

Heat Load Index Calculation

Calculation of the Heat Load Index (HLI) requires Temperature (T) in °C, Relative Humidity (RH) expressed as a percentage, Wind Speed (WS) in m/s and Black Globe Temperature (BGT) in °C. Of these, T, RH and WS are routinely measured by the great majority of weather stations. Although sensors for measuring BGT exist, these are not normally included as part of the standard weather station and must be ordered from a suitable supplier. In the absence of a BGT sensor, the BGT can be inferred from measurements of T and Solar Radiation (SR).

$$BGT = 1.33 \cdot T - 2.65\sqrt{T} + 3.21 \cdot \log(SR + 1) + 3.5$$

In the past, the HLI was calculated using one of two equations, depending on whether the BGT is above or below 25°C as follows:

$$\begin{cases} BGT < 25 \rightarrow HLI_{LO} = 1.3 \cdot BGT + 0.28 \cdot RH - WS + 10.66 \\ BGT \geq 25 \rightarrow HLI_{HI} = 1.55 \cdot BGT + 0.38 \cdot RH - 0.5 \cdot WS + e^{(2.4-WS)} + 8.62 \end{cases}$$

where the HLI value was taken as either HLI high or HLI low depending on the BGT value.

One issue that has been identified is that large jumps in HLI occur under some circumstances when the BGT passes through 25°C – for example from 24.9°C to 25.1°C. To overcome this, a blending function - $S(BGT)$ - is used to produce a smooth transition in HLI values calculated using the two different equations. The blending function is:

$$S(BGT) = \frac{1}{1 + e^{\left(\frac{BGT-25}{2.25}\right)}}$$

Using this blending function, a value of the HLI can be calculated as follows:

$$HLI = S(BGT) \cdot HLI_{HI} + (1 - S(BGT)) \cdot HLI_{LO}$$

Where HLI high or HLI low are defined above.

Finally, the HLI value is not allowed to decrease below 50.

Accumulated Heat Load Unit Calculation

The Accumulated Heat Load Unit (AHLU) represents the amount of heat accumulated in cattle over a period of time. The rate of accumulation depends on the current HLI value. Large HLI values result in a more rapid increase in AHLU, conversely, low HLI values result in a decrease of the AHLU (ie the cattle cool down and recover). Whether cattle recover or become stressed depends on the value of certain thresholds. The first threshold occurs at a HLI value of 77. For HLI values below 77, the cattle cool down and recover. The second or **UPPER_THRESHOLD** depends on the type and condition of the cattle and their pen environment. Its value ranges from about 80 for unacclimated (and possibly compromised) black angus cattle to about 95 for acclimatised Brahman cattle. The range of HLI values

between 77 and the upper threshold is called the thermo-neutral zone. For this zone, cattle neither recover nor become stressed. It is important that the correct **UPPER_THRESHOLD** is used otherwise the AHLU values will erroneously indicate the state of the cattle. The **UPPER_THRESHOLD** can be calculated using the CHLT on-line calculator at: <http://chlt.com.au/rap-calculator/>

The equation for calculating AHLU is as follows:

$$\text{AHLU}_{\text{CURRENT}} = \text{AHLU}_{\text{PREVIOUS}} + \text{INCREMENT} * \text{INTERVAL}$$

For example, the AHLU at 2pm is calculated by adding an **INCREMENT** to the AHLU at 1pm. The **INCREMENT** is calculated as follows:

If (HLI is between 77 and the upper threshold) then INCREMENT = ZERO

If (HLI < 77) then INCREMENT = (HLI - 77) / 2

If(HLI > UPPER_THRESHOLD) then INCREMENT = (HLI – UPPER_THRESHOLD)

and

INTERVAL is the time interval between successive HLI measurements. Its value is 1.0 for an interval of one hour, 0.5 for an interval of 30 minutes, 0.25 for an interval of 15 minutes and so on.

Some points worth noting:

- The INCREMENT can be positive or negative.
- If HLI is below 77, then INCREMENT is halved (ie the rate of recovery or heat loss is half of the rate of heat accumulation).
- AHLU values do not go below zero. If any calculation results in an AHLU value below zero, it is set to zero.

The following table contains sample data that you can use to test your implementation of the HLI equations above:

Relative Humidity = 33%			
	Black Globe Temperature		
Wind Speed	20°	25°	30°
2 m/s	50.0	55.4	67.1
4 m/s	50.0	53.3	64.8
6 m/s	50.0	51.7	63.5
Relative Humidity = 66%			
	Black Globe Temperature		
Wind Speed	20°	25°	30°
2 m/s	54.3	66.3	79.3
4 m/s	52.3	64.2	77.0
6 m/s	50.4	62.6	75.8

Relative Humidity = 99%			
	Black Globe Temperature		
Wind Speed	20°	25°	30°
2 m/s	63.9	77.2	91.5
4 m/s	61.9	75.0	89.2
6 m/s	59.9	73.5	88.0

The following table contains data that you can use to test your implementation of the AHLU equations:

HLI	AHLU-80	AHLU-86	AHLU-91
70	0	0	0
72	0	0	0
74	0	0	0
76	0	0	0
78	0	0	0
80	0	0	0
82	2	0	0
84	6	0	0
86	12	0	0
88	20	2	0
90	30	6	0
92	42	12	1
94	56	20	4
96	72	30	9
98	90	42	16
100	110	56	25
98	128	68	32
96	144	78	37
94	158	86	40
92	170	92	41
90	180	96	41
88	188	98	41
86	194	98	41
84	198	98	41
82	200	98	41
80	200	98	41
78	200	98	41
76	199.5	97.5	40.5
74	198	96	39
72	195.5	93.5	36.5
70	192	90	33
68	187.5	85.5	28.5
66	182	80	23
64	175.5	73.5	16.5
62	168	66	9
60	159.5	57.5	0.5
58	150	48	0
56	139.5	37.5	0
54	128	26	0
52	115.5	13.5	0
50	102	0	0

50	88.5	0	0
50	75	0	0
50	61.5	0	0
50	48	0	0
50	34.5	0	0
50	21	0	0
50	7.5	0	0
50	0	0	0
50	0	0	0