

Engineering Fundamentals : part I

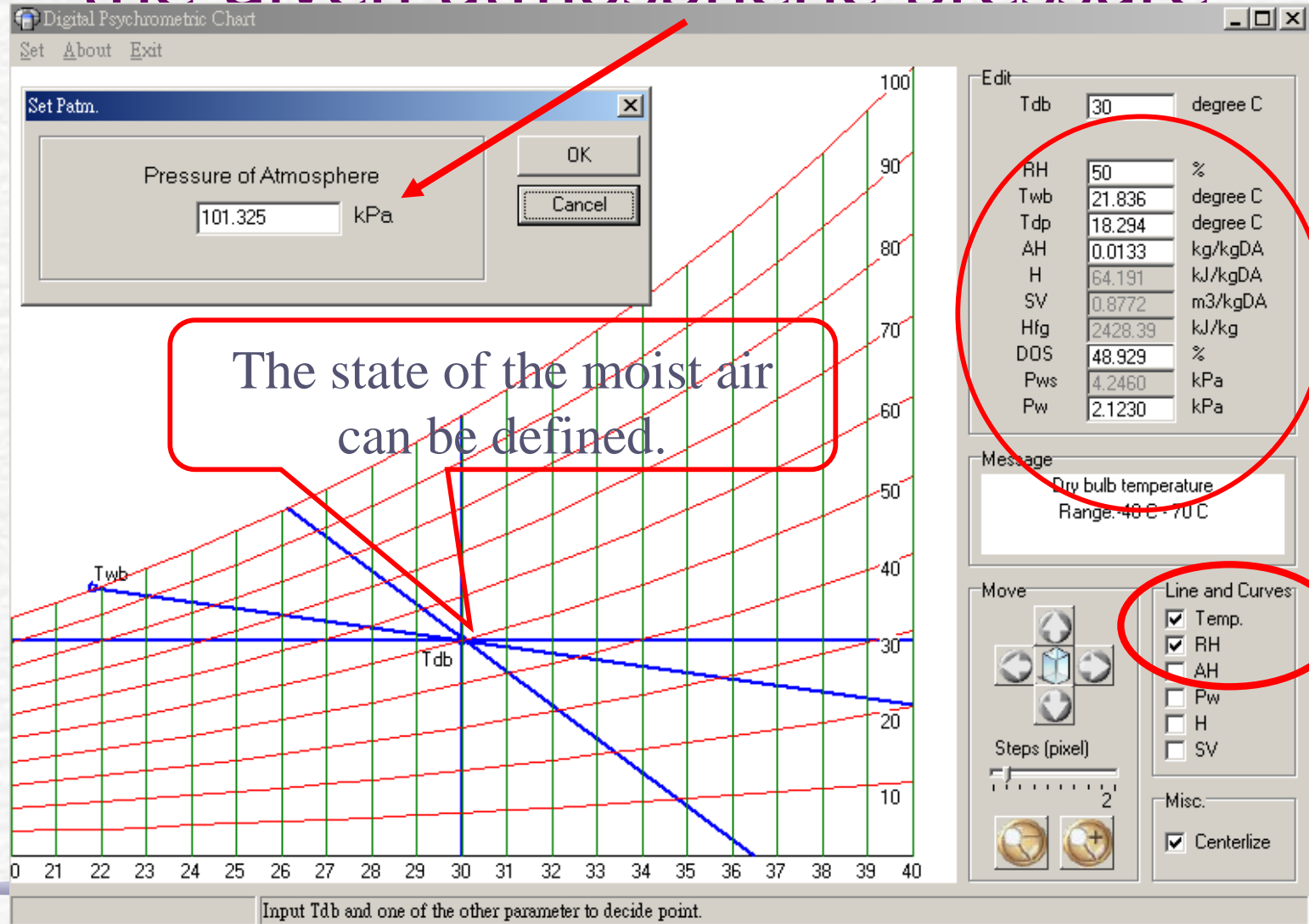
Related to moist air and water

1. Thermodynamic properties of moist air
 1. State
 2. Process
2. Pad and Fan system
 1. Pad efficiency at various facing velocity
 2. Pad efficiency and pressure drop at various thickness
 3. Fan curves
3. Efficiency of the nozzle in misting/fogging system
4. Psychrometric related Tables generated by Psychart software

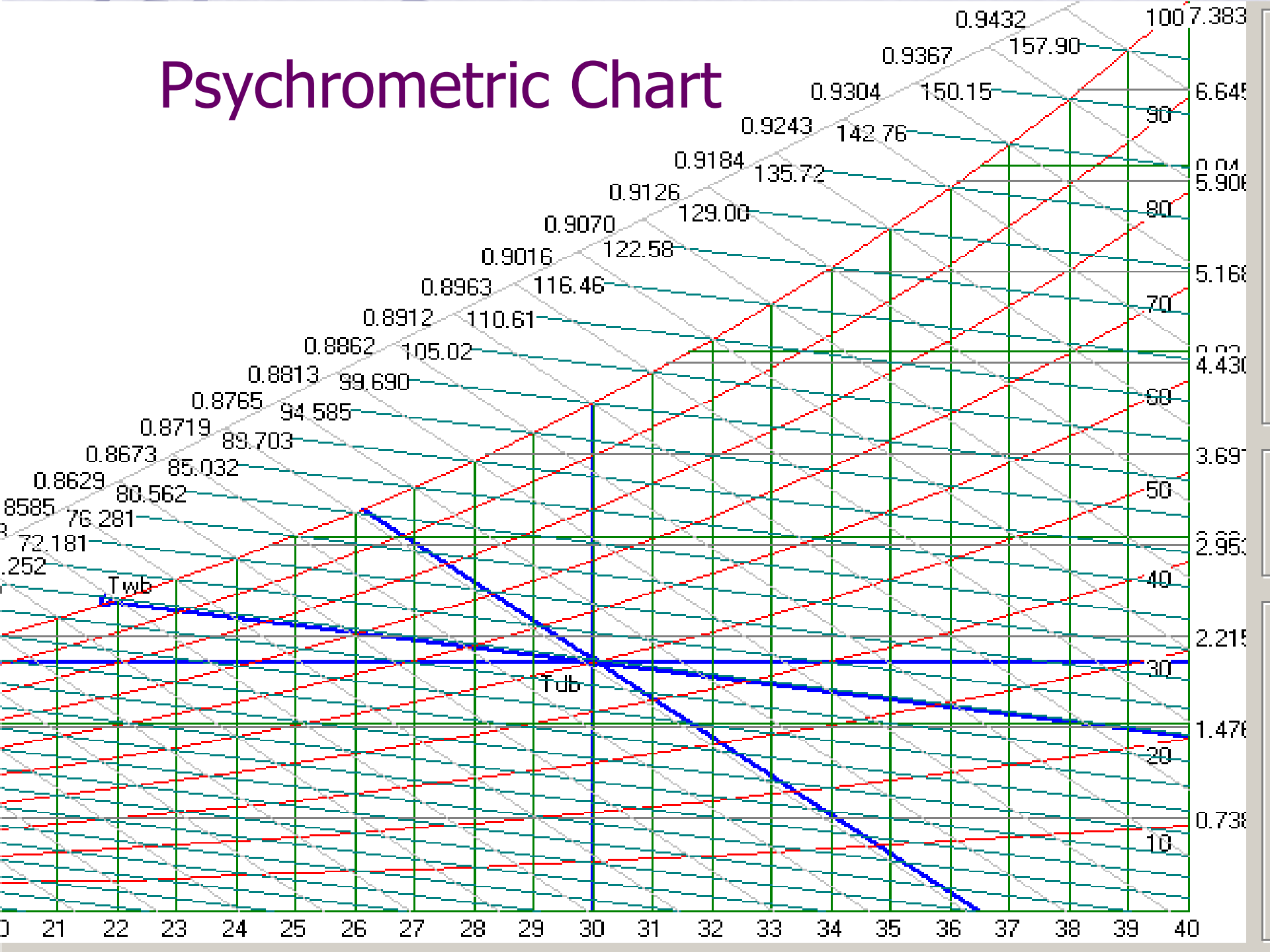
Thermodynamic properties of moist air

1. dry bulb T
2. wet bulb T
3. dew point T
4. relative humidity
5. absolute humidity
(humidity ratio)
6. specific volume
7. enthalpy
8. vapor pressure
9. saturated vapor pressure

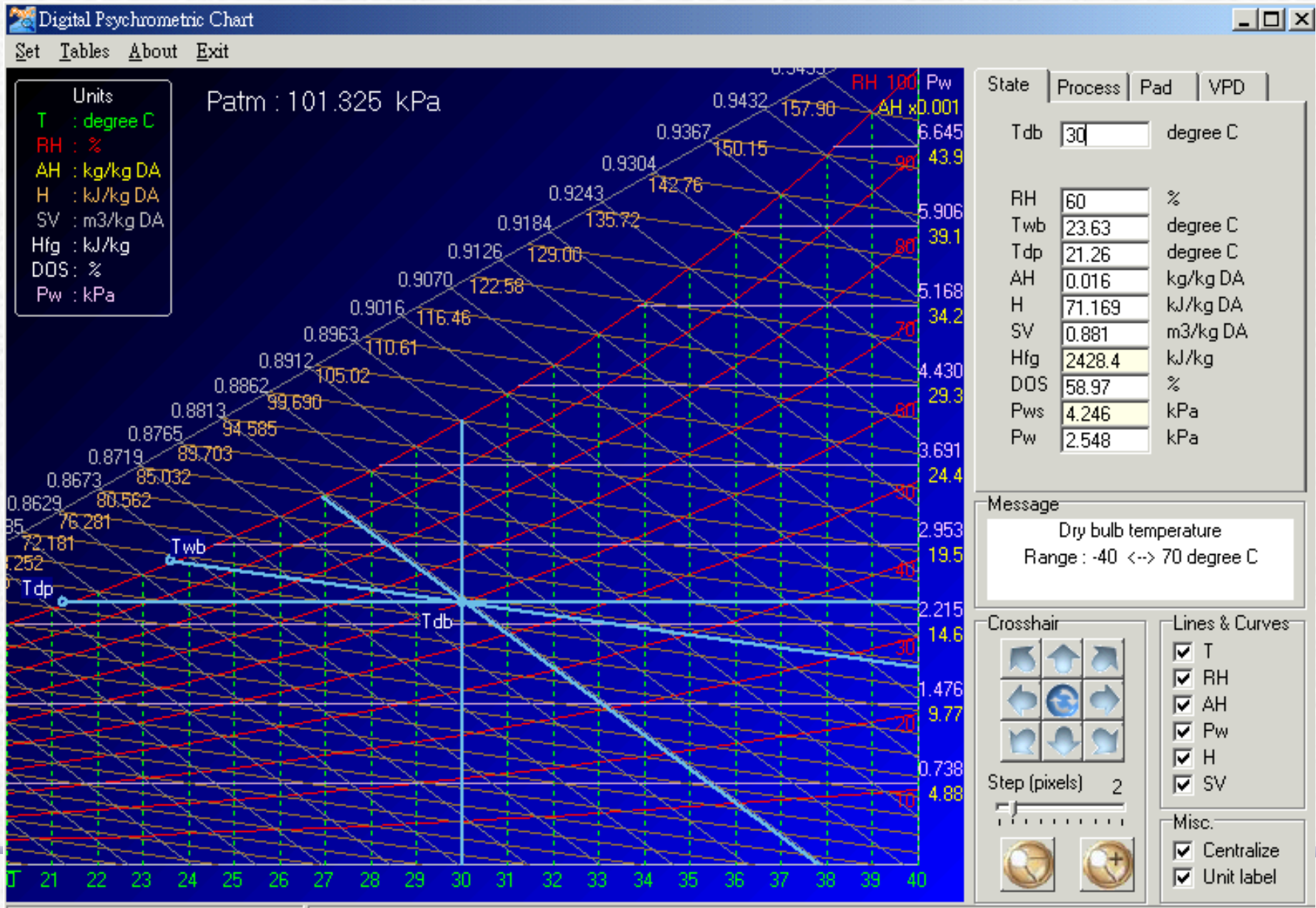
With 2 independent properties and the given atmospheric pressure



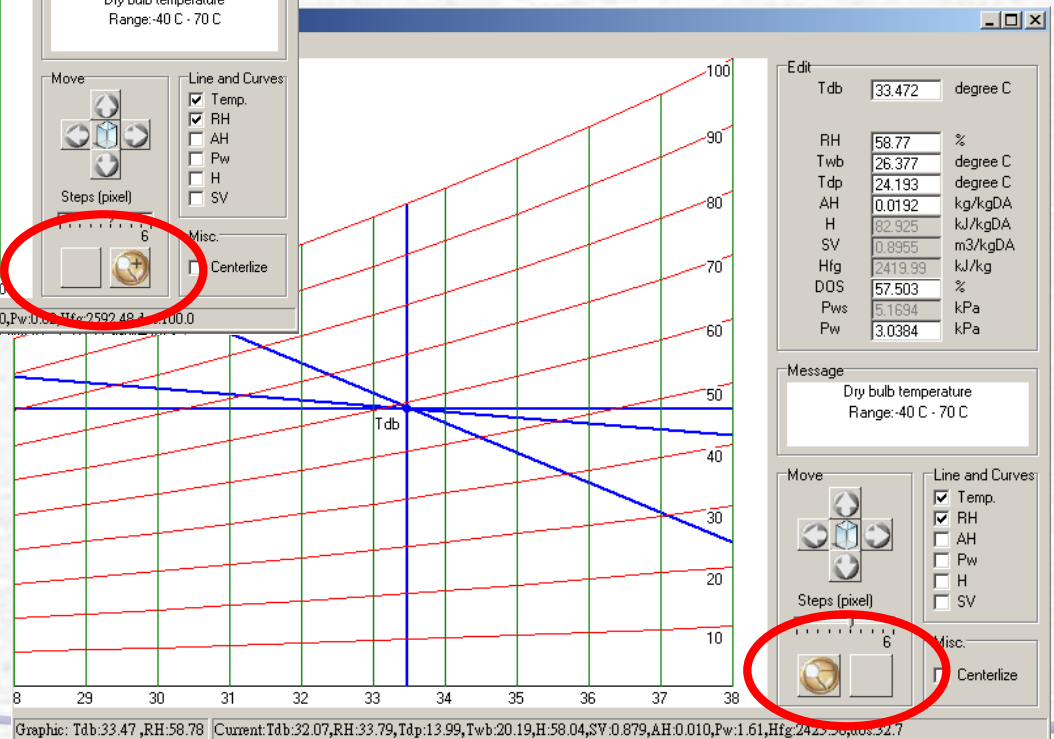
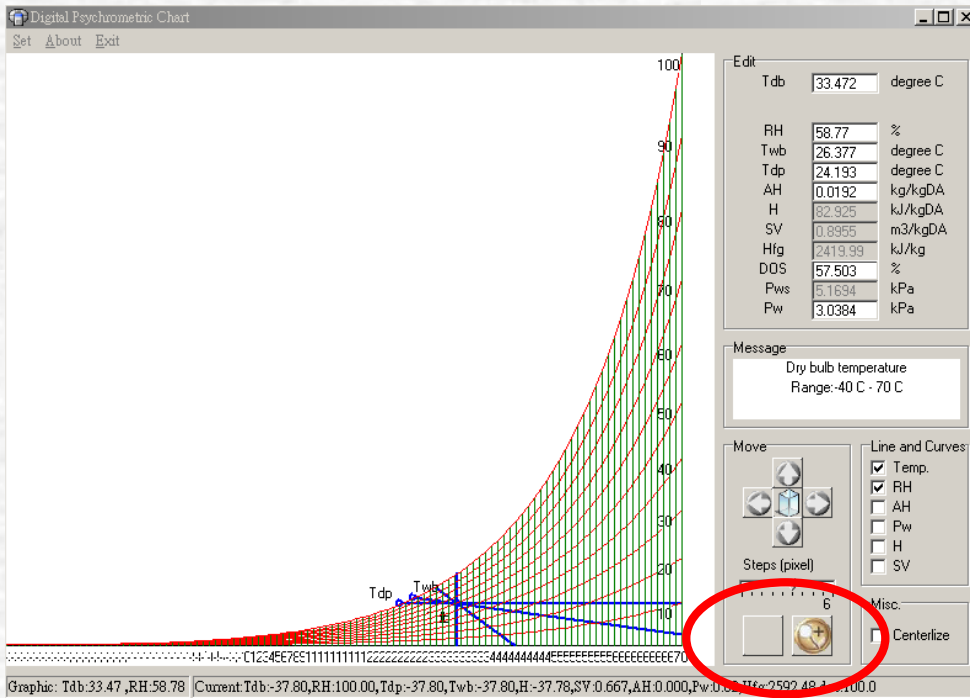
Psychrometric Chart



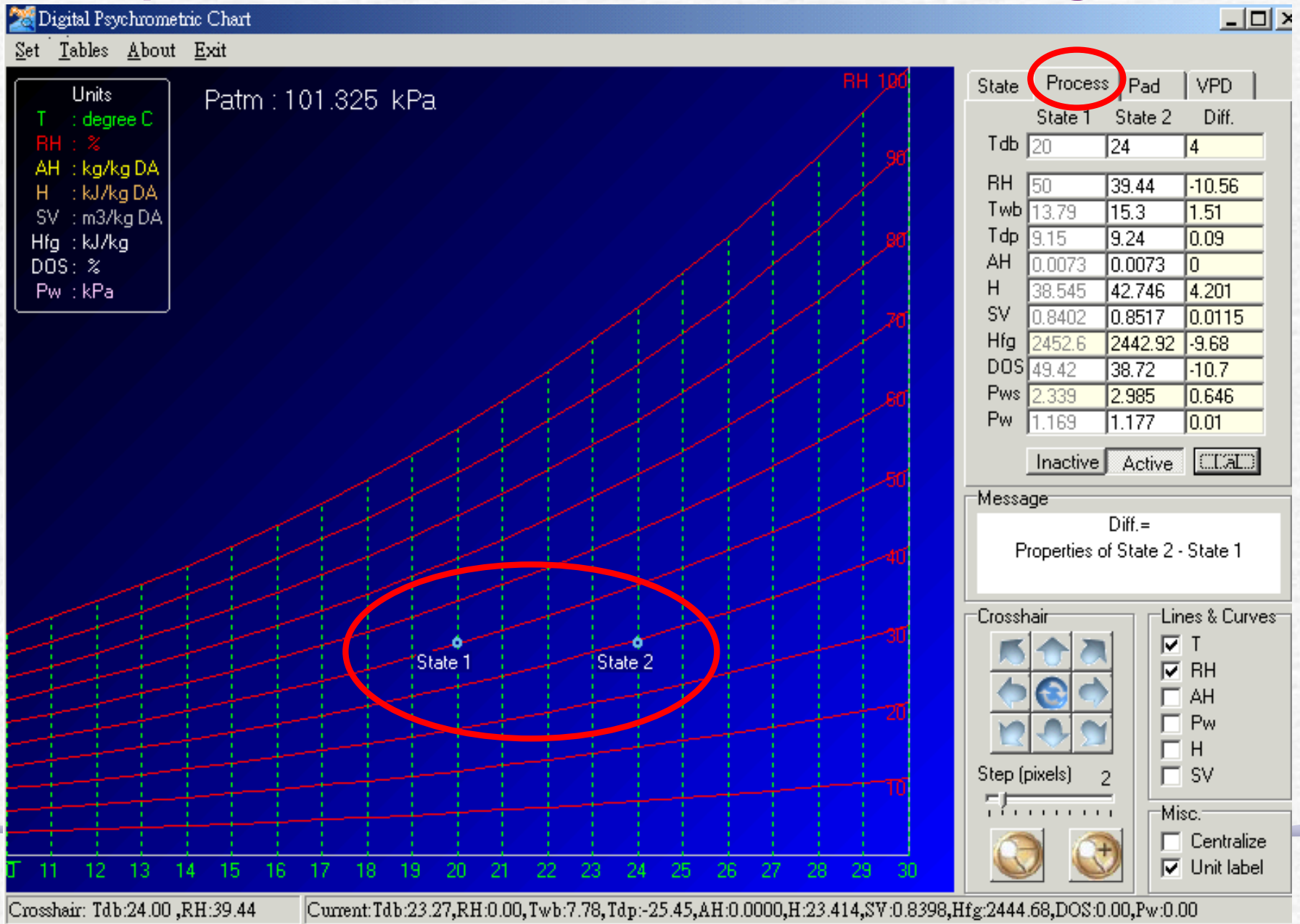
Digital Psychrometric Chart



Zoom in & Zoom out



A process with sensible heat gain



Move along prefix lines & Curves

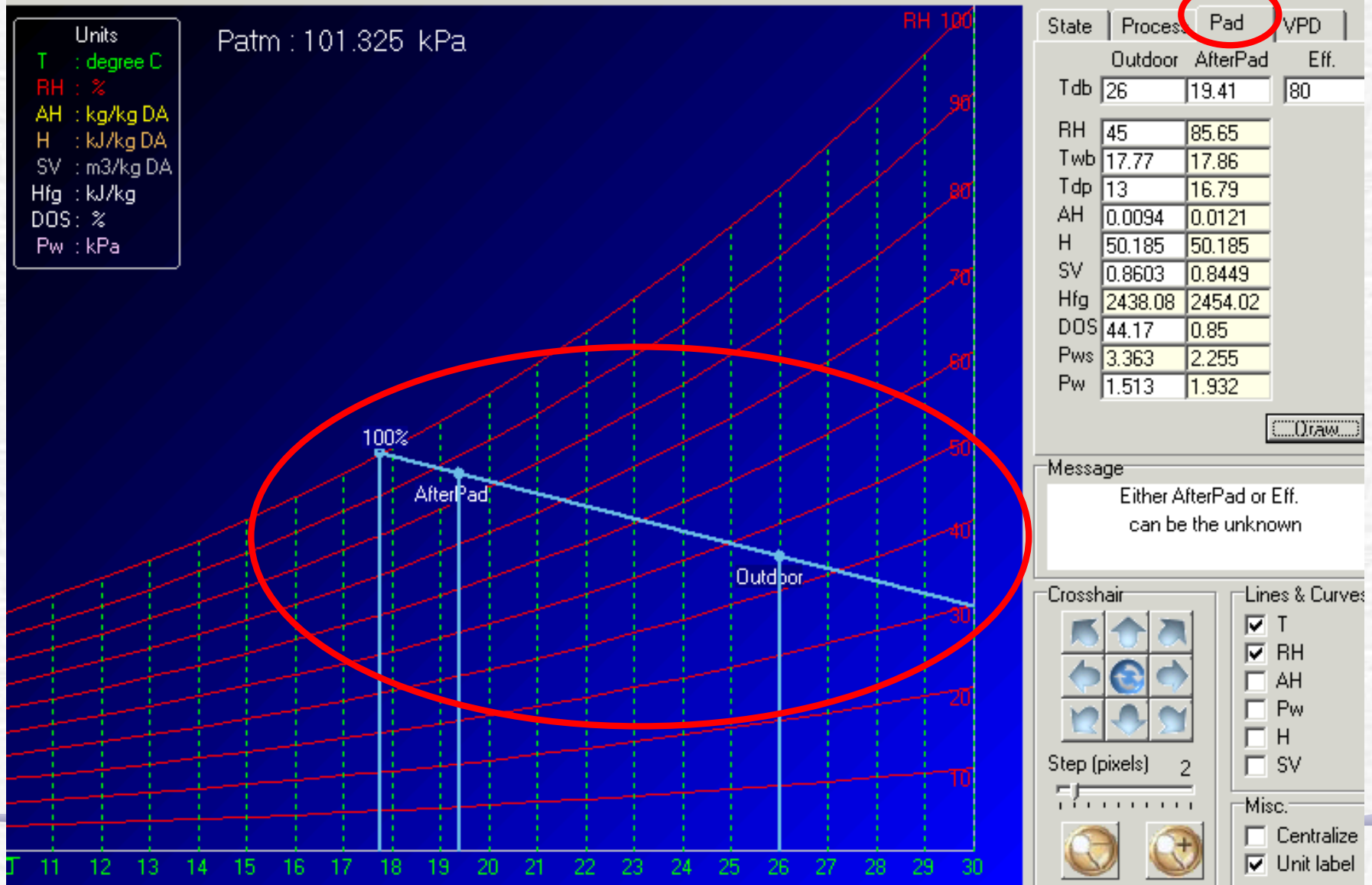
The image shows a software interface for navigating along prefix lines and curves. The interface includes a grid of directional arrows, a 'Step (pixels)' slider, and a 'Lines & Curves' panel with checkboxes for T, RH, AH, Pw, H, SV, Centralize, and Unit label. Callout boxes link specific arrows to labels:

- Constant Twb** (Red box) points to the top-right arrow.
- Constant RH** (Blue box) points to the top-middle arrow.
- Constant Tdp, Pw, AH** (Purple box) points to the top-left arrow.
- Constant Tdp, Pw, AH** (Purple box) points to the middle-right arrow.
- Constant RH** (Blue box) points to the middle-left arrow.
- Constant Twb** (Red box) points to the bottom-right arrow.

The 'Lines & Curves' panel has the following settings:

- T
- RH
- AH
- Pw
- H
- SV
- Centralize
- Unit label

Efficiency of a Pad and Fan system



Pad efficiency at various facing velocity

$$\text{Eff} = 86.62 - 20.787 * V + 2.755 * V^2$$

Kool-Cel pad

$$\text{Eff} = 91.034 - 17.91 * V + 5.231 * V^2$$

CELdek pad

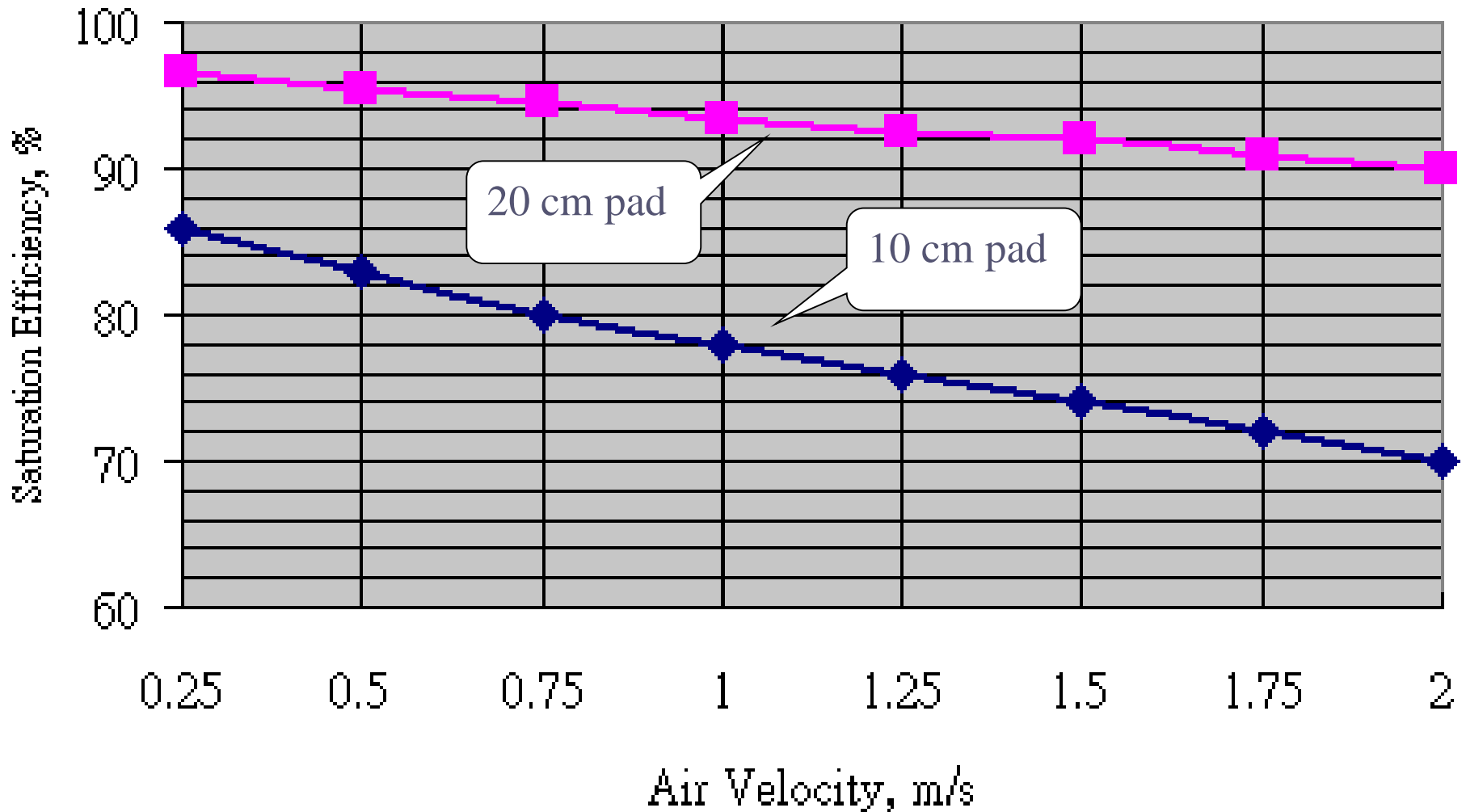
$$\text{Eff} = 76.055 + 2.909 * V - 17.414 * V^2$$

Excelsior pad

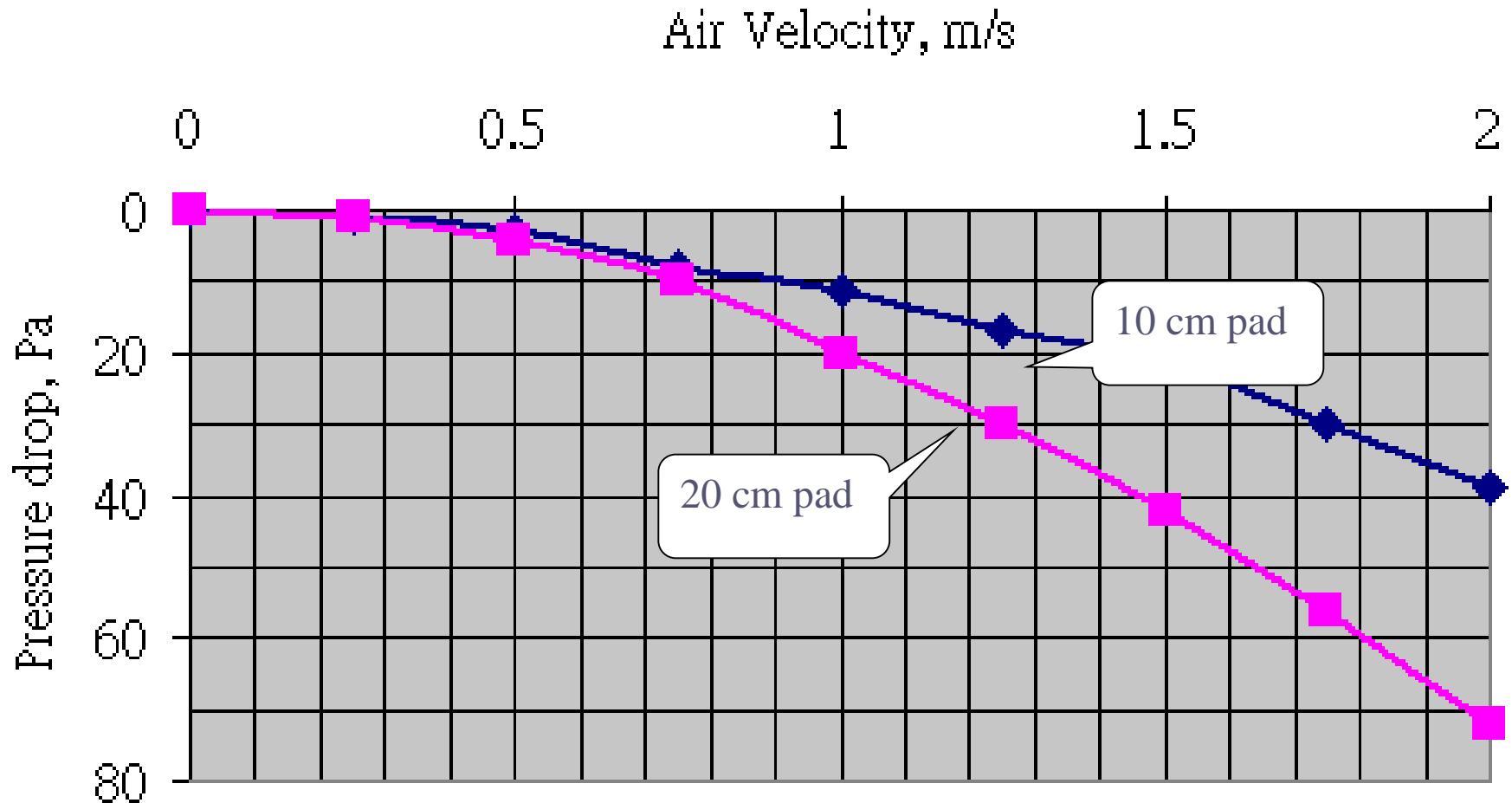
Trumbull, et al. (1986)

Thickness of the pads were not mentioned. 10 cm ?

Pad efficiency at various facing velocity and thickness

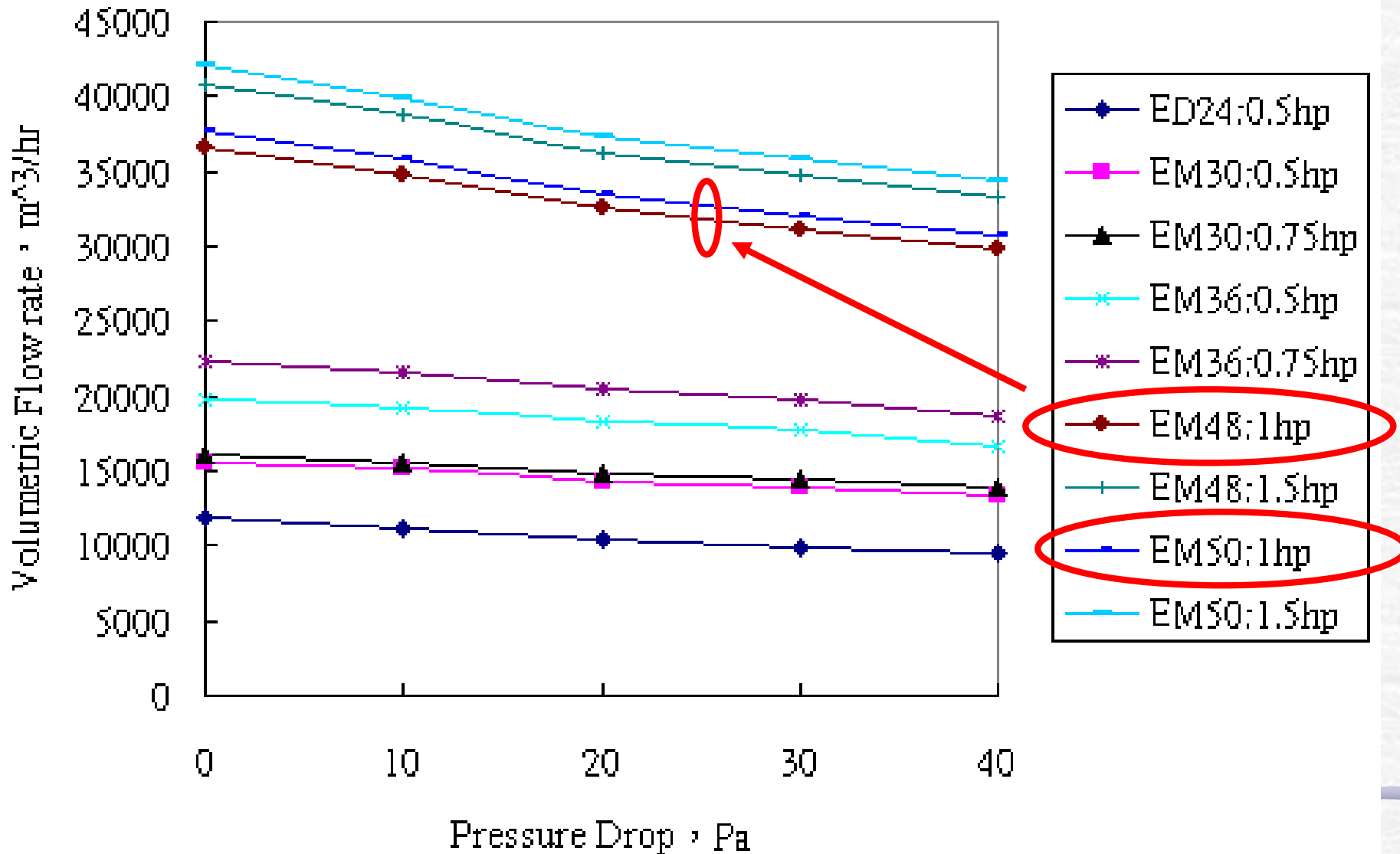


Pressure drop at various facing velocity and pad thickness



Fan curves of various models of

Euroemme Fans



Blow-off of water from the pad

- at 1 m/s for the Excelsior pad,
- at 1.6 m/s for the Kool-Cel pad and
- at 2 m/s for the CELdek pad

Trumbull, et al. (1986)

Efficiency of nozzle (misting/fogging system)

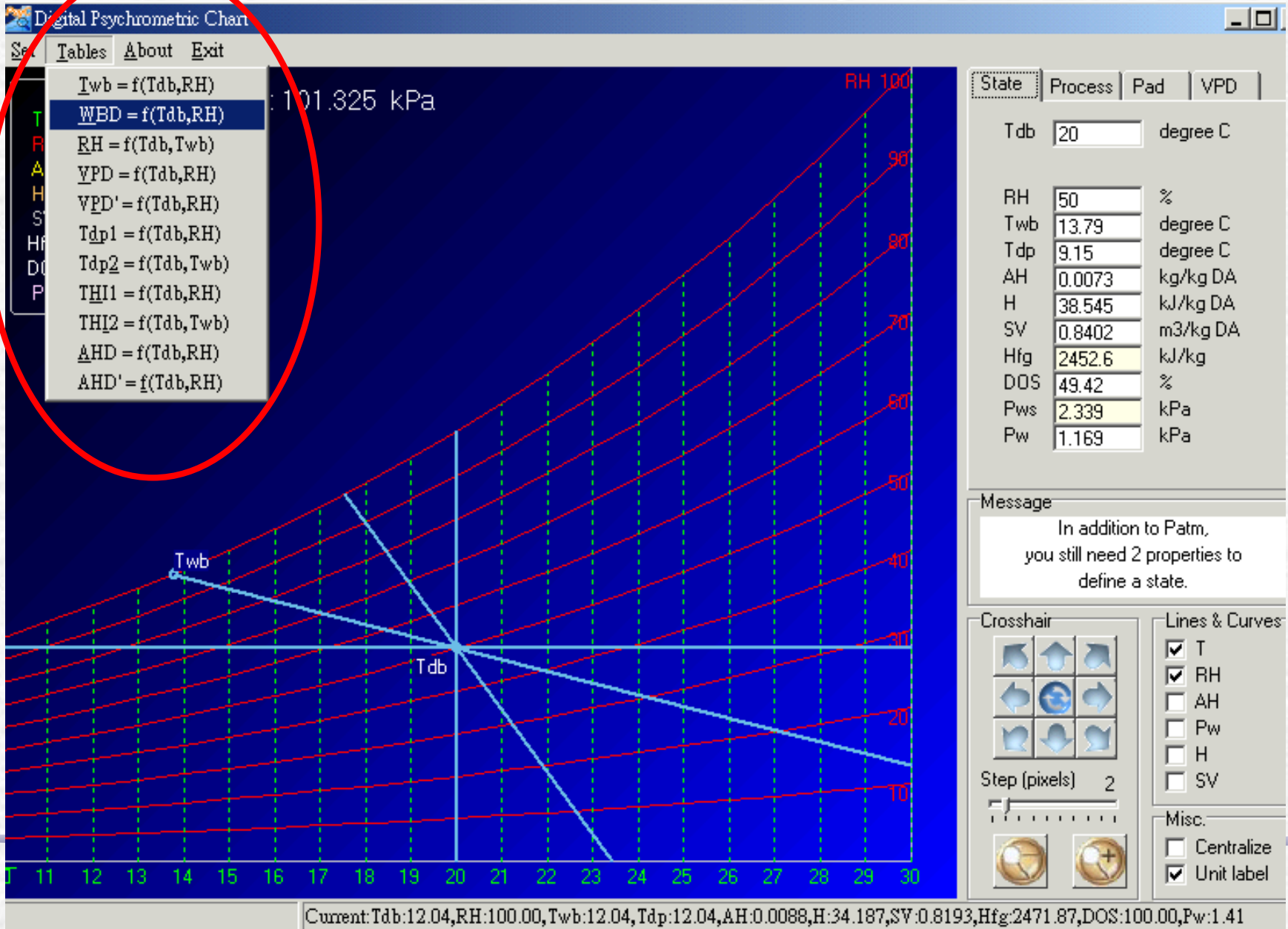
$$\beta = 0.124 + 1.35 * 10^{-4} * P$$

Bottcher et al. (1991)

$$P = 64.888 \text{ ATM} \rightarrow \beta = 100\%$$

Considering some head loss and friction loss,
70 ATM (70 kg/cm²) was used in my research.

Handy Tables



User friendly 3-step design in PsyTable

1. Define the ranges

2. Set the intervals

3. list the values

Wet Bulb Temperature (in degree C)

	20	21	22	23	24	25	26	27	28	29	30	31	32
50	13.79	14.59	15.39	16.2	17	17.8	18.61	19.41	20.22	21.03	21.84	22.65	23.46
55	14.47	15.3	16.12	16.95	17.77	18.6	19.43	20.26	21.08	21.91	22.75	23.58	24.42
60	15.15	15.99	16.84	17.68	18.53	19.38	20.23	21.07	21.93	22.78	23.63	24.49	25.34
65	15.81	16.67	17.54	18.4	19.27	20.14	21.01	21.87	22.75	23.62	24.49	25.37	26.25
70	16.45	17.34	18.22	19.11	19.99	20.88	21.77	22.66	23.55	24.44	25.33	26.23	27.13
75	17.09	17.99	18.9	19.8	20.7	21.61	22.51	23.42	24.33	25.24	26.15	27.07	27.99
80	17.71	18.63	19.56	20.48	21.4	22.32	23.25	24.17	25.1	26.03	26.96	27.89	28.82
85	18.33	19.27	20.2	21.14	22.08	23.02	23.96	24.91	25.85	26.8	27.74	28.69	29.64
90	18.93	19.89	20.84	21.8	22.75	23.71	24.67	25.63	26.59	27.55	28.51	29.48	30.45
95	19.53	20.5	21.47	22.44	23.41	24.38	25.36	26.33	27.31	28.29	29.27	30.25	31.24
100	20	21	22	23	24	25	26	27	28	29	30	31	32

$$T_{wb} = f(T_{db}, RH)$$

	20	22	24	26	28	30	32	34	36	38	40	42	44
50	13.79	15.39	17.01	18.61	20.22	21.84	23.46	25.09	26.73	28.38	30.04	31.7	33.38
55	14.47	16.12	17.77	19.43	21.08	22.75	24.42	26.09	27.78	29.47	31.18	32.89	34.62
60	15.15	16.84	18.53	20.23	21.93	23.63	25.34	27.06	28.79	30.53	32.28	34.04	35.81
65	15.81	17.54	19.27	21.01	22.75	24.49	26.25	28.01	29.78	31.56	33.35	35.16	36.97
70	16.45	18.22	19.99	21.77	23.55	25.33	27.13	28.93	30.74	32.56	34.39	36.24	38.09
75	17.09	18.9	20.7	22.51	24.33	26.15	27.99	29.83	31.67	33.53	35.4	37.28	39.17
80	17.71	19.56	21.4	23.25	25.1	26.96	28.82	30.7	32.59	34.48	36.39	38.3	40.23
85	18.33	20.2	22.08	23.96	25.85	27.74	29.64	31.56	33.48	35.41	37.35	39.3	41.26
90	18.93	20.84	22.75	24.67	26.59	28.51	30.45	32.39	34.35	36.31	38.28	40.27	42.26
95	19.53	21.47	23.41	25.36	27.31	29.27	31.24	33.21	35.2	37.19	39.2	41.21	43.24
100	20	22	24	26	28	30	32	34	36	38	40	42	44

RH (50 – 100%) and T_{db} (20 – 44 °C)

$$RH = f(T_{db}, T_{wb})$$

	20	22	24	26	28	30	32	34	36	38	40	42	44
20	100	82.63	69.02	57.61	48.81	40.89	33	27.14	22.14	17.83	14.26	11.17	8.55
22	N/A	100	83.49	70.48	59.48	50.13	42.16	35.35	29.52	24.52	20.24	16.57	13.42
24	N/A	N/A	100	84.34	71.84	61.18	52.06	44.23	37.49	31.69	26.69	22.38	18.67
26	N/A	N/A	N/A	100	85.17	73.11	62.75	53.83	46.12	39.45	33.68	28.67	24.34
28	N/A	N/A	N/A	N/A	100	85.98	74.3	64.21	55.45	47.85	41.24	35.49	30.48
30	N/A	N/A	N/A	N/A	N/A	100	86.78	75.43	65.56	56.95	49.44	42.88	37.13
32	N/A	N/A	N/A	N/A	N/A	N/A	100	87.56	76.49	66.81	58.33	50.89	44.36
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	88.32	77.49	67.96	59.58	52.19
36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	89.03	78.39	68.99	60.68
38	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	89.67	79.18	69.87
40	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	90.19	79.82
42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	90.57
44	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100

RH

T_{wb} (20 – 44 °C) and T_{db} (20 – 44 °C)

$$WBD = f(T_{db}, RH)$$

	20	22	24	26	28	30	32	34	36	38	40	42	44
50	6.21	6.61	7.01	7.39	7.78	8.16	8.54	8.91	9.27	9.62	9.96	10.3	10.62
55	5.53	5.88	6.23	6.57	6.92	7.25	7.58	7.91	8.22	8.53	8.82	9.11	9.38
60	4.85	5.16	5.47	5.77	6.07	6.37	6.66	6.94	7.21	7.47	7.72	7.96	8.19
65	4.19	4.46	4.73	4.99	5.25	5.51	5.75	5.99	6.22	6.44	6.65	6.84	7.03
70	3.55	3.78	4.01	4.23	4.45	4.67	4.87	5.07	5.26	5.44	5.61	5.76	5.91
75	2.91	3.1	3.3	3.49	3.67	3.85	4.01	4.17	4.33	4.47	4.6	4.72	4.83
80	2.29	2.44	2.6	2.75	2.9	3.04	3.18	3.3	3.41	3.52	3.61	3.7	3.77
85	1.67	1.8	1.92	2.04	2.15	2.26	2.36	2.44	2.52	2.59	2.65	2.7	2.74
90	1.07	1.16	1.25	1.33	1.41	1.49	1.55	1.61	1.65	1.69	1.72	1.73	1.74
95	0.47	0.53	0.59	0.64	0.69	0.73	0.76	0.79	0.8	0.81	0.8	0.79	0.76
100	0	0	0	0	0	0	0	0	0	0	0	0	0

Wet Bulb Depression is the limit of evaporative cooling methods.

Evaporative cooling Methods

- Pad and Fan system
- Spraying
- Misting
- Fogging
- Multi-Net Fogging and Fan system