPERATURE

What is WBGT?

- Used by ACGIH and NIOSH
- The WBGT is a combined temperature derived from:
  - Ambient temperature (dry bulb temperature)
  - Humidity (wet bulb temperature)
  - Radiant heat (globe temperature)
**WET BULB GLOBE TEMPERATURE**

WBGT values are calculated using one of the following equations:

With direct exposure to sunlight:

\[ \text{WBGT}_{\text{out}} = 0.7 \ T_{\text{nwb}} + 0.2 \ T_g + 0.1 \ T_{\text{db}} \]

Without direct exposure to the sun:

\[ \text{WBGT}_{\text{in}} = 0.7 \ T_{\text{nwb}} + 0.3 \ T_g \]

Where:
- \( T_{\text{nwb}} \) = natural wet-bulb temperature
- \( T_g \) = globe temperature
- \( T_{\text{db}} \) = dry-bulb (air) temperature

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**ACGIH CLOTHING ADJUSTMENT FACTORS**

**TABLE 1. Clothing-Adjustment Factors for Some Clothing Ensembles**

<table>
<thead>
<tr>
<th>Clothing Type</th>
<th>Addition to WBGT</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work clothes (long sleeve shirt and pants)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cloth (woven material) coveralls</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Double-layer woven clothing</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>SMS polypropylene coveralls</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Polyolefin coveralls</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Limited-use vapor-barrier coveralls</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>

*These values must not be used for completely encapsulating suits, often called Level A. Clothing Adjustment Factors cannot be added for multiple layers. The coveralls assume that only modesty clothing is worn underneath, not a second layer of clothing.*

Source: ACGIH® Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices 2020
**WET BULB GLOBE TEMPERATURE**

Table 2. Screening Criteria for TLV® and Action Limit for Heat Stress Exposure

<table>
<thead>
<tr>
<th>Allocation of Work in a Cycle of Work and Recovery</th>
<th>TLV (WBGT values in °C)</th>
<th>Action Limit (WBGT values in °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Light</td>
<td>Moderate</td>
</tr>
<tr>
<td>75% to 100%</td>
<td>31.0</td>
<td>28.0</td>
</tr>
<tr>
<td>50% to 75%</td>
<td>31.0</td>
<td>29.0</td>
</tr>
<tr>
<td>25% to 50%</td>
<td>32.0</td>
<td>30.0</td>
</tr>
<tr>
<td>0% to 25%</td>
<td>32.5</td>
<td>31.5</td>
</tr>
</tbody>
</table>

Source: ACGIH® Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices 2020

**METABOLIC RATE CATEGORIES**

**TABLE 3.** Metabolic Rate Categories and the Representative Metabolic Rate with Example Activities

<table>
<thead>
<tr>
<th>Category</th>
<th>Metabolic Rate (W)</th>
<th>Example Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>115</td>
<td>Sitting with light manual work with hands or hands and arms, and driving. Standing with some light arm work and occasional walking</td>
</tr>
<tr>
<td>Light</td>
<td>180</td>
<td>Sustained moderate hand and arm work, moderate arm and leg work, moderate arm and trunk work or light pushing and pulling. Normal walking.</td>
</tr>
<tr>
<td>Moderate</td>
<td>300</td>
<td>Intense arm and trunk work, carrying, shoveling, manual sawing, pushing and pulling heavy loads; and walking at a fast pace.</td>
</tr>
<tr>
<td>Heavy</td>
<td>415</td>
<td>Very intense activity as fast to maximum pace</td>
</tr>
<tr>
<td>Very Heavy</td>
<td>520</td>
<td></td>
</tr>
</tbody>
</table>

* The effect of body weight on the estimated metabolic rate can be accounted for by multiplying the estimated rate by the ratio of actual body weight divided by 70 kg. (154 lb.).

Source: ACGIH® Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices 2020

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**Heat Stress: Exposure Hazards, Health Effects, and Measurement Protocol**

8/05/2020
WET BULB GLOBE TEMPERATURE

WBGT Exposure Assessment

| Location or Task Description | Maintenance | 2 | 3 | 4 | 5 | Rest Area
|-----------------------------|-------------|---|---|---|---|----------|
| Clothing Encumbrance         | Work Clothes | Work Clothes | Work Clothes | Work Clothes | Work Clothes | Work Clothes
| Metabolic Rate              | 300         | 27 | 27 | 27 | 27 | 27
| Exposure Time [min]         | 75          | 75 | 75 | 75 | 75 | 75
| Environment (Enter Values)  | 82.5
| WBT [°F]                    | 86.9        | 86.9 | 86.9 | 86.9 | 86.9 | 86.9
| Enter WBGT or Temperature   | 0°          | 0° | 0° | 0° | 0° | 0°
| Task                        | 12          | 12 | 12 | 12 | 12 | 12

* Minimum Recovery Time

Heat Stress: Exposure Hazards, Health Effects, and Measurement Protocol

HEAT ASSESSMENT EXAMPLE
DIRECT MEASUREMENT WBGT

A chemical packaging facility located in Arizona, June 26, 2018.

- Packaging inorganic acids, alkali, and H2Os
- Most dispensing occurs in an air conditioned building
- One outdoor dispensing platform
  - Covered shelter open on two sides for vehicle movement
**TABLE 1**

<table>
<thead>
<tr>
<th>Location</th>
<th>Group No.</th>
<th>Measurement Period</th>
<th>Average Measured WBGT °C</th>
<th>Range Measured WBGT °C</th>
<th>ACGIH TLV (°C)</th>
<th>ACGIH Action Limit (°C)</th>
<th>Screening Criteria (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor Mix Platform Early Morning</td>
<td>A1</td>
<td>6:00 – 8:01 (91)</td>
<td>21.1</td>
<td>19.0 – 21.6</td>
<td>28.0</td>
<td>25.0</td>
<td>No clothing adjustment</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>8:19 – 8:23 (24)</td>
<td>16.6</td>
<td>16.4 – 16.8</td>
<td>28.0</td>
<td>25.0</td>
<td>No clothing adjustment</td>
</tr>
<tr>
<td>Compound Room</td>
<td>A3</td>
<td>8:33 – 9:31 (56)</td>
<td>15.7</td>
<td>15.0 – 16.7</td>
<td>28.0</td>
<td>25.0</td>
<td>No clothing adjustment</td>
</tr>
<tr>
<td>Dispensing Room</td>
<td>A4</td>
<td>9:40 – 10:40 (60)</td>
<td>31.6</td>
<td>26.1 – 34.9</td>
<td>28.0</td>
<td>25.0</td>
<td>Measuring inside the suit</td>
</tr>
<tr>
<td>Inside Coveralls Employee Name Dispensing Room</td>
<td>A5</td>
<td>10:46 – 13:12 (112)</td>
<td>25.3</td>
<td>19.7 – 26.2</td>
<td>28.0</td>
<td>25.0</td>
<td>No clothing adjustment</td>
</tr>
</tbody>
</table>

**NOTES:**

All values shown in this table represent moderate work and a 75% - 100% work/recovery cycle.

Bold denotes the value exceeds the Action Limit; Bold and Italic together denotes the value exceeds the TLV.

*Limited use vapor-barrier coveralls currently worn as PPE for HF.
WET BULB GLOBE TEMPERATURE

Figure 1. Evaluating heat stress and strain

Goal of the TLV is to maintain body core temperature below 38°C for the average person.

Source: ACGIH® Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices 2020

HEAT ASSESSMENT
LOCAL WEATHER FORECAST

Local weather forecast (dry bulb temperature and humidity) when outdoor weather conditions are representative of conditions in the workplace.

www.weatherunderground.com

OSHA – NIOSH Heat Safety Tool App
HEAT ASSESSMENT
HEAT STRESS CALCULATOR SCREENING TOOL

• This tool is intended as a screening survey to identify heat sources that may contribute to potential heat stress conditions in the workplace.

• Developed based from the following references:
  - U.S. National Weather Service
  - U.S. NIOSH Publication 86-113 “Occupational Exposure to Hot Environments”
  - HSE RESEARCH REPORT 008 – “The development of a practical heat stress assessment methodology for use in UK industry”, Damian Bethea & Ken Parsons, Department of Human Sciences, Loughborough University
  - U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) – Heat Stress Assessment

The dry-bulb temperature (DBT) is the ambient air temperature measured by a thermometer freely exposed to the air but shielded from radiation and moisture.

The % relative humidity measurement may be obtained through a local weather station, however best to measure with appropriate meter.
HEAT ASSESSMENT
ACCLIMATIZATION

To adapt to a new temperature or climate such that there is a lower or no increase in body core temperature, little or no change in heart rate and less salt loss.

- Previous experience in hot jobs,
  - 50% exposure on Day 1
  - 60% on Day 2
  - 80% on Day 3 and
  - 100% on Day 4.
- For new workers,
  - 20% or less on Day 1 and
  - a daily increase of no more than 20% in exposure time each additional day.
- Note: loss of acclimatization begins when the activity under those heat stress conditions is discontinued. The loss becomes noticeable after 4 days and may be completely lost in three to four weeks.

HEAT ASSESSMENT
CLOTHING

Evaluate impact of clothing (FRC) and PPE

- Light or thick garments
- Full body chemical protective Suits
- SCBA
HEAT ASSESSMENT

WORKLOAD

Evaluate the level of **physical workload**

**Light Work:** sitting with light manual work with hands, or hands and arms, and driving. Standing with some light hand and arm work and occasional walking.

**Moderate Work:** Sustained moderate hand and arm work, moderate arm and leg work, moderate arm and trunk work, or light pushing and pulling. Normal walking.

**Heavy Work:** Intense arm and trunk work, carrying, shoveling, manual sawing, pushing and pulling heavy loads and walking at a fast pace.

HEAT ASSESSMENT

**RISK BASED ON RESULTS**

**Heat-Related Illness Risk Level**

**None** - Adjusted Heat Index less than action limit (90°F / 32°C). No adverse impact expected.

**Low Risk** - Adjusted Heat Index more than 90°F / 32°C and less than 104°F /40°C. Heat exhaustion or cramps possible without controls.

**Medium Risk** - Adjusted Heat Index > 104°F / 40°C and < 130°F / 54°C. Heat cramps or exhaustion likely without controls. Heat stroke possible without controls.

**High Risk** - Adjusted Heat Index more than 130°F / 54°C. Heat stroke likely without controls.
Detailed Analysis

Detailed analysis - can get complicated. Involves using the effective WBGT (WBGT plus clothing factor) and metabolic rate and involves the use of rational models to measure (i.e., ISO 7933). Usually leads to implementing general controls and job-specific controls anyway.

The ACGIH Screening criteria require the minimal set of data to make a determination, the detailed analysis requires more data about the exposures.

If no data available for detailed analysis, conduct physiological monitoring to assess the degree of heat strain.
HEAT-STRAIN

PHYSIOLOGICAL MONITORING

Heat Strain

One or more of the following measures may mark excessive heat strain, and an individual's exposure to heat stress should be discontinued when any of the following occur:

- Heart rate > 180 bpm minus individual's age in years;
- Core temp. > 38.5°C (101.3°F) acclimatized and healthy; or
- Core temp. > 38°C (100.5°F) unacclimatized; or
- Recovery heart rate at one minute after a peak work effort is greater than 120 bpm; or
- There are symptoms of sudden and severe fatigue, nausea, dizziness, or lightheadedness

PERSONAL HEAT STRESS

MONITORING RESULTS

<table>
<thead>
<tr>
<th>Employee / Location</th>
<th>Graph Number</th>
<th>Sampling Period (minutes)</th>
<th>Measured Ear Temperature</th>
<th>Normal Ear Temp °C</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employee #1 Dispense Room and Alkaline Room</td>
<td>P1</td>
<td>5:09 – 12:09 (370)</td>
<td>36.5</td>
<td>36.3 – 36.8</td>
<td>37</td>
</tr>
<tr>
<td>Employee #2 Compound Room</td>
<td>F2</td>
<td>6:26 – 12:58 (392)</td>
<td>36.5</td>
<td>35.9 – 37.4</td>
<td>37</td>
</tr>
<tr>
<td>Employee #3 Alkaline Room and Other</td>
<td>F3</td>
<td>6:31 – 12:23 (362)</td>
<td>35.7</td>
<td>34.9 – 36.2</td>
<td>37</td>
</tr>
<tr>
<td>Employee #4 Dispensing Room</td>
<td>P4</td>
<td>6:44 – 12:33 (349)</td>
<td>36.3</td>
<td>35.3 – 37.3</td>
<td>37</td>
</tr>
<tr>
<td>Employee #5 Dispensing Room</td>
<td>F5</td>
<td>6:17 – 12:37 (394)</td>
<td>37.8</td>
<td>36.4 – 38.7</td>
<td>37</td>
</tr>
<tr>
<td>Employee #6 Shipping</td>
<td>F6</td>
<td>7:48 – 12:43 (293)</td>
<td>36.9</td>
<td>33.4 – 37.3</td>
<td>37</td>
</tr>
</tbody>
</table>

NOTE:

*Range and average values have been corrected where it is obvious that the ear plug fit was compromised. Most of personal heat stress measurements may be an underestimation, due to difficulty in maintaining a good earplug fit. A temperature differential greater than 10°C between the ear temperature and the mold temperature suggests an insufficient seal, decreasing accuracy.
HEAT-STRAIN

PHYSIOLOGICAL MONITORING

An individual may be at greater risk of heat-related disorders if:

- Profuse sweating is sustained over hours; or
- Weight loss over a shift is greater than 1.5% of body weight; or
- 24-hour urinary sodium excretion is less than 50 mmoles

EMERGENCY RESPONSE:

If symptoms such as disorientation or confusion, inexplicable irritability, malaise, or chills are observed. The worker should be immediately removed for rest in cool location and should be treated as a medical emergency with immediate transport to a hospital.

- If any heat strain measures are exceeded — implement job specific controls
- If none of the heat strain measures are exceed — implement general controls
HEAT STRESS CONTROL
HIERARCHY OF CONTROLS

Elimination
- Modification of the hot process or operation to a lower temperature.

Engineering Controls
- Radiant Heat – examples include reducing the surface temperature or shielding the worker from the radiant heat source.
- Convective Heat – examples include modification of air temperature and/or air movement.
- Evaporative Heat – examples include decreasing ambient humidity, minimizing excess moisture sources, and increasing air movement.

Administrative Controls
- Train and educate workers and supervisors on risk factors and early warning signs of heat stress.
- Scheduling very hot jobs in a cooler part of the day, when possible.
- Scheduling routine maintenance and repair work in hot areas during cooler seasons.
- Shorten duration of exposure (i.e. reduce workday, increase rest breaks, restrict overtime). Shorter, but more frequent work/rest cycles provide the greatest benefit to the employee.
- Where possible, breaks should be taken in an area cooler than work environment (air-conditioned break room, shade, etc.).
- The rest area should be close to the work area.
- Allow unacclimatized workers to break-in slowly.
- Rotate workers or tasks where appropriate.
- Use of the Buddy System in which employees work with a fellow employee or in small teams and can observe for early signs of heat stress.
HEAT STRESS CONTROL
HIERARCHY OF CONTROLS

Administrative Controls

Require workers the freedom to interrupt work when they feel extreme heat discomfort.

Reduce metabolic demands of activity by using mechanical methods, specialized tools/equipment, or an increased number of employees.

Ensure adequate fluid replacement

- 5-8 oz of cool water every 20-30 minutes.
- Individual drinking cups must be provided.

Use electrolyte replacement fluids. The use of salt tablets is prohibited.

Personal Protective Equipment

Cooled fluid or ice-cooled clothing or air-cooled garments especially under heavy protective gear or full enclosure suits.

Wear absorptive or evaporative cooling clothing (wetted cloths over garments, such as terrycloth or cotton when using impermeable clothing)

Reflective clothing or aprons

Wear broad brimmed hats and light weight clothing to reduce direct sun exposure.
TRAINING

Heat Stress Awareness should include:

- Training to all affected employees upon assignment and annually thereafter
- Heat stress and its potential effects on health and life
- Factors that contribute to heat stress
- The importance of early recognition of heat stress and the signs and symptoms of heat-related illnesses
- Emergency response to heat stress (first aid measures and/or treatment as early as possible).
- Predisposing factors that increase an individual's susceptibility to developing heat stress
- Precautions for working in heat stress areas, including acclimatization
- The proper use and care of heat protective clothing and equipment (if required).

REFERENCES


U.S. National Weather Service

U.S. NIOSH Publication 86-113 “Occupational Exposure to Hot Environments”

HSE RESEARCH REPORT 008 – “The development of a practical heat stress assessment methodology for use in UK industry”, Damian Bethea & Ken Parsons, Department of Human Sciences, Loughborough University

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