**FUNDAMENTALS OF INDUSTRIAL HYGIENE, 6TH ED.**

**HOMEWORK #8**

**INDIVIDUAL MEASUREMENT OF THERMAL STRESS**

**Name: KEY *87 pts. possible***

**EXERCISES:** Perform the calculations identified below. Show your work neatly and clearly in a manner similar to the examples provided above (i.e., write the formula and define each variable in the formula where requested, show steps of your calculations). *(1 point each – 18 pts. total)*

**Part I: Calculation of Relative Humidity**

1a) The air temperature on a construction site is measured and a dry-bulb reading of 13*°C* (55.4*°F*) is obtained. The amount of water vapor in the air is 7 *g*H2O/*kg*air.

What is the specific humidity? ***7 gH2O/kgair***

What is the maximum amount of water vapor the air can hold at this temperature? ***10 gH2O/kgair***

What is the relative humidity? ***70%***

Calculations: ***7 gH2O/kgair ÷ 10 gH2O/kgair = 0.70 (70%)***

1b) The air temperature in a warehouse is measured and a dry-bulb reading of 30*°C* (86*°F*) is obtained. The amount of water vapor in the air is 21 *g*H2O/*kg*air.

What is the specific humidity? ***21 gH2O/kgair***

What is the maximum amount of water vapor the air can hold at this temperature? ***28 gH2O/kgair***

What is the relative humidity? ***75%***

Calculations: ***21 gH2O/kgair ÷ 28 gH2O/kgair = 0.75 (75%)***

1c) The air temperature in the steam bath room of a food-processing plant is measured and a dry-bulb reading of 40*°C* (104*°F*) is obtained. The amount of water vapor in the air is 42 *g*H2O/*kg*air.

What is the specific humidity? ***42 gH2O/kgair***

What is the maximum amount of water vapor the air can hold at this temperature? ***50 gH2O/kgair***

What is the relative humidity? ***84%***

Calculations: ***42 gH2O/kgair ÷ 50 gH2O/kgair = 0.84 (84%)***

2a) Following the correct use of a sling psychrometer, the dry-bulb temperature was found to be 16*°C* (60.8*°F*) and the wet bulb temperature was found to be 12*°C* (53.6*°F*).

What is the wet-bulb depression? ***4°C***

What is the relative humidity? **6*2%***

2b) Following the correct use of a sling psychrometer, the dry-bulb temperature was found to be 22*°C* (71.6*°F*) and the wet bulb temperature was found to be 13*°C* (55.4*°F*).

What is the wet-bulb depression? ***9°C***

What is the relative humidity? ***33%***

2c) Following the correct use of a sling psychrometer, the dry-bulb temperature was found to be 27*°C* (80.6*°F*) and the wet bulb temperature was found to be 19*°C* (66.2*°F*).

What is the wet-bulb depression? ***8°C***

What is the relative humidity? ***46%***

**Part II: Calculation of WBGT Index**

Temperature measurements were taken on a construction site during a clear, summer day. One employee was monitored during the performance of tasks during the hottest time of the day. The employee was engaged in tying off rebar, and took breaks in an air-conditioned trailer. The job-site supervisor insisted employees take a 15-minute break every 45 minutes and that they drink plenty of water or electrolyte supplement (e.g., Gatorade®).

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample** | **Sampling**  **Period** | **Time**  **(min)** | **Area**  **Sampled** | **Activity** | **Readings from Heat Stress Monitor (in *°F*)** | | | |
| ***Tg*** | ***Tdb*** | ***Tnw*b** | ***WGBT*** |
| 1 | 1:30 to 2:00 | 30 | Foundation Pit | Rebar tying – moderate work | 99 | 96 | 81 | ***86*** |
| 2 | 2:00 to 2:15 | 15 | Foundation Pit | Rebar tying – moderate work | 100 | 94 | 83 | ***88*** |
| 3 | 2:15 to 2:30 | 15 | Break Room | Break | 75 | 73 | 67 | ***69*** |
| 4 | 2:30 to 2:45 | 15 | Foundation Pit | Rebar tying – moderate work | 101 | 97 | 73 | ***81*** |
| 5 | 2:45 to 3:15 | 30 | Laydown Yard | Unloading/packing rebar – heavy work | 102 | 96 | 85 | ***90*** |
| 6 | 3:15 to 3:30 | 15 | Break Room | Break | 75 | 74 | 70 | ***72*** |

3a) Determine the *WBGT* for each sampling period. *(8 points)*

Formula(s):***WBGTout = 0.7Tnwb + 0.2Tg + 0.1Tdb*** and ***WBGTout = 0.7Tnwb + 0.3Tg***

period 1: *(0.7 1°F) + (0.2  99°F) + (0.1  96°F) = 56.7°F + 19.8°F + 9.6°F =* ***86.1°F***

period 2: *(0.7 83°F) + (0.2  100°F) + (0.1  94°F) = 58.1°F + 20.0°F + 9.4°F =* ***87.5°F***

period 3: *(0.7 67°F) + (0.3  75°F) = 46.9°F + 22.5°F =* ***69.4°F***

period 4: *(0.7 73°F) + (0.2  101°F) + (0.1  97°F) = 51.1°F + 20.2°F + 9.7°F =* ***81.0°F***

period 5: *(0.7  85°F) + (0.2  102°F) + (0.1  96°F) = 59.5°F + 20.4°F + 9.6°F =* ***89.5°F***

period 6: *(0.7  70°F) + (0.3  75°F) = 49.0°F + 22.5°F =* ***71.5°F***

3b) Round each of the answers to the nearest whole number and record them in the table. *Note: Use these rounded figures for future calculations.* *(2 points)*

3c) Determine heat stress based on a two-hour time-weighted average. *(4 points)*

Formula:

Calculations: (*WBGT*1)(*t*1) = *(86°F)(30 min)* = *2580°F min*

(*WBGT*2)(*t*2) = *(88°F)(15 min)* = *1320°F min*

(*WBGT*3)(*t*3) = *(69°F)(15 min)* = *1035°F min*

(*WBGT*4)(*t*4) = *(81°F)(15 min)* = *1215°F min*

(*WBGT*5)(*t*5) = *(90°F)(30 min)* = *2700°F min*

(*WBGT*6)(*t*6) = *(72°F)(15 min)* = *1080°F min*

total min = ***120 min*** total = ***9930°F min***

*(round to nearest tenth)*

3c) What work/rest regime and category does this individual fall under? *(1 pt.)*  ***75% work/25% rest - moderate***

3d) Has an overexposure occurred with this worker? Explain. *(1 point)*  ***Yes. The TLV for 75%/25%***

***moderate work is 82.0°F.***

Temperature measurements were taken on a logging site during a warm, clear day during the late spring. One employee was monitored during the performance of tasks during the hottest time of the day. The employee was working on a log landing, and took short, intermittent breaks by standing in the shade of a nearby tree.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample** | **Sampling**  **Period** | **Time**  **(min)** | **Area**  **Sampled** | **Activity** | **Readings from Heat Stress Monitor (in *°F*)** | | | |
| ***Tg*** | ***Tdb*** | ***Tnw*b** | ***WGBT*** |
| 1 | 12:30 to 12:35 | 5 | Log Landing | Unhooking chokers – moderate work | 75 | 70 | 59 | ***63*** |
| 2 | 12:35 to 12:48 | 13 | Log Landing | Log limbing – heavy work | 75 | 71 | 57 | ***62*** |
| 3 | 12:48 to 12:51 | 3 | Standing in Shade | Break | 73 | 69 | 56 | ***61*** |
| 4 | 12:51 to 12:57 | 6 | Log Landing | Unhooking chokers – moderate work | 76 | 71 | 59 | ***64*** |
| 5 | 12:57 to 1:07 | 10 | Log Landing | Log limbing – heavy work | 76 | 72 | 58 | ***63*** |
| 6 | 1:07 to 1:21 | 14 | Log Landing | Cutting logs to length – heavy work | 76 | 73 | 58 | ***63*** |
| 7 | 1:21 to 1:25 | 4 | Standing in Shade | Break | 74 | 70 | 56 | ***61*** |
| 8 | 1:25 to 1:32 | 7 | Log Landing | Unhooking chokers – moderate work | 77 | 72 | 60 | ***65*** |
| 9 | 1:32 to 1:43 | 11 | Log Landing | Log limbing – heavy work | 77 | 73 | 61 | ***65*** |
| 10 | 1:43 to 1:57 | 14 | Log Landing | Cutting logs to length – heavy work | 78 | 73 | 63 | ***67*** |
| 11 | 1:57 to 2:12 | 15 | Log Landing | Fueling/Sharpening Saw – light work | 78 | 74 | 62 | ***66*** |
| 12 | 2:12 to 2:30 | 18 | Log Landing | Piling Slash – very heavy work | 76 | 73 | 60 | ***65*** |

4a) Determine the *WBGT* for each sampling period. *(13 points)*

Formula(s):***WBGTout = 0.7Tnwb + 0.2Tg + 0.1Tdb*** and ***WBGTout = 0.7Tnwb + 0.3Tg***

period 1: *(0.7 59°F) + (0.2  75°F) + (0.1  70°F)* = *41.3°F + 15.0°F + 7.0°F* =***63.3°F***

period 2: *(0.7 57°F) + (0.2  75°F) + (0.1  71°F)* = *39.9°F + 15.0°F + 7.1°F* =***62.0°F***

period 3: *(0.7 56°F) + (0.3  73°F)* = *39.2°F + 21.9°F* =***61.1°F***

period 4: *(0.7 59°F) + (0.2  76°F) + (0.1  71°F)* = *41.3°F + 15.2°F + 7.1°F* =***63.6°F***

period 5: *(0.7  58°F) + (0.2  76°F) + (0.1  72°F)* = *40.6°F + 15.2°F + 7.2°F* =***63.0°F***

period 6: *(0.7  58°F) + (0.2  76°F) + (0.1  73°F)* = *40.6°F + 15.2°F + 7.3°F* =***63.1°F***

period 7: *(0.7 56°F) + (0.3  74°F)* = *39.2°F + 22.2°F* =***61.4°F***

period 8: *(0.7 60°F) + (0.2  77°F) + (0.1  72°F)* = *42.0°F + 15.4°F + 7.2°F* =***64.6°F***

period 9: *(0.7 61°F) + (0.2  77°F) + (0.1  73°F)* = *42.7°F + 15.4°F + 7.3°F* =***65.4°F***

period 10: *(0.7 63°F) + (0.2  78°F) + (0.1  73°F)* = *44.1°F + 15.6°F + 7.3°F* =***67.0°F***

period 11: *(0.7  62°F) + (0.2  78°F) + (0.1  74°F)* = *43.4°F + 15.6°F + 7.4°F* =***66.4°F***

period 12: *(0.7  60°F) + (0.2  76°F) + (0.1  73°F)* = *42.0°F + 15.2°F + 7.3°F* =***64.5°F***

4b) Round each of the answers to the nearest whole number and record them in the table. *Note: Use these rounded figures for future calculations.* *(3 points)*

4c) Determine heat stress based on a two-hour time-weighted average. *(4 points)*

Formula:

Calculations: (*WBGT*1)(*t*1) = *(63°F)(5 min)* = *315°F min*

(*WBGT*2)(*t*2) = *(62°F)(13 min)* = *806°F min*

(*WBGT*3)(*t*3) = *(61°F)(3 min)* = *183°F min*

(*WBGT*4)(*t*4) = *(64°F)(6 min)* = *384°F min*

(*WBGT*5)(*t*5) = *(63°F)(10 min)* = *630°F min*

(*WBGT*6)(*t*6) = *(63°F)(14 min)* = *882°F min*

(*WBGT*7)(*t*7) = *(61°F)(4 min)* = *244°F min*

(*WBGT*8)(*t*8) = *(65°F)(7 min)* = *455°F min*

(*WBGT*9)(*t*9) = *(65°F)(11 min)* = *715°F min*

(*WBGT*10)(*t*10) = *(67°F)(14 min)* = *938°F min*

(*WBGT*11)(*t*11) = *(66°F)(15 min)* = *990°F min*

(*WBGT*12)(*t*12) = *(65°F)(18 min)* = *1170°F min*

total min = ***120* *min*** total = ***7712°F min***

*(round to nearest tenth)*

4d) What work/rest regime and category does this individual fall under? *(1 pt.)*  ***continuous - heavy***

4e) Has an overexposure occurred with this worker? Explain. *(1 point)* ***No. The TLV for continuous heavy***

***work is 77.0°F.***

**Part III: Clothing Adjustment Factors**

Temperature measurements were taken at a hazardous waste cleanup site during a warm, clear day during the late spring. One employee was monitored during the performance of tasks during the hottest time of the day. The employee was engaged in working on spill cleanup, and took short, intermittent breaks by standing in the shade provided by an awning. Let us assume this individual performed tasks comparable in intensity to those performed by the logger in the previous example, and that all temperature conditions were identical to those experienced by the logger. The only difference is that the worker engaged in cleanup activities was wearing vapor-barrier coveralls (over cloth coveralls and with a hood, but without a respirator).

5a) What is the *WBGT* Clothing Adjustment Factor? *(1 point)* ***12.7°C ( 22.9°F)***

5b) How did you determine the CAF? Show work. *(2 points)*

*vapor-barrier coveralls over cloth coveralls = 12.0°C (21.6°F)*

*hood = + 1.0°C ( 1.8°F)*

*subtotal = 13.0°C (23.4°F)*

*respirator = - 0.3°C ( 0.5°F)*

*total =* ***12.7°C (22.9°F)***

5c) Revise the original *WBGT*s. *Note: Use the original, unrounded, values to avoid potential compounding of errors). (12 points)*

original *WBGT* CAF *WBGT* + CAF rounded to nearest

whole number\*

period 1: *63.3°F* + *22.9°F* = *86.2°F* ***86°F***

period 2: *62.0°F* + *22.9°F* = *84.9°F* ***85°F***

period 3: *61.1°F* + *22.9°F* = *84.0°F* ***84°F***

period 4: *63.6°F* + *22.9°F* = *86.5°F* ***87°F***

period 5: *63.0°F* + *22.9°F* = *85.9°F* ***86°F***

period 6: *63.1°F* + *22.9°F* = *86.0°F* ***86°F***

period 7: *61.4°F* + *22.9°F* = *84.3°F* ***84°F***

period 8: *64.6°F* + *22.9°F* = *87.5°F* ***88°F***

period 9: *65.4°F* + *22.9°F* = *88.3°F* ***88°F***

period 10: *67.0°F* + *22.9°F* = *89.9°F* ***90°F***

period 11: *66.4°F* + *22.9°F* = *89.3°F* ***89°F***

period 12: *64.5°F* + *22.9°F* = *87.4°F* ***87°F***

*\*Note: Use these rounded values in future calculations.*

Recalculate heat stress based on a two-hour time-weighted average. *(4 points)*

Formula:

Calculations: (*WBGT*1)(*t*1) = *(86°F)(5 min)* = *430°F min*

(*WBGT*2)(*t*2) = *(85°F)(13 min)* = *1105°F min*

(*WBGT*3)(*t*3) = *(84°F)(3 min)* = *252°F min*

(*WBGT*4)(*t*4) = *(87°F)(6 min)* = *522°F min*

(*WBGT*5)(*t*5) = *(86°F)(10 min)* = *860°F min*

(*WBGT*6)(*t*6) = *(86°F)(14 min)* = *1204°F min*

(*WBGT*7)(*t*7) = *(84°F)(4 min)* = *336°F min*

(*WBGT*8)(*t*8) = *(88°F)(7 min)* =  *616°F min*

(*WBGT*9)(*t*9) = *(88°F)(11 min)* = *968°F min*

(*WBGT*10)(*t*10) = *(90°F)(14 min)* = *1260°F min*

(*WBGT*11)(*t*11) = *(89°F)(15 min)* = *1335°F min*

(*WBGT*12)(*t*12) = *(87°F)(18 min)* = *1566°F min*

total min = ***120 min*** total = ***10454°F min***

*(round to nearest tenth)*

What work-load category does this individual fall under? *(1 pt.)* ***continuous - heavy***

Has an overexposure occurred with this worker? Explain. *(1 point)* ***Yes. The TLV for continuous***

***heavy work is 77.0°F.***

**Part IV: Screening Levels for Heat Stress**

You are in charge of health and safety at a job site. For each of the following workplace scenarios, identify the action limit screening WBGT temperature (in *°F*) and the TLV screening temperature (in *°F*). *(10 points)*

**Action Limit Screening TLV Screening**

continuous, light work ***82.6°F***  ***87.4°F***

27% work/73% rest, very heavy work ***76.3°F*** ***82.2°F***

48% work/52% rest, moderate work ***81.0°F***  ***86.2°F***

76% work/24% rest, heavy work ***exceeds*** ***exceeds***

17% work/83% rest, moderate work ***83.8°F*** ***88.3°F***