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THE USE OF PSYCHROMETRIC ANALYSIS KIT FORLEARNING AIR CONDITIONING PROCESS IN VOCATIONAL EDUCATION

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Abstract

This study aims to demonstrate the use of a psychrometric analysis kit for the air conditioning process learning in vocational education. The dimensions of this kit are relatively small, which is 150 x 60 x 70 cm, making it easy to move and use in various places and classrooms. Its components consist of a round air duct made of PVC, a blower motor, heater, thermostat, humidity meter, anemometer, air flow regulator, cooling components, humidifier, electric power regulator, and pressure gauge. Psychrometric processes simulated during the test include cooling and sensible heating, cooling and dehumidification, heating and humidifying processes. All air variable data measured during the test are recorded and plotted on a psychrometric diagram to determine the condition of other air variable data. The performance test results show that this kit can show air conditioning processes and all air variable measurement results can be observed directly on the display board. In the future, this kit can be connected to a computer so the recording can be accurate.

Keywords: Air conditioning process, Practicum learning, Psychrometric analysis kit, Vocational education.

1. Introduction

The indoor air conditioning process has a substantial influence on human thermal comfort [1]. Thermal comfort is obtained by adjusting temperature, humidity, flow rate, and cleanliness of indoor air [2]. Indonesia, which is located in the tropical region, has high temperatures and humidity throughout the year [3]. High levels of humidity can reduce indoor air quality [4], trigger mold growth that causes respiratory discomfort and allergies [5] and contribute to deterioration of building materials [6]. Many houses in the tropics are equipped with air conditioners in order to resolve this disturbing condition.

Basic air conditioning is the main course for vocational students in the refrigeration field. In order to acquire the competence of the course, an understanding of the psychrometric process is essential to fully understand the multiple processes involved in air conditioning. Psychrometric is a field of science that deals with the determination of the thermodynamic properties of gas-vapor mixtures, specifically moist air, a mixture of dry air and water vapor [7]. Psychrometric parameters are usually observed by changes in dry bulb temperature, wet bulb temperature, dew point temperature, relative humidity, humidity ratio, specific enthalpy, and so on [8].

Psychrometric processes demonstrate many everyday phenomena that are applied in various household and industrial applications. Furthermore, sensible processes of cooling and heating, cooling and dehumidification, cooling and humidification, heating and humidification, chemical dehumidification and air flow mixing are widely used psychrometric processes include [9]. Learning activities must be in harmony between theory and practice. Learning practices have to be in compromise to theoretical and empirical work to provide an understanding of phenomena in the real world [10]. Practical activities are useful in strengthening, constructing and reconstructing scientific knowledge [11]. Practicum can also provide practical skills to students [12] and can be used as a medium to cope with student preconceptions [13]. Experience in applying practical knowledge allows students to resolve problems in the future workplace [14].

In order to increase students' understanding, many researchers have reported their ideas and strategies in teaching [15], including the use of psychrometry workbooks in an open source and platform independent interactive Web site using standard HTML and JavaScript technology [8], and the use of computational tools developed in Microsoft Excel to improve students' understanding of psychrometric processes [9]. Furthermore, creating an active learning design by increasing the scale of the exercises centered around the colour coding of the psychrometric chart and then applying it to several types of classical problems [16], using the edutainment method to make psychrometric learning activities become interesting and insightful [17], and using MATLAB as a teaching-learning tool for basic psychrometric processes [18]. The aforementioned strategies are successful and useful strategy as it could simulate psychrometric processes, however, problem have still been established. Needless to say, additional instruments are required to obtain data on the properties of the air to be analysed, additional tools are needed, namely a psychrometer or sling psychrometer [19]. In doing so, students have to rotate the psychrometer sling in the air around one minute, and then data from both thermometers will be recorded. This process is repeated several times to ensure that the wet bulb temperature is accurately recorded [7].

Nowadays, particularly in developing countries such as Indonesia, the number of practicum equipment capable of serving simulations of the psychrometric process by controlling the variable data of air properties is costly. The procurement of equipment for commercial technical practicum learning is exorbitant, therefore, it is difficult to provide [20]. Even though the use of physical equipment involves a real investigation process and the finding of unexpected events during the practice [21]. The difference between theory and practice is an important part for students to understand their role in implementing practicum [22].

Therefore, to overcome this issue, we need to build our own portable practicum media according to the skills that students need. The aim of this study is to demonstrate the use of a psychrometric analysis kit for learning the air conditioning process in vocational education. The distinction between the kit that we produce and other products is that they are simple to assemble. In addition, this kit is relatively small with dimensions of 150 x 60 x 70 cm and accessible because it is easily moved and can be used in various places and classrooms. This novelty makes this kit suitable for developing countries with a lot of limited trial space and funding.

2. Method

2.1. Design of psychrometric analysis kit

Figure 1 shows a psychrometric analysis kit with two views: (a) front view and (b) rear view. Based on the information in Fig. 1(a), three colour indicators can be seen along the round air channel consisting of green, blue and red. This indicator describes the air condition when it passes through various conditioning processes, where green indicates humid air, blue indicates cold air, and red indicates warm air.

The main components of this kit are composed of 4” PVC air ducts (Rucika), blower (Imatsu; CDI-100P-CY), electric resistance heater (Teach; 175/600 W, 220 VAC/50 Hz, with thermostat), refrigeration system (Teach ; Qo = 1340 Btu/h, 220 VAC/50 Hz), gauge pressure (Blue; BLB, BLR/OPG-63), multimeter (Peacefolr; PZEM), anemometer (UNI-T; UT363BT), temperature-humidity meter (UNI-T; UT333BT), pilot lamp (Hager; 220 VAC/50 Hz, diameter 22 mm Red), circuit breaker (Hager; Single Phase, 6 A), ultrasonic humidifier (Warmtoo; 24 VDC), power supply (220 VAC to 5 VDC, 3 A), variable power control (100-220 VAC 2000 W), and sensor cable (Belden; AWG 18x4 W/shielding).

In order to prevent condensation along the duct during the test, insulation is installed in all air ducts. All components are assembled on an aluminum frame with the respective length, width, and height of 150, 60, and 70 cm. The gauge display is mounted on an acrylic laser cutting and printing panel to facilitate psychrometric analysis. The display makes the air conditioning system operation simple for students, students can observe the parameters read on each measuring instrument and record any changes that occur during the test.

2.2. Validation of the psychrometric kit

A laboratory assistant and an industry practitioner validated the kit. In order to capture the technical and aesthetic aspects of the kit, a questionnaire consisting of 10 statement was used. Furthermore, the performance test is conducted through the alpha test by providing input and seeing the output results through laboratory experiments.

The results of the questionnaire from the technical and aesthetic aspects are shown in Table 1 and the results of the alpha test are presented in Table 2.

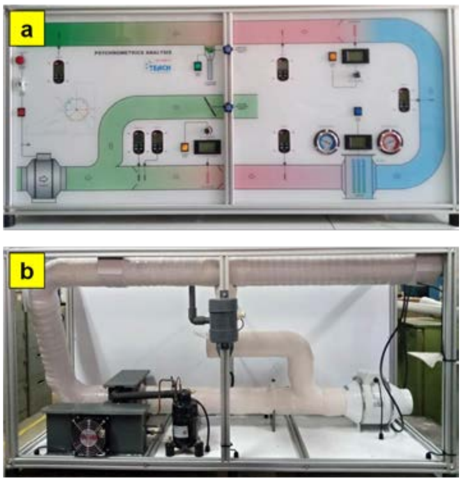

Fig. 1. Psychrometric analysis kit with two views: (a) front view; and (b) rear view.

Table 1. Expert validation results for the feasibility of the kit.

No.	Validation Indicators	EV1	EV2	Total	Average
1	This psychrometric kit has an attractive design	4	4	8	4
2	The configuration of the components in the kit panel is users friendly and easily understood.	4	4	8	4
3	Psychrometric kit is easily used and simple to operate	4	4	8	4
4	Psychrometric kit is effective in learning	3	4	7	3.5
5	Depending on the mode of use, the dimensions of the psychrometric kit are ergonomic	3	3	6	3
6	This psychrometric kit provides clear data information	4	4	8	4
7	This psychrometric kit is able to demonstrate its applicable functions in real life	4	3	7	3.5
8	The accuracy of the composition of the circuit image, voltage source, measuring instrument, components, indicator lights, description	4	4	8	4
9	The colour illustration on the psychrometric kit background is suitable	4	4	8	4
10	Psychrometric kit is easy to move around the room and classroom	4	4	8	4
	Total	38	38	76	34
	Average	3.8	3.8	7.6	3.4

**Note: EV = Expert Validation*

Based on the validation results, it can be assumed that this kit is functioning properly. The next step is validating through beta testing for kit users. The beta testing stage process is to determine that the product is users friendly. However, in this study the beta test could not be carried out due to the COVID-19 pandemic outbreak and the learning process has been conducted through distant learning [23].

Table 2. Alpha test result data about the performance of the kit.

Test Case	Testing Scenarios	The Expected Results	Testing Results	Conclusion
Power	Power button is pressed ON	The kit is in standby position and ready to use	Relevant	Valid
Air flow value setting	Change the volume damper value (clockwise and counterclockwise)	There is a change in the air flow value (the indicator reads on the anemometer)	Relevant	Valid
Pre-heater power setting	Set heater power values from 0 - 1200 W	Read the desired heater power value	Relevant	Valid
Refrigerant pressure regulation	Establish low pressure standards as the baseline for recording data	Measured low pressure of 2.75 bar as a steady condition	Relevant	Valid
Re-heater power setting	Set heater power values from 0 - 1200 W	Read the desired heater power value	Relevant	Valid
Humidifier setup	Adjusting the modulating humidifier damper for adding moisture to the air	Read the value of change in humidity according to the desired (the indicator is read on the RH meter)	Relevant	Valid

*Note: Test format adapted from [24].

2.3. Operation procedure of the kit

The first stage of the psychrometric analysis kit involves turning on the circuit breaker and main power switch. Furthermore, the blower will operate by blowing air through the air duct. The amount of air flow rate can be controlled by adjusting the airflow modulating damper. The value of air velocity and temperature will be detected by the anemometer and first Temperature/RH sensors (T1/RH1). The pre-heater power switch can be switched on to increase the temperature of the flowing air. The amount of heater power will vary from 0-1200 W and the measurement results are shown by the second Temperature/RH sensor (T2/RH2).

The second step is to turn on the cooler power to activate the refrigeration system and start the air-cooling process. The low-pressure indicator of 2.75 bar is used as a reference in recording changes in temperature and humidity air flowing through the evaporator coil. Air cooling measurement results are displayed by the third Temperature/RH sensor (T3/RH3). Then the air will continue to flow along the duct and through the re-heater. If the air temperature is to be increased, the re-heater power switch must be activated. Changes in temperature and RH data are indicated by the fourth Temperature/RH sensor (T4/RH4).

The final step is to turn on the humidifier power switch to add water content to the air flowing in the duct. Data on the changes in air characteristics passing through the humidifier are detected by the fifth Temperature/RH sensor (T5/RH5). All recorded measurement data are then plotted on a psychrometric diagram to find out other parameters required for further analysis. In this study, the plotting of the measured data was assisted by Daikin's psychrometric diagram viewer software, shown in Fig. 2. This application is very helpful for knowing the properties of the air being analysed. At any given time, the air condition can be interpreted as a point on the graph. If conditions change, the dots will move around the chart. The direction the point moves depends on what properties of the air are changing. In psychrometric analysis this change in state can be caused by adding or removing heat, causing work to be performed on or by the fluid, adding or removing mass (usually of water vapor), or mixing two fluids which are at dissimilar states.

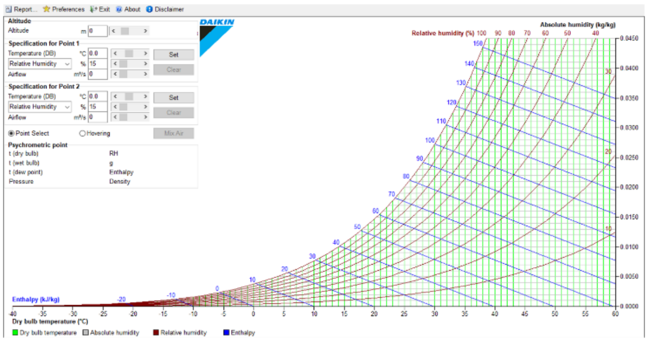

Fig. 2. Psychrometric diagram viewer (Daikin).

3. Results and Discussions

In the field of air conditioning, psychrometric parameters include measuring and calculating the properties of the outdoor air and the indoor air being conditioned [25]. Psychrometric is also used to find air conditions that will definitely be more comfortable in a conditioned room. In psychrometric, there are several processes that can be analysed, namely sensible cooling and heating, cooling and dehumidifying, heating and humidifying processes. In using this kit, each process can be simulated alternately. Changes in air heat load can be achieved by adjusting the electric power value of the heater and the air flow rate that flows along the channel.

3.1. Sensible cooling and heating process

The sensible cooling and heating process are ways to reduce or increase the room air temperature without changing the amount of water vapor in the air. In the simulation conducted in this study, it was initiated by a sensible heating process with the initial conditions of the air entering the test equipment, designed at a temperature (T1) of 29.3 °C and Relative Humidity (RH1) of 60%. Water flow rate flowing in the channel is kept constant 0.047 m^3/s. Then the air flows through the heater with the heat load set at 800 W. After that, the air passes through the T2 and

RH2 sensors, and the values are 43.8 °C and 27%, respectively. This data is then plotted on the psychrometric diagram shown in Fig. 3. During this process the humidity ratio remains constant and only changes in temperature occur [9].

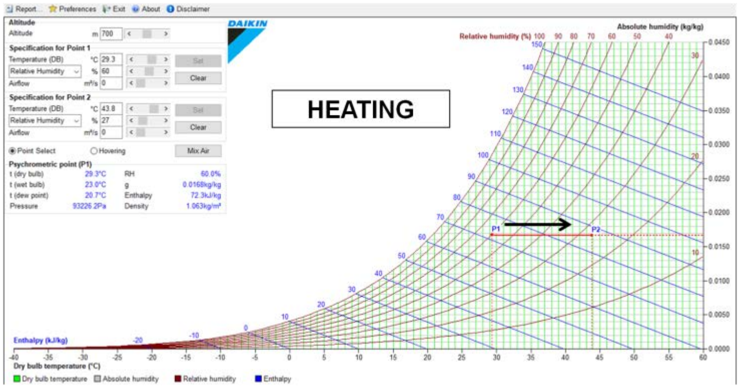

Fig. 3. Sensible heating process.

The same condition also occurs in the sensible cooling process. At first, air flows into the channel at T1 of 30.3 °C and RH of 57%. Before passing through the cooling coil, the air is passed to the heater so that changes in T2 and RH2 become 44.5 °C and 28%. The recording of changes in temperature and relative humidity through the cooling coil is carried out after the refrigeration cycle is in a steady state which is indicated by a minimum suction pressure value of 2.75 bar. In this condition the refrigerant is perfectly circulating and the heat transfer process is ideal. When the T2 and RH2 air passed through the cooler, the suction and discharge pressure conditions were 3.1 and 11.2 bar, respectively. As a result, the air passing through the cooling coil produces changes in T3 and RH3 of 28.1 °C and 69%, respectively. This data is then plotted on the psychrometric diagram shown in Fig. 4.

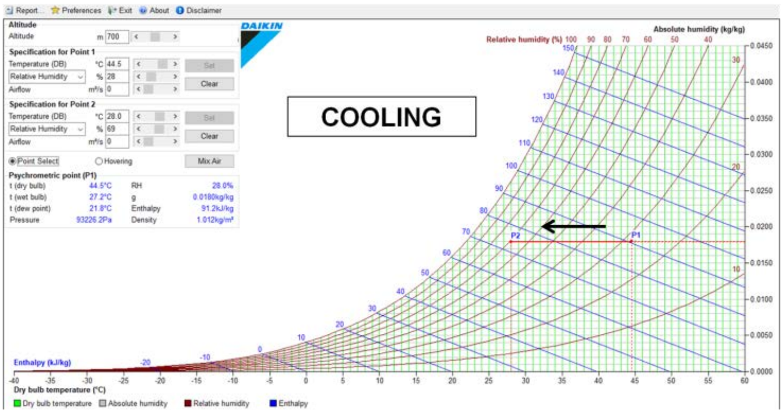

Fig. 4. Sensible cooling process.

The results obtained in the sensible cooling and heating process are depicted by a straight line from point 1 (P1) to point 2 (P2). Based on the data from these two points, other parameters can be seen, as shown in Table 3. Referring to these data, we can find out the cooling and heating process by looking at the changes in the dry bulb wet bulb temperature data, RH, enthalpy, and density in columns P1 and P2.

Table 3. Data from psychrometric plotting on sensible cooling and heating processes.

Variable of air	Heating		Cooling	
	P1	P2	P1	P2
T (dry bulb), °C	29.3	43.8	44.5	28
T (wet bulb), °C	23	26.3	27.2	23.4
T (dew point), °C	20.7	20.7	21.8	21.8
Pressure, Pa	93226.2	93226.2	93226.2	93226.2
Humidity, %	60	27	28	69
Ratio Humidity (g), kg/kg	0.0168	0.0168	0.018	0.018
Enthalpy, kJ/kg	72.3	87.1	91.2	73.9
Density/m³	1.063	1.015	1.012	1.067
Airflow, m^3/s	0.047	0.047	0.047	0.047

3.2. Cooling and dehumidifying processes

In this process, moist air passes through the surface of the cooling coil and part of the airflow is cooled below its dew point temperature. When air is cooled below the dew point temperature, condensation occurs and water vapor is removed from the air stream. The exhaust airflow has a lower temperature to humidity ratio than the intake air stream. Cooling to condense water from the air is called latent cooling or dehumidification. Experiments carried out in this process are with the initial data design (Table 4).

Air temperature of 40.1 °C and RH of 38.5% flow through the air duct to the cooling coil. The refrigeration system is conditioned at a low pressure of 3 bar and a high pressure of 11.2 bar. The air passing through the cooling coil produces a change in temperature and RH of 23.5 °C and 80%, respectively. Then, the air flows through the re-heater to reduce the water vapor content. Thus, the air characteristics change again to produce a temperature of 28.5 °C and RH of 63.9%. The resulting data is then plotted on the psychrometric diagram shown in Fig. 5.

Table 4. Data from measurement of cooling and dehumidifying processes.

Variable	Unit	Value
Pre- Heater Power	W	800
Airflow rate	m^3/s	0.047
Temperature (T2)	°C	40.1
Relative Humidity (RH2)	%	38.5
Low Pressure Gauge	bar	3
High Pressure Gauge	bar	11.2
Cooling Power	W	205
Temperature (T3)	°C	23.5
Relative Humidity (RH3)	%	80
Re-Heater Power	W	200
Temperature (T4)	°C	28.5
Relative Humidity (RH4)	%	63.9

Referring to the psychrometric chart (Fig. 5), the cooling and dehumidifying process is represented as a line sloping down and to the left (P1-P2). Based on the data from these two points, other parameters can be seen, as shown in Table 5. Referring to this data, we can find out the cooling process by looking at changes in the dry bulb temperature, wet bulb, and dew point data in columns P1 and P2. Meanwhile, the dehumidifying process can be seen from the changes in the values of density, enthalpy, and humidity ratio (g) in the same column.

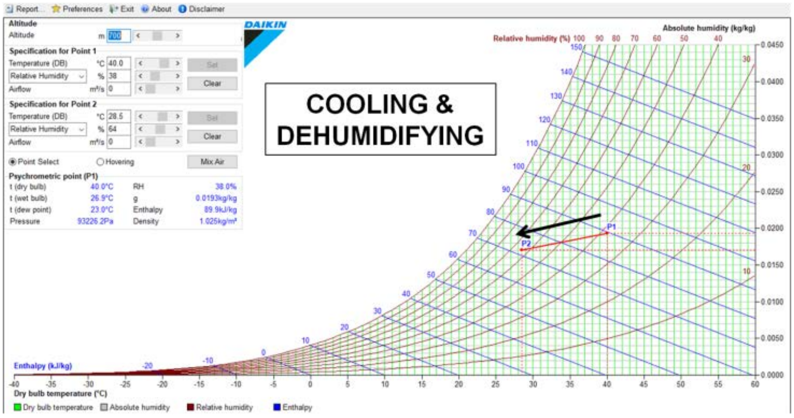

Fig. 5. Psychrometric diagram of cooling and dehumidifying process.

Table 5. Data from psychrometric plotting on cooling and dehumidifying processes.

Variable of air	P1	P2
***T* (dry bulb), °C**	40	28.5
***T* (wet bulb), °C**	26.9	23
***T* (dew point), °C**	23	21
Pressure, Pa	93226.2	93226.2
RH, %	38	64
Humidity ratio (g), kg/kg	0.0193	0.0171
Enthalpy, kJ/kg	89.9	72.3
Density, kg/m³	1.025	1.066
Airflow, m³/s	0.047	0.047

3.3. The process of heating and humidifying

Heating and humidifying are the process of simultaneously increasing both the dry-bulb temperature and humidity ratio of the air. The total heat gained in going from the initial to the final condition can be broken into sensible and latent heat portions. In winter, humidification frequently is required because the cold outside air, infiltrating into a heated space or intentionally brought in to satisfy the space ventilation requirement, is too dry. In summer, humidification is typically performed as part of an evaporative cooling system.

In this study, a simulation of the heating and humidifying process is carried out by using the measurement data design as presented in Table 6. The air flows in the duct with a temperature of 35.7 °C and a RH of 47%. Furthermore, the air flows through the re-heater which has a power of 800 W so that there is a change in temperature and relative humidity, respectively 45.6 °C and 29.9%. All data are then recorded, and the data is plotted on a psychrometric diagram, see Fig. 6.

On a psychrometric chart (see Fig. 6), this process is shown as an upward sloping line (P1-P2). After these two points are known, the other data conditions can be known as shown in Table 7. Changes in temperature data for dry bulb, wet bulb, and dew point from column P1 to P2 have shown the occurrence of the heating process. Likewise, the humidifying process can be witnessed by looking at the changes in the humidity ratio (g), enthalpy, and density values of the same column. The heating and humidifying processes occur sequentially. Starting with the addition of the dry bulb temperature, which is sensible heating that occurs when air passes through the heat exchanger. Then proceed with the humidification process, namely adding water vapor to the air using an ultrasonic humidifier. During this process, both sensible heat as well as latent heat change [18].

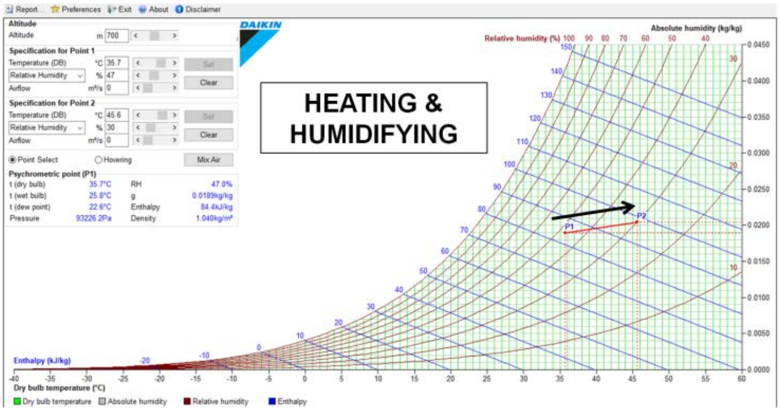

Fig. 6. Psychrometric diagram of heating and humidifying process.

Table 6. Data from measurements in the heating and humidifying process.

Variable	Unit	Value
Pre- Heater Power	W	800
Airflow rate	m^3/s	0.047
Temperature (T3)	°C	35.7
Relative Humidity (RH3)	%	47.1
Re- Heater Power	W	800
Temperature (T5)	°C	45.6
Relative Humidity (RH5)	%	29.9

Table 7. Data from psychrometric plotting on heating and humidifying processes.

Variable of air	P1	P2
T (dry bulb), °C	35.7	45.6
T (wet bulb), °C	25.8	28.7
T (dew point), °C	22.6	23.9
Pressure, Pa	93226.2	93226.2
RH, %	47	30
Humidity ratio (g), kg/kg	0.0189	0.0205
Enthalpy, kJ/kg	84.4	98.7
Density, kg/m³	1.04	1.007
Airflow, m^3/s	0.047	0.047

4. Conclusions

This paper presents a simulation method for air conditioning processes using a psychrometric analysis kit for learning air conditioning in vocational education. To show the performance of our kit, we conduct tests on various psychrometric processes. The performance test results show that this kit can show air conditioning processes and all air variable measurement results can be observed directly on the display board. In addition, this kit is able to provide an overview of psychrometric processes such as real conditions.

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