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AN EXPERIMENT ON THE AIR VELOCITY, TEMPERATURE AND MOISTURE RELATIONSHIPS

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SUMMARY

In this experiment, the effect of air velocity on the condensation, wet and dry bulb temperatures with and without additional heat or vapor was investigated by means of an air conditioning unit. Here, 22 different conditions in terms of additional heat or vapor and refrigeration were tested. Most of the results were in agreement with the literature, but neverthless there were some figures seemed to be surprising, like although added heat was 2 kW, extracted was 2.884 kW. One possible cause of this may be the imperfection of 2 kW heating element in the unit. Heat removal by refrigeration cycle was smaller than total which was that of given heat plus given vapor.

INTRODUCTION

Air conditioning process can be described as "controling of the air of a living environment". This control basically contain temperature and relative humidity which are the main factors on the comfort level of the environment. To understant the psychrometry of the air some definitions are desired. These are as follows;

Dry bulb temperature: the temperature which is sensible (i.e.we feel it),

Wet bulb temperature: the temperature at which air having a dry bulb temperature becomes full of water vapor,

Dew point temperature: the temperature below which air is unable to hold all the water it contains in the form of vapor (i.e.water condensates below this temperature),

Relative humidity (rh) refers to the degree of dryness of air and expressed as a ratio of the actual vapor pressure to the saturation vapor pressure at the prevailing temperature. In other words, rh is the raito of water that air is holding to that air could

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hold at the same temperature. Upper limit of rh is 100 percent (saturated air), thus rh of any air sample lies somewhere between 0 percent (completely dry air) and 100 percent. If an air sample is heated rh decreases, if cooled then it increases. Usually the amount of cooling or wet bulb depression is related to the amount of water in the air (rh) which can be determined by standard calculations or from psychrometric chart.

MATERIAL AND METHOD

Material

During the laboratory experiment, an air conditioning unit which has different options was used. Six thermometers, whose 3 were dry and 3 were wet bulb, were in application. Fan speed was variable and this gave the possibility to observe the effects of different speeds on the air properties during the each process. Unit itself had a cooling part and a small water store for vapor processes. Schematic layout of air conditioning laboratory unit is shown in Figure 1.

Method

The thermometers were placed on the unit as shown in Figure 1. For heating and vaporization cycles, measurements from the first and second thermometers (A, D) were taken. However for the cooling cycle, points D and G were the measurement places. In each treatment, about 5 minutes were allowed to pass in order to stabilize the thermometer measurements. Condensed water, during the refrigeration cycle, was collected in a container. Evaporator inlet and outlet temperatures, condenser outlet temperature, evaporator and condenser outlet pressures were recorded in the unit of kN/m^2. In each process, manometer pressure was recorded in mmWg and air flow rate (m^3/hr) was read from the calibration graph of the unit, which is shown in Figure 2.

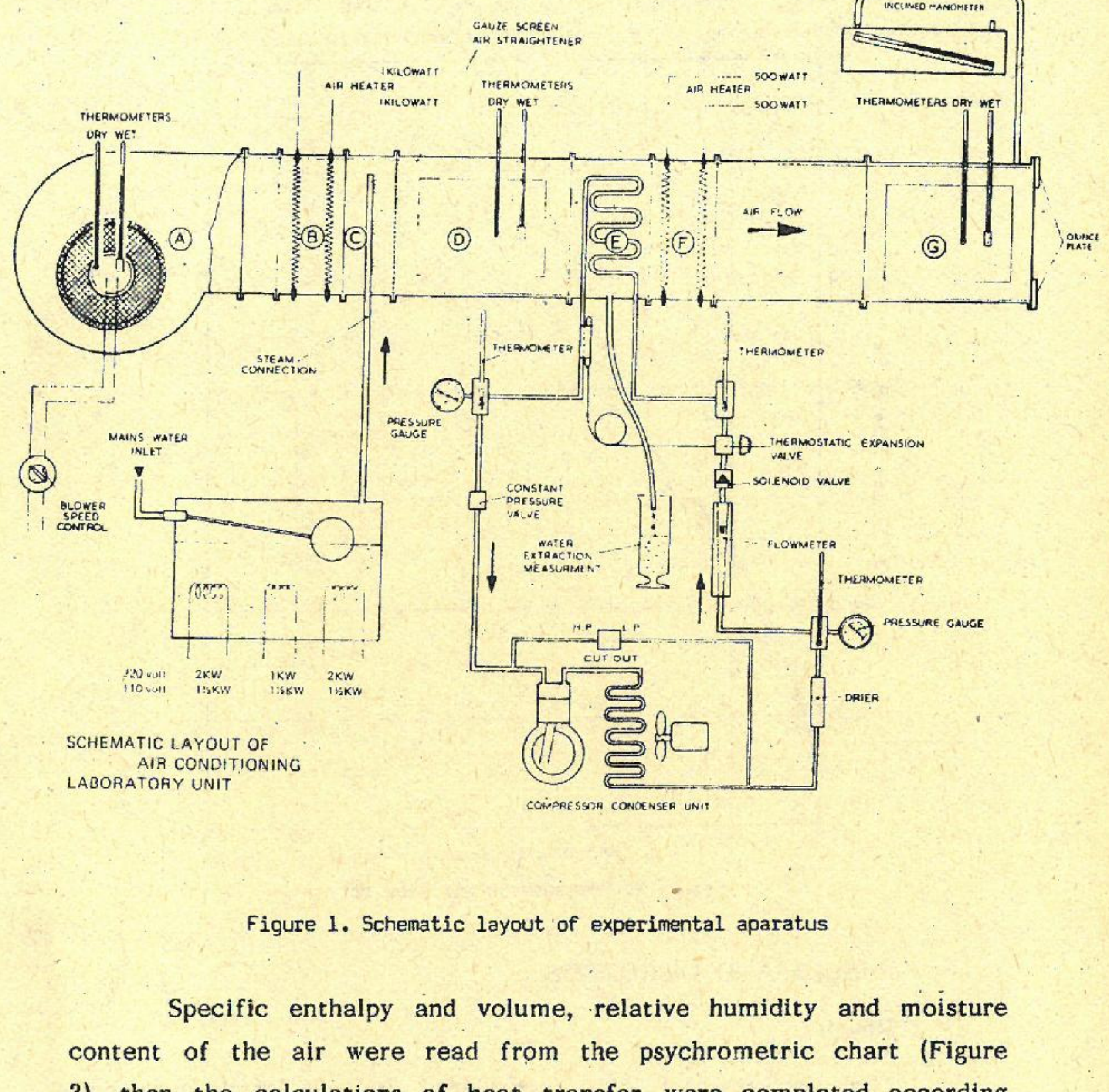

Figure 1. Schematic layout of experimental aparatus

Specific enthalpy and volume, relative humidity and moisture content of the air were read from the psychrometric chart (Figure 3), then the calculations of heat transfer were completed according to literature. Because of the difference in specific volume of the air at the entrance and exit, calculations were for both of these values in each part of the measurement points.

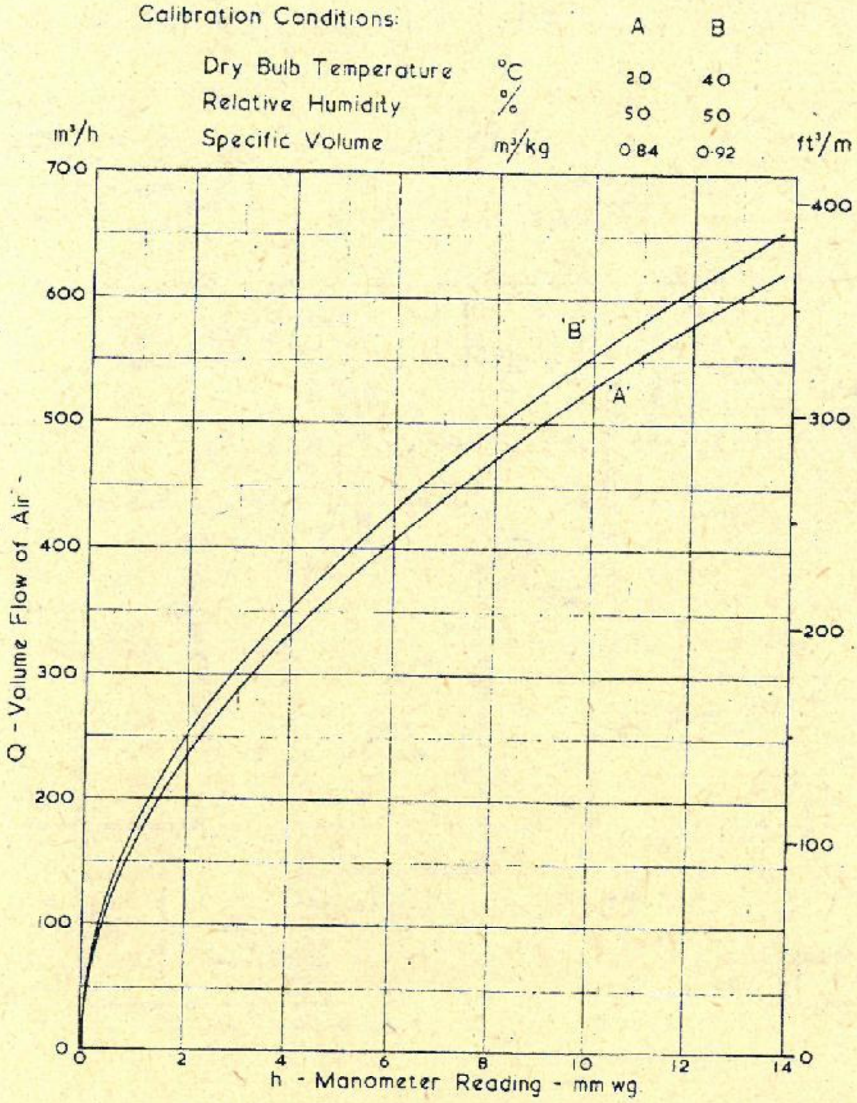

Figure 2. Pressure vs air flow rate

RESULT AND DISCUSSION

Results

The experimental data considered in this trial are shown in the table below, which contains 22 different conditions.

The first 6 tests were conducted in order to look at the effect of changing air velocities on the wet bulb temperature. In theory, fan velocity does not affect dry bulb temperature, but accelerates the evaporation thereby reducing the bulb temperature. Normaly added heat at the inlet should be given up at the outlet. As indicated above this was not the case observed, but during the injection of vapor

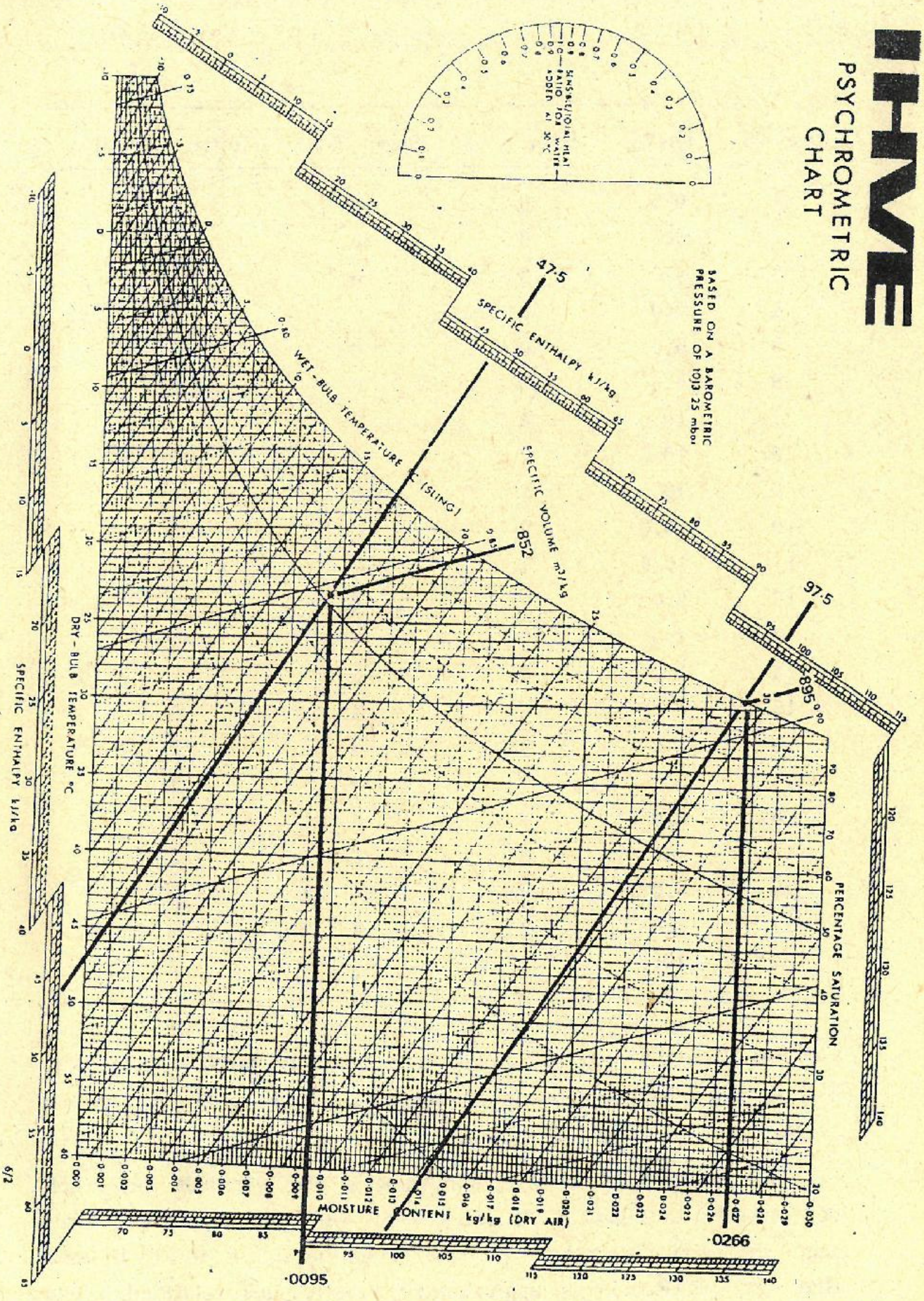

Figure 3. Psychrometric Chart

Test No	mmWg	Heat (kW)	Steam (kW)	Refrigera.(kW)
1	0.5	0	0	0
2	3.0	0	0	0
3	4.0	0	0	0
4	5.0	0	0	0
5	6.0	0	0	0
6	8.0	0	0	0
7	10.0	2	0	0
8	10.0	2	4	0
9	10.0	1	0	2
10	10.0	2	0	2
11	10.0	1	2	2
12	3.0	2	4	2
13	4.0	0	4	0
14	7.0	0	4	0
15	10.0	0	4	0
16	3.0	0	4	2
17	5.0	0	4	2
18	6.0	0	4	2
19	10.0	0	4	2
20	5.0	2	4	2
21	8.0	2	4	2
22	10.0	2	4	2

into the air, this can be expected due to additional heat by vapor. The air temperatures in each measurement and the properties related to these are shown in Table 2 and 3.

The relationship between air velocity and wet bulb depressioh can be seen in Figure 4. Velocity versus wet bulb depression represents the cooling degree of process. From the figure, it can be said that the relationship is approximately linear. This relationship can also be shown on the graph as wet bulb depression vs relative humidity (Figure 5).

Table 2. Measured Temperatures (^{o}C)

Test No	Dry Bulb in	Dry Bulb out	Wet Bulb in	Wet Bulb out	Condensation (Kg/hr)
1	18.2	17.6	11.2	12.8	-
2	18.2	17.8	11.0	12.6	-
3	18.4	18.0	11.0	12.4	-
4	18.4	18.0	11.0	12.2	-
5	18.4	18.2	10.8	12.2	-
6	18.6	18.4	11.0	12.2	-
7	19.4	31.2	11.2	17.8	-
8	20.2	34.5	11.4	24.5	-
9	25.8	15.2	14.0	10.0	-
10	32.6	20.2	16.6	12.0	-
11	27.0	16.0	14.6	10.0	-
12	25.6	18.4	25.8	18.6	2
13	18.6	22.4	11.0	22.0	-
14	19.0	22.0	11.2	20.4	-
15	18.6	21.4	11.6	19.4	-
16	24.6	17.2	24.6	17.2	-
17	22.0	16.6	20.6	16.6	1.2
18	22.2	16.6	20.8	16.6	1.5
19	22.0	16.6	19.8	16.4	1.1
20	39.0	23.8	27.0	22.0	1.0
21	36.0	23.0	25.0	21.2	0.7
22	34.6	22.8	24.0	20.6	0.4

Table 3. Properties of air related to Table 2

Fl.R.	rh (%) in	rh (%) out	Moist.Cont(Kg/Kg) in	Moist.Cont(Kg/Kg) out	Spec.Ent(kJ/Kg) in	Spec.Ent(kJ/Kg) out	Spec.Vol(m^3/Kg) in	Spec.Vol(m^3/Kg) out
124	41	57.5	0.0054	0.0072	31.75	35.75	0.831	0.833
290	40	52.5	0.0050	0.0070	31.20	35.00	0.831	0.834
332	39	51.0	0.0052	0.0066	31.10	34.75	0.833	0.835
373	39	49.0	0.0052	0.0064	31.10	34.00	0.833	0.835
409	38	49.0	0.0050	0.0064	30.90	34.00	0.832	0.835
474	37.5	47.0	0.0050	0.0062	31.25	34.00	0.833	0.834
529	33	25.0	0.0047	0.0072	31.30	49.80	0.835	0.872
529	31.3	42.5	0.0047	0.0160	32.00	73.30	0.838	0.894
529	25	52.0	0.0052	0.0057	38.50	29.00	0.852	0.823
529	12	36.0	0.0050	0.0053	45.00	38.50	0.873	0.838
529	22	45.0	0.0052	0.0052	40.20	28.60	0.858	0.827
290	100	100.	0.0208	0.0134	78.50	52.50	0.875	0.845
332	37.5	96.0	0.0050	0.0166	31.25	64.50	0.833	0.859
440	36	86.0	0.0050	0.0144	31.50	53.50	0.834	0.855
529	42	83.0	0.0056	0.0132	32.50	55.00	0.833	0.852
290	100	100.	0.0196	0.0122	74.50	48.00	0.870	0.838
373	87	100.	0.0146	0.0118	59.00	46.50	0.856	0.836
409	88	100.	0.0150	0.0118	60.00	46.50	0.857	0.836
529	81	100.	0.0136	0.0118	56.50	46.50	0.854	0.836
373	38	81.0	0.0175	0.0159	84.00	56.50	0.908	0.854
474	38.5	84.0	0.0153	0.0150	75.00	61.00	0.897	0.859
529	40	81.0	0.0143	0.0142	71.00	59.00	0.892	0.857

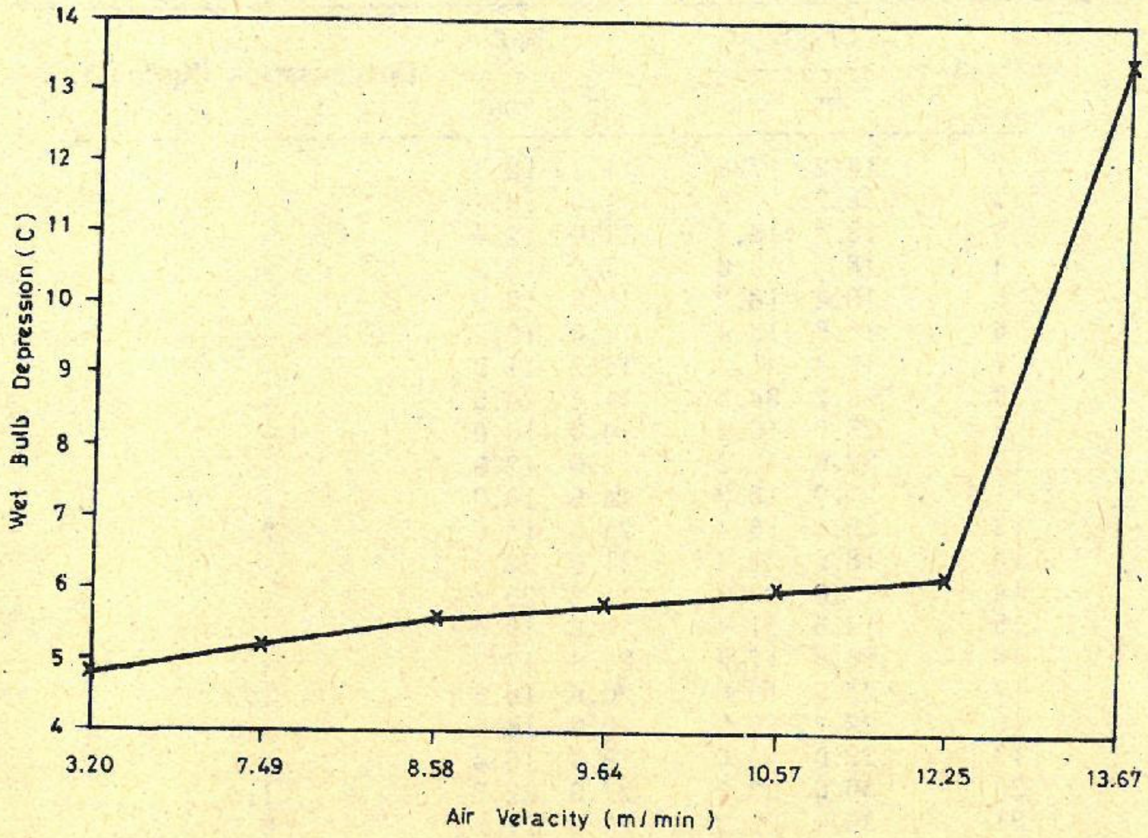

Figure 4. Air velocity versus wet bulb depression

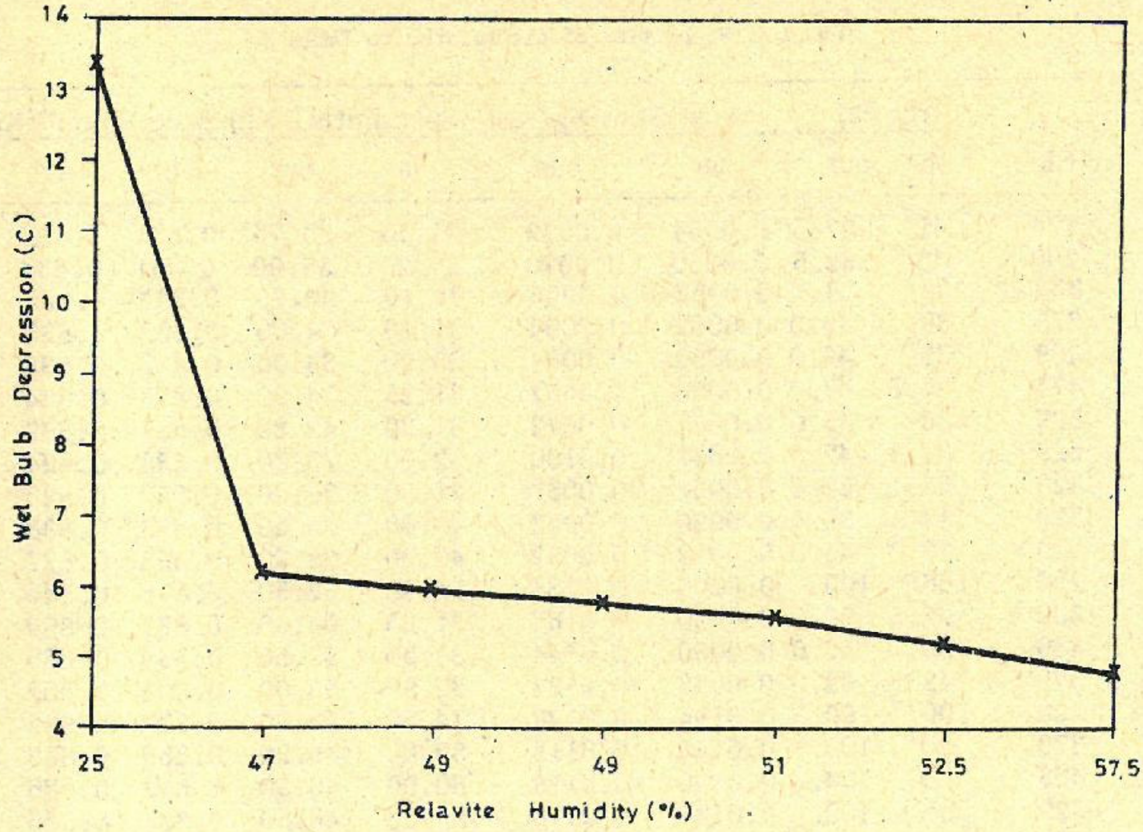

Figure 5. Relative humidity vs wet bulb depression

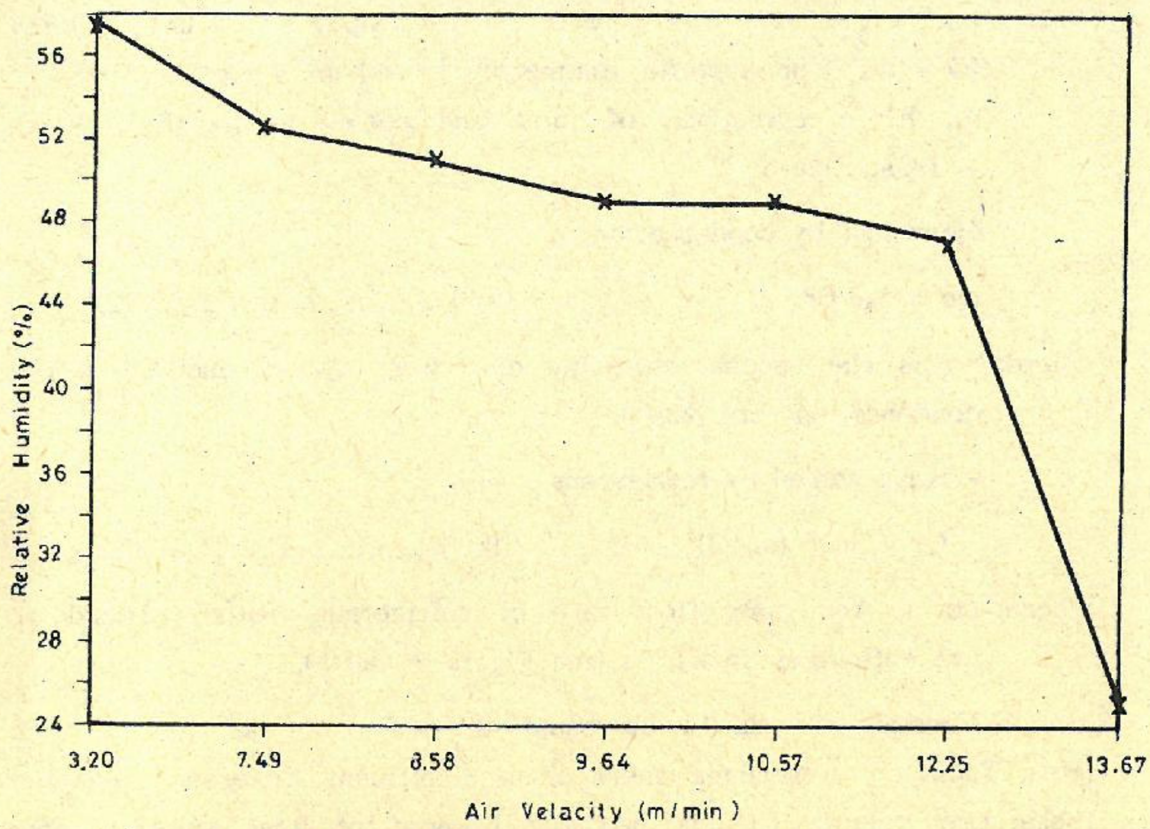

Figure 6. Relative humidity vs air velocity

As the fan velocity increases, provided that the amount of vapor added is same for each velocity, moisture content of the outlet air decreases. Because in this condition increasing fan velocity decreases the evaporation on the wet bulb. Figure 6 represents this.

Specific enthalpy of the air increases with increasing heat input, but decreases with increasing fan velocity at the same heat input.

During the refrigeration cycle, unit can not transfer all the heat which is transported by the air while 4 kW of vapor is sent onto evaporator. The critical velocity at which condensation tends to stop seemed to be around when the manometer pressure was 10 mmWg.

Calculations

- Heat lost or gained by the air;

q = ma* (hl-h2) (kW) ....(1)

Where; ma is the mass flow rate of the air (Kg/s) which is Q/3600*sv ($Q = m^3$ / hr, specific volume of air (sv) m^3 / Kg),

hl, h2 = enthalpies of inlet and outlet air (kJ/Kg), which is from Figure 3.

Heat lost by condensation

Qc = Se*Cr (kW) .... (2)

Where; Se is the specific enthalpy of water (kJ/Kg) and Cr is the condensation rate (Kg/s).

- Heat gained by refrigerant

Qr = mr* (hl-h4) (kW) .... (3)

Where; mr is the mass flow rate of refrigerant (Kg/s), hl and h2 are enthalpies in kJ/Kg (see Figure 7 and 8).

Normaly Qr should be equal to q+Qc, but as can be seen from Table 5, sometimes there is a significant difference between these two values. This is probably because of heat transfer from or to outside air or material of the air conditioning unit. For the refrigeration cycle, enthalpies at the outlet of evaporator and condenser are as follows (from Figure 8).

Table 5. Enthalpies in refrigeration cycle

Test No	hl (Evaporator)	h2 (Condenser)
9	188	68
10	194	69
11	192	69
12	195	72
16	194	69
17	193	68
18	193	69
19	193	69
20	197	72
21	196	72
22	196	72

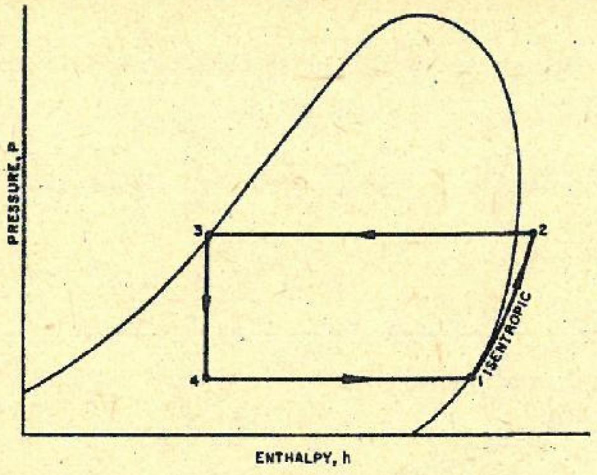

Figure 7. Pressure enthalpy diagram for refrigerant 12(R12)

At hl the refrigerant leaves the evaporator as a low pressure, low temperature, dry, saturated vapor and enters the compressor, where it is compressed reversibly and isentropically. At h3, which is equal to h4 (i.e.refrigerant leaves expansion valve), it leaves the condenser as a high pressure, medium temperature, saturated liquid and enters the expansion valve. General view of pressure-enthalpy diagram for basic vapor compression cycle is shown in Figure 7.

Results of all calculations can be seen in Table 6.

Table 6. Calculation Results (kW)

Heat Lost or Gained			
By Air	By Conden.	Total	Heat Gained By R12
0.162	-	0.162	-
0.356	-	0.356	-
0.395	-	0.395	-
0.351	-	0.351	-
0.407	-	0.407	-
0.428	-	0.428	-
2.884	-	2.884	-
6.437	-	6.437	-
-1.462	-	-1.462	1.720
-0.823	-	-0.823	1.280
-1.803	-	-1.803	1.845
-2.221	-1.3	-3.521	2.080
3.465	-	3.465	-
3.018	-	3.018	-
3.753	-	3.753	-
-2.284	-	-2.284	2.080
-1.378	-0.74	-2.118	2.010
-1.635	-0.92	-2.555	2.000
-1.548	-0.69	-2.238	2.000
-2.730	-0.62	-3.350	2.290
-1.659	-0.43	-2.089	2.200
-1.580	-0.24	-1.820	2.200

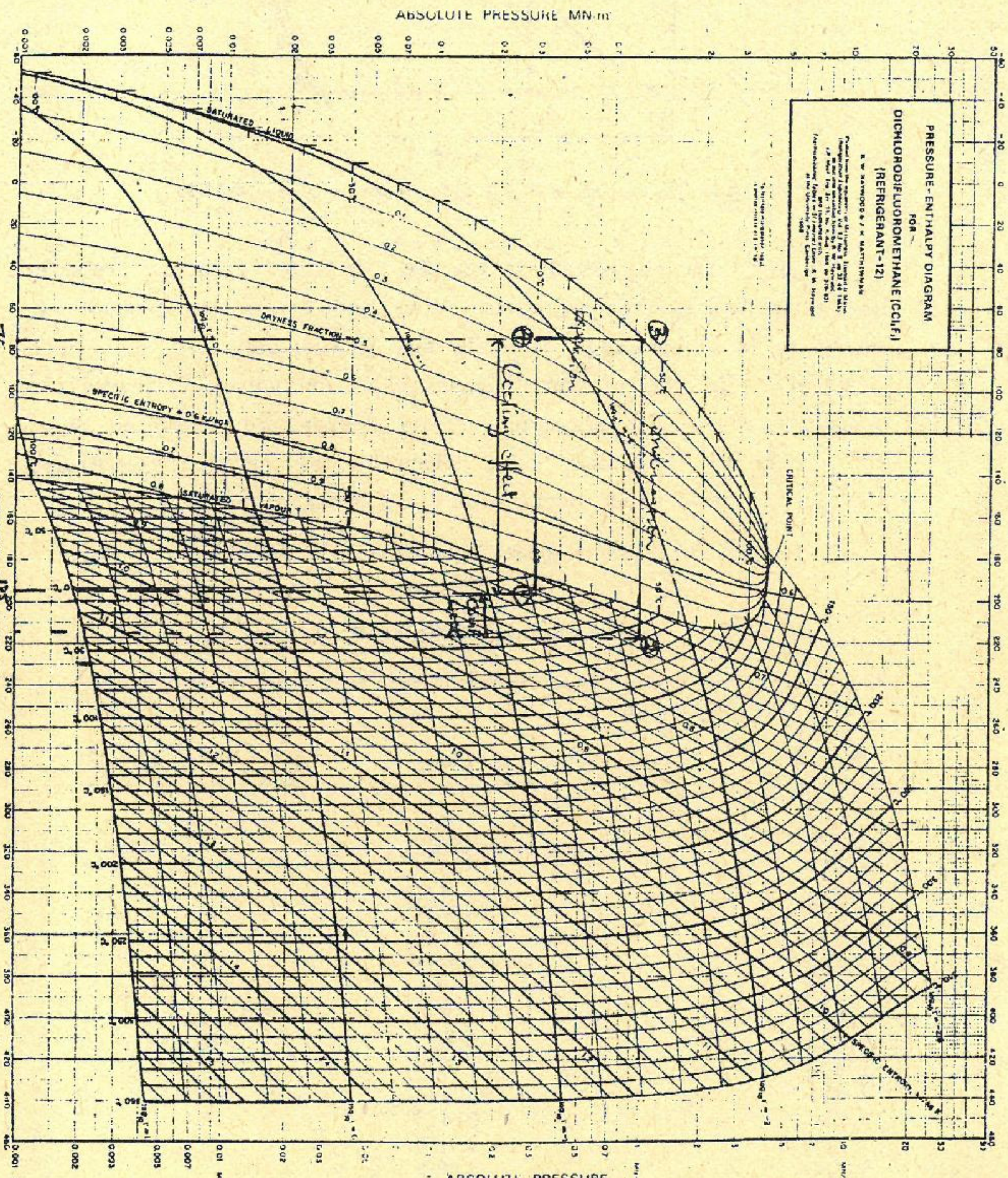

Figure 8. Complete pressure enthalpy diagram for R12

Discussion

The results of this experiment confirm the predictions with some tolerance values. In fact these deviations were either because of the test environment or properties of the unit. Similar types of experiments for air conditioning in greenhouses and livestocks, considering the comfort of the plants and animals, will be useful in terms of having an optimum environment.

ÖZET

HAVA HIZI, SICAKLIK VE NEM İLİŞKİLERİ ÜZERİNDE BİR ARAŞTIRMA

Bu deneyde hava hızı, sıcaklık ve nem arasındaki ilişki araştırıldı. Deneyde farklı girdiler verebilen bir hava ısıtma-soğutma ünitesi kullanıldı ve 22 değişik girdi değerinin havanın özellikleri üzerine etkisi incelendi. Her bir uygulamada, ıslak ve kuru termometre sıcaklıkları ile manometre basıncı 5 dakikalık bekleme aralıkları ile kaydedildi. Soğutma çevrimi sırasında evaporator giriş-çıkış sıcaklıkları ve çıkış basıncı, yoğunlaştırıcı çıkış sıcaklığı ve basıncı kaydedildi. Transfer edilen ısının hesabında fizikrometrik kart ve soğutucunun (R12) basınç entalpi diyagramından yararlanıldı. Genelde elde edilen değerler girdi değerleri ile belli toleranslar içerisinde uyum halindeydi. Deney öncesi umulan hava özellikleri büyük oranda gerçekleşti. Gerek seralarda ve gerekse hayvan barınaklarında benzer şekilde yapılacak deneyler, optimum çevrenin oluşturulmasına büyük katkı sağlayacaktır.

REFERANCE

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