Web-based real time air properties display application

A Badarudin*, P Pratikto and M A Falahuddin
Refrigeration and Air Conditioning Department, Politeknik Negeri Bandung, Jln. Gegerkalong Hilir, Ciwaruga, Bandung, 40012

*apipbdr@polban.ac.id

Abstract. A point on the psychrometric chart can show 7 properties of air. If two properties are known then 5 other properties can be calculated. Air treatment will change the properties of air conditions. Changes in air condition can be determined by measuring each air properties and plotted on a psychrometric chart. One of the uses of psychrometric analysis is to determine the amount of cooling capacity used in air conditioning systems. To show the condition of the air at any time needed a system that is integrated between the data acquisition device and data display. This research designs and develops applications that are ready to display data and psychrometric charts that can later be integrated with hardware equipped with sensors through an interface. Psychrometric applications are designed using the JavaScript programming language, so they can be opened using any web browser. Psychrometric charts are drawn using iteration calculation methods. Based on the results of data analysis, the difference in value between the results of manual calculations and applications is as follows: wet-bulb temperature (Twb) is 0.27%, Moisture Content (ω) is 0.77%, specific enthalpy (h) is 0.52 %, Specific Volume (v) is 0.28%, Dew-Point Temperature (Tdp) is 0.92%.

1. Introduction
Over the years, the application of passive ventilation technology in refrigeration and dehumidification of green buildings has become a trend. Li et al proposed a passive lateral ventilation evaporative cooling technique, which is based on the capillary action. By comparison from psychrometric chart, the final state point of air is nearly 2.2% lower than the begin point. That means the temperature of air decreases by 2.2% after passing over through the capillary window, but this value does not exclude the possible errors caused by drawing, marking and reading [1].

Case studies of the demarcation criteria for the formation of frost on the evaporator coil using experimental measured data and on the walls of the cold storage freezer using measured literature data are used to validate the formula and results are found to be completely in line with the psychrometric chart data graph [2].

Thermal comfort within a region of the psychrometric chart can be identified by a comfort zone. Two approaches for measuring thermal comfort are used by the control schemes to improve thermal comfort. A characteristic of the schemes is the assumption of a SIMO (single input, multiple output) building system, where variables are measured indoor temperature and relative humidity, and the single manipulated variable is the power applied to the HVAC device [3]. Within a psychrometric chart thermal comfort can be defined by a comfort zone. The comfort zone of the ASHRAE is shown in Figure 1.
Psychrometric charts are very important in the design and analysis of air processing systems. Madu analyzes the air treatment system at a given ambient temperature [4]. Horan and Luther introduces various psychrometric chart applications for research analysis and reporting and addresses Microsoft Office Excel software to generate the chart and display user data [5]. Energy efficiency and exergy analysis can be done using data and psychrometric equations [3,6,7]. Vadoudi and Marinhas approach the AHU (Air Handling Unit) energy efficiency calculation using psychrometric chart [8].

The temperature of the dew point and the temperature of the wet-bulb on the psychrometric chart can be used to estimate the frost potential and to determine the best time for frost protection sprinklers to turn on. The nighttime low temperature is determined by the heat lost to the atmosphere and the temperature at the dew point, unless a weather front causes cold air to move into an area. At night, the dry-bulb temperature decreases as heat radiates to the atmosphere [9].

A psychrometric chart point shows 7 properties of an air condition. If two properties are known, then it is possible to calculate 5 other properties. Air treatment can change the air properties. It is possible to determine changes in air properties by measuring each air properties and plotting them on a psychrometric chart. Determining the amount of cooling capacity used in air conditioning systems is one of the applications of psychrometric analysis. A system that is integrated between the data acquisition device and data display was needed to show the air properties at any time. This research designs and develops applications that are ready to display data and psychrometric charts that can later be integrated with hardware equipped with sensors through an interface.

An air mixing system is a system that changes air conditions by mixing air streams that have different temperatures. In some systems, supply air is usually a mixture of outside air with return air so that the use of energy is more efficient. The process of mixing water is often found in room air conditioning systems that use Air Handling Units (AHU) or Fan Coil Units (FCU). The air mixing is in the cooling coil input (entering water, EA). The use of return air (RE) from rooms with temperatures lower than environmental air (fresh / outdoor air, OA), with sufficient discharge will reduce the level of energy entering the coil and reduce capacity or save energy absorption in the cooling coil. The scheme and process line of the water mixing system can be seen in Figure 2 and Figure 3.
2. Methods
The method used to draw psychrometric charts is based on the work done by Bucklin et al [9]. The psychrometric chart has been widely used to analyze air processes in air conditioning systems.

To show the condition of the air at any time needed a system that is integrated between the data acquisition device and data display. This research designs and develops applications that are ready to display data and psychrometric charts that can later be integrated with hardware equipped with sensors through an interface [10-13]. Psychrometric applications are designed using the JavaScript programming language, so they can be opened using any web browser. Psychrometric charts are drawn using iteration calculation methods [14].

3. Results and discussion
Figure 4 shows the initial appearance of the Psychrometric application. This application can be used off-line, not connected with data acquisition equipment. However, simulations can still be used to obtain the properties of air.
Figure 4. Psychrometric application.

Figure 5 shows the simulation output using a psychrometric application. In this study, simulations were carried out with the input variable Dry-bulb Temperature (Tdb) and Relative Humidity (RH). Whereas the output is Wet-bulb Temperature (Twb), Moisture Content (ω), Specific Enthalpy (h), Specific Volume (v), Dew-Point Temperature (Tdp). Simulation output compared to manual plots on psychrometric charts.

Figure 5. Simulation psychrometric application.
Table 1 shows the output results from the $T_{wb}$ simulation drawn manually on the psychrometric chart and $T_{wb}$ from the application. The average difference between the values of manual $T_{wb}$ with $T_{wb}$ application is 0.0433 °C (0.27%) with a standard deviation of 0.0418 °C.

**Table 1.** The result of $T_{wb}$ drawn manually on the psychrometric chart and $T_{wb}$ from the application.

| Input | T$_{db}$ [°C] | RH [%] | Manual [°C] | Application [°C] | Difference [°C] | Percentage (%) |
|-------|---------------|-------|-------------|------------------|-----------------|----------------|
| 35    | 75            | 30.90 | 30.94       | 0.04             | 0.129           |
| 35    | 70            | 30.05 | 30.07       | 0.02             | 0.067           |
| 35    | 60            | 28.20 | 28.18       | 0.02             | 0.071           |
| 35    | 50            | 26.20 | 26.14       | 0.06             | 0.229           |
| 33    | 75            | 29.20 | 29.10       | 0.10             | 0.343           |
| 33    | 70            | 28.30 | 28.24       | 0.06             | 0.212           |
| 33    | 60            | 26.60 | 26.43       | 0.17             | 0.639           |
| 33    | 50            | 24.60 | 24.49       | 0.11             | 0.447           |
| 30    | 70            | 25.60 | 25.50       | 0.10             | 0.391           |
| 30    | 60            | 23.80 | 23.82       | 0.02             | 0.084           |
| 30    | 50            | 22.05 | 22.01       | 0.04             | 0.181           |
| 28    | 60            | 22.05 | 22.07       | 0.02             | 0.091           |
| 28    | 50            | 20.40 | 20.36       | 0.04             | 0.196           |
| 27    | 60            | 21.20 | 21.21       | 0.01             | 0.047           |
| 27    | 50            | 19.60 | 19.54       | 0.06             | 0.306           |
| 26    | 60            | 20.30 | 20.34       | 0.04             | 0.197           |
| 26    | 50            | 18.80 | 18.72       | 0.08             | 0.426           |
| 25    | 50            | 18.00 | 17.88       | 0.12             | 0.667           |
| 25    | 45            | 17.05 | 17.06       | 0.01             | 0.059           |
| 24    | 50            | 17.05 | 17.06       | 0.01             | 0.059           |
| 24    | 45            | 16.30 | 16.26       | 0.04             | 0.245           |
| 23    | 50            | 16.30 | 16.24       | 0.06             | 0.368           |
| 23    | 45            | 15.60 | 15.46       | 0.14             | 0.897           |
| 22    | 50            | 15.40 | 15.42       | 0.02             | 0.130           |
| 22    | 45            | 14.80 | 14.68       | 0.12             | 0.811           |
| 15    | 100           | 15.00 | 15.00       | 0.00             | 0.000           |
| 15    | 90            | 14.10 | 14.01       | 0.09             | 0.638           |
| 15    | 80            | 13.00 | 12.99       | 0.01             | 0.077           |
| 14    | 100           | 14.00 | 14.00       | 0.00             | 0.000           |
| 14    | 90            | 13.10 | 13.04       | 0.06             | 0.458           |
| 14    | 80            | 12.05 | 12.05       | 0.00             | 0.000           |
Table 1. Cont.

| Input | RH [%] | Manual [°C] | Application [°C] | Difference [°C] | Percentage (%) |
|-------|--------|-------------|------------------|-----------------|----------------|
| Twb   |        |             |                  |                 |                |
| T_{db} [°C] |       | Manual [°C] | Application [°C] | Difference [°C] | Percentage (%) |
| 13    | 100    | 13.00       | 13.01            | 0.01            | 0.077          |
| 13    | 90     | 12.10       | 12.07            | 0.03            | 0.248          |
| 13    | 80     | 11.10       | 11.10            | 0.00            | 0.000          |
| 12    | 100    | 12.00       | 12.00            | 0.00            | 0.000          |
| 12    | 90     | 11.20       | 11.10            | 0.10            | 0.893          |
| 12    | 80     | 10.10       | 10.17            | 0.07            | 0.693          |
| 11    | 100    | 11.00       | 11.01            | 0.01            | 0.091          |
| 11    | 90     | 10.10       | 10.13            | 0.03            | 0.297          |
| 11    | 80     | 9.20        | 9.23             | 0.03            | 0.326          |
| 10    | 100    | 10.00       | 10.00            | 0.00            | 0.000          |
| 10    | 90     | 9.20        | 9.16             | 0.04            | 0.435          |
| 10    | 80     | 8.30        | 8.28             | 0.02            | 0.241          |
| 9     | 100    | 9.00        | 9.01             | 0.01            | 0.111          |
| 9     | 90     | 8.20        | 8.19             | 0.01            | 0.122          |
| 9     | 80     | 7.40        | 7.35             | 0.05            | 0.676          |
| 8     | 100    | 8.00        | 8.00             | 0.00            | 0.000          |
| 8     | 90     | 7.20        | 7.22             | 0.02            | 0.278          |
| 8     | 80     | 6.40        | 6.42             | 0.02            | 0.313          |

| Average | 0.0433 | 0.270 |
| Standard Deviation | 0.0418 |

Another simulation shows Moisture Content (ω) that the average difference is 0.079 gv/kga (0.77%) with a standard deviation of 0.0502 gv/kga. While the Specific Enthalpy (h) the average of the difference is 0.2376 kJ/kg (0.52%) with a standard deviation of 0.1609 kJ/kg. Furthermore, the Specific Volume (v) of the average difference is 0.0024 m³/kg (0.28%) with a standard deviation of 0.0031 m³/kg. For Dew-Point Temperature (T_{dp}) the average difference of 0.1155 °C (0.92%), the standard deviation of 0.1029 °C.

4. Conclusion
Based on the results of data analysis, the difference in value between the results of manual calculations and applications is as follows: wet-bulb temperature (Twb) is 0.27%, Moisture Content (ω) is 0.77%, specific enthalpy (h) is 0.52 %, Specific Volume (v) is 0.28%, Dew-Point Temperature (T_{dp}) is 0.92%.

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