



Pergamon

Energy 27 (2002) 923–946

ENERGY

www.elsevier.com/locate/energy

New outdoor cooling design data for Turkey

Hüsamettin Bulut ^a, Orhan Büyükalaca ^{b,*}, Tuncay Yılmaz ^b

^a *Department of Mechanical Engineering, University of Harran, 63300 Şanlıurfa, Turkey*

^b *Department of Mechanical Engineering, University of Çukurova, 01330 Adana, Turkey*

Received 22 August 2001

Abstract

Outdoor design conditions are weather data for design purposes showing the characteristic features of the climate at a particular location. In this study, new outdoor design conditions for cooling were determined for 78 locations within Turkey according to the format recommended by the American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc. (ASHRAE). Dry-bulb temperature corresponding to 0.4, 1 and 2% annual cumulative frequency of occurrence and the mean coincident wet-bulb temperature, the mean and standard deviation of the annual maximum dry-bulb temperatures, and the mean daily ranges were obtained. In these calculations, the hourly data measured during at least 13 years were used. The current cooling design conditions used in the calculation of cooling load in Turkey were analysed based on their frequency levels. Comparison of the existing cooling design data with the data obtained in this study revealed that the current cooling design temperatures are generally stringent. © 2002 Elsevier Science Ltd. All rights reserved.

1. Introduction

Energy consumption in Turkey is increasing in steady parallel to its development. Total energy consumption in Turkey was approximately 79 million tons of oil equivalent in 2000 [1]. Since the country's natural energy resources are insufficient, the amount of energy imported is also increasing and problems related to the energy deficit are on Turkey's political agenda. This deficit exerts a considerable pressure on the economy. Therefore, every means to use energy in a much more rational way should be taken into consideration.

Heating, cooling, ventilating and air conditioning (HVAC) systems are major energy users in residential and commercial buildings. Energy consumption of buildings in Turkey is calculated

* Corresponding author. Tel.: +90-322-338-6485; fax: +90-322-338-6126.
E-mail address: orhan1@mail.cu.edu.tr (O. Büyükalaca).

to be 25–30% of the total annual energy consumption according to the data given in Turkey's Energy Yearbook [1]. Since the standard of living and utilization of HVAC systems are rising dramatically in Turkey, the amount of energy consumed for heating/cooling is also increasing and is estimated to be more than half of the total energy consumption in buildings [2–4].

Due to the intensive use of air-conditioning systems, electricity consumption is high, especially in summer and the shortage of electricity is a big problem for the industry and tourism sectors. Therefore, the government has introduced new ways, such as variable tariffs in electric consumption and more stringent insulation standards in buildings, to encourage the reduction of energy use in recent years.

The first step in the design of air-conditioning systems is the calculation of heating and cooling loads of the building that depend on its characteristics, the indoor conditions to be maintained, and on outside weather conditions. If the air-conditioning system is expected to provide the indoor conditions specified (comfort conditions) at all times, it should be designed for peak conditions that are determined by the most extreme weather data recorded for the locality in which the building is located. This approach, however, will result in oversized air conditioning equipment, which in turn, will increase the initial equipment cost and the operating cost. The latter is due to the reduced system efficiency of air conditioning systems at part-load conditions. Therefore, in practice, a risk of slight discomfort under rare extremes of weather is taken, and by doing so, both the initial and operating costs of the air conditioning equipment are reduced considerably if cold storage is not an available option [5].

The American Society of Heating, Refrigeration and Air-Conditioning Engineers Inc. (ASHRAE) publishes climatic design conditions corresponding to different levels of probability for several locations in the United States and around the world [6,7]. They are the outdoor conditions that are exceeded during a specified percentage of time. The temperature and humidity conditions were provided at 1, 2.5 and 5 percentile frequency of occurrence during summer months (June through September) in the 1993 edition of the ASHRAE Handbook—Fundamentals [6]. These percentiles were replaced by annual percentile values of 0.4, 1 and 2 in the 1997 edition of ASHRAE Handbook—Fundamentals [7]. The change was made in order to provide design conditions representing the same probability of occurrence anywhere, regardless of the seasonal distribution of extreme temperature and humidity.

Climatic design data may include information on dry-bulb and wet-bulb temperatures, humidity, wind, rainfalls and solar data [8]. For cooling, the 1997 ASHRAE Handbook—Fundamentals [7] provides design values for dry-bulb temperature with mean coincident wet-bulb temperature, wet-bulb and dewpoint temperatures with mean coincident dry-bulb temperature and humidity ratio. The data are obtained from hourly observations and given for 0.4, 1 and 2% annual frequency of occurrence. Design values of dry-bulb and wet-bulb temperatures and dewpoint corresponding to various annual percentiles represent the value that is exceeded on average by the indicated percentage of the total number of hours in a year (8760 h). The 0.4, 1 and 2% values are exceeded on average 35, 88 and 175 h. Mean coincident values are the average of the indicated weather element occurring concurrently with the corresponding design value. In the 1997 ASHRAE Handbook-Fundamentals [7], the data for mean daily range are also given.

Representing the climatic design data for several frequencies of occurrence will enable engineers to choose different risk levels desired for the project in hand. The choice depends on the comfort level to be maintained indoors, thermal inertia and insulation of the building structure.

For ordinary buildings, it is customary to use the design data corresponding to annual percentile of 1.0 in cooling. More stringent percentiles are preferred for critical applications such as luxury hotels, hospitals, nurseries or some industrial applications. In this case 0.4 percentile can be used for cooling [5,9].

2. Cooling design data currently used in Turkey

Cooling load calculations in Turkey are generally carried out using the climatic design data provided by the Turkish Chamber of Mechanical Engineers (MMO) in Publication No. 115 [10] and by the Turkish Ministry of Reconstruction and Settlement in Technical Publication No. 9 [11]. The cooling design data given in these publications are not detailed for design evaluations and building energy analyses. They include only three weather elements: dry-bulb and wet-bulb temperatures, and mean daily temperature range. It is not clear whether the wet-bulb temperature given is ‘design wet-bulb temperature’ or ‘coincident wet-bulb temperature’.

The existing cooling design data are based on old weather observations that were taken with the limited instrumentation of the past, which raise doubts about the accuracy of the measurements. The design data have not been updated for the last 35 years. Therefore, a possible change in the climatic conditions during the recent decades cannot have been taken into consideration in load calculations. The method used in determining the cooling design data from the observations is also controversial; the process of the data observed was performed with hand calculations and the criteria followed were not clear. There is no information about whether the design data were based on the average or the maximum of the observations over a certain period of time or some other methods were applied.

Lack of data for various frequency levels is one of the drawbacks of the existing design data that are based on only one level of probability (frequency of occurrence). Therefore, designers do not have the opportunity to choose different risk levels desired for the project in hand. The same level of risk factor is assumed for all types of buildings because of the lack of design data for different frequencies of occurrence. Therefore, some designers tend to adopt their past experience and modify the existing design data imposed by the official bodies for non-governmental buildings.

In addition to all these shortcomings, cooling design conditions are not available for some locations. Design data for 55 locations are available in the publication of Ministry of Reconstruction and Settlement [11] and for 69 locations in the publication of Turkish Chamber of Mechanical Engineers [10].

In Turkey, the number of studies concerning weather data that are needed for design of air-conditioning systems and energy consumption calculations is very limited. The subject has been considered seriously only in recent years and it is not complete yet. Some independent studies have been performed to expose climatic design conditions of Turkey in recent years. Turkish Society of HVAC & Sanitary Engineers (TTMD) published results of a project on weather data of Turkey in a report [12]. In this report, design data for only six weather stations located in four cities were given according to the frequency levels suggested by the 1997 ASHRAE Handbook—Fundamentals [7]. The design data were obtained from long-term hourly measurements. Üner [13] presented weather data for 23 cities in Turkey according to the frequency levels used in the 1993

ASHRAE Handbook—Fundamentals [6]. The design conditions were determined using Typical Meteorological Year (TMY) data generated from seven years of hourly observations. The climatic design data given in the 1997 edition of ASHRAE Handbook—Fundamentals [7] are incomplete for Turkey; only eight Turkish localities are considered. A comprehensive analysis of the data for degree-days and temperature bins for 78 weather stations of Turkey was presented previously by the present authors [14,15]. In this paper, the results of the cooling design data studies are reported.

3. Recommended cooling design conditions

The weather design data being used in load calculations and energy analysis determines accuracy and characteristics of the results. Design data are usually determined by statistical analyses of long-term weather observations. The observations should cover a long period of time and should be taken during recent years [6,8]. The number of years for which the weather data are available determines the breadth of the weather database. In principle, as many years as possible should be considered for a proper analysis. The longer the period of records is, the better and more persuasive the results will be (since shorter periods will exhibit variations from the long-term average). For determining design conditions, weather data for at least 12 years are considered as long-term data by ASHRAE [7]. Ten or more years of weather data are required to increase the statistical reliability of recommended models for weather data and thus the estimated loads [16].

In this study, cooling design conditions were obtained for the locations within Turkey for which regular, long-term hourly dry-bulb temperature observations are available. In Turkey, although there are more than 350 weather stations in operation, only 78 of them satisfy these criteria. However, since these weather stations are located in 77 different provinces of Turkey (total number of provinces is 81), they cover almost all parts of the country.

The hourly dry-bulb temperatures measured during at least 13 years between 1981 and 1998, were used in the calculations. The raw data were taken from The State Meteorological Affairs General Directorate (DMI) in diskettes. Table 1 provides information for the weather stations and the periods of the data considered.

Table 2 shows recommended cooling design dry-bulb temperatures for 78 locations within Turkey. Three annual frequency levels (0.4, 1 and 2%) are offered for each location as suggested by the 1997 ASHRAE Handbook—Fundamentals [7]. As can be seen from the table, 0.4, 1 and 2% design dry-bulb temperatures for the locations within Turkey vary between 40.8 and 26.6 °C, 39.7 and 25.1 °C, and 38.5 and 23.5 °C, respectively.

Table 2 also shows mean coincident wet-bulb temperatures. Coincident wet-bulb temperature is the mean of all wet-bulb temperatures occurring at the design dry-bulb temperature. In Turkey, wet-bulb temperature and relative humidity are recorded only at 07:00, 14:00, and 21:00 h. Therefore, it is not possible to obtain coincident wet-bulb temperatures directly. The following approach was used for determining coincident wet-bulb temperature: variation of humidity ratio during a day is insignificant, especially in the summer. Humidity ratio does not fluctuate and it can be assumed to be constant during the day [17–19]. It was calculated at 07:00, 14:00, and 21:00 h using the measured relative humidity and dry-bulb temperatures at these hours. Analysis of the humidity ratio values obtained revealed that the differences between them are insignificant. Since,

Table 1
Weather database and basic information for weather stations

Province	Longitude (°E)	Latitude (°N)	Elevation (m)	Hourly dry-bulb temperatures (°C)		Daily extreme temperatures (°C) and relative humidity (%)	
				Period	Total years	Period	Total years
Adana	35.18	36.59	20	1983–1998	16	1981–1996	16
Adapazarı	30.25	40.47	30	1982–1998	17	1982–1998	17
Adıyaman	38.17	37.45	678	1981–1998	18	1981–1998	18
Afyon	30.32	38.45	1034	1981–1998	18	1981–1998	18
Ağrı	43.08	39.31	1585	1981–1998	18	1981–1998	18
Aksaray	34.03	38.23	980	1981–1998	18	1981–1998	18
Amasya	35.51	40.39	412	1981–1998	18	1981–1998	18
Ankara	32.53	39.57	894	1983–1995	13	1981–1995	15
Antakya	36.07	36.15	100	1983–1998	16	1981–1996	16
Antalya	30.42	36.53	42	1983–1998	16	1981–1995	15
Ardahan	42.42	41.08	1829	1981–1998	17	1981–1998	18
Artvin	41.49	41.10	597	1981–1998	18	1981–1998	18
Aydın	27.50	37.51	57	1983–1998	16	1983–1998	16
Balıkesir	27.52	39.39	147	1983–1997	15	1983–1997	15
Bartın	32.21	41.38	30	1981–1998	18	1981–1998	18
Batman	41.10	37.52	540	1983–1998	15	1983–1998	16
Bayburt	40.15	40.16	1550	1981–1998	18	1981–1998	18
Bilecik	29.58	40.09	526	1981–1998	17	1981–1998	18
Bingöl	40.30	38.52	1177	1981–1998	18	1981–1998	17
Bitlis	42.06	38.22	1559	1981–1998	18	1981–1998	18
Bolu	31.36	40.44	742	1981–1998	18	1981–1998	18
Burdur	30.20	37.40	967	1981–1998	18	1981–1998	18
Bursa	29.04	40.11	100	1983–1998	16	1983–1998	16
Çanakkale	26.24	40.08	3	1981–1998	17	1981–1998	17
Çankırı	33.37	40.36	751	1981–1995	13	1981–1995	15
Çorum	34.58	40.33	798	1981–1998	18	1981–1998	18

(continued on next page)

Table 1 (continued)

Province	Longitude (°E)	Latitude (°N)	Elevation (m)	Hourly dry-bulb temperatures (°C)		Daily extreme temperatures (°C) and relative humidity (%)	
				Period	Total years	Period	Total years
Denizli	29.05	37.47	428	1983–1998	16	1983–1998	16
Diyarbakır	40.12	37.55	660	1983–1998	16	1981–1996	16
Edirne	26.34	41.40	48	1983–1998	16	1983–1998	16
Elazığ	39.13	38.40	1105	1981–1998	18	1981–1998	18
Erzincan	39.30	39.44	1215	1981–1998	18	1981–1998	18
Erzurum	41.16	39.55	1869	1983–1998	14	1983–1998	16
Eskişehir	30.31	39.46	800	1983–1998	15	1991–1998	8
Gaziantep	37.22	37.05	855	1983–1998	16	1981–1996	16
Giresun	38.24	40.55	38	1981–1998	18	1981–1998	18
Gümüşhane	39.27	40.27	1219	1981–1998	18	1981–1998	18
Hakkari	43.46	37.34	1720	1981–1998	18	1981–1998	18
İğdır	44.02	39.56	858	1981–1998	16	1981–1998	16
İskenderun	36.07	36.37	3	1981–1998	18	1981–1998	18
Isparta	30.33	37.45	997	1981–1998	18	1981–1998	18
Istanbul	29.05	40.58	39	1983–1998	16	1981–1996	16
Izmir	27.10	38.24	25	1983–1998	16	1981–1996	16
K.Maraş	36.56	37.36	549	1984–1998	15	1983–1998	16
Karaman	33.14	37.11	1025	1981–1998	18	1981–1998	18
Kars	43.05	40.36	1775	1983–1998	15	1983–1998	16
Kastamonu	33.46	41.22	791	1981–1998	18	1981–1998	18
Kayseri	35.29	38.43	1068	1983–1998	16	1981–1996	16
Kilis	37.05	36.44	638	1981–1998	17	1981–1998	18
Kırkkale	33.30	39.50	725	1981–1995	15	1981–1995	15
Kırklareli	27.13	41.44	232	1981–1998	18	1981–1998	18
Kırşehir	34.10	39.08	985	1981–1995	15	1981–1995	15
Kocaeli	29.54	40.46	76	1981–1998	18	1981–1998	18
Konya	32.30	37.52	1028	1983–1998	16	1981–1996	16

(continued on next page)

Table 1 (continued)

Province	Longitude (°E)	Latitude (°N)	Elevation (m)	Hourly dry-bulb temperatures (°C)		Daily extreme temperatures (°C) and relative humidity (%)	
				Period	Total years	Period	Total years
Kütahya	29.58	39.24	969	1981–1998	17	1981–1998	18
Malatya	38.18	38.21	998	1983–1998	16	1983–1998	16
Manisa	27.26	38.36	71	1983–1998	16	1983–1998	16
Mardin	40.44	37.18	1080	1983–1998	16	1983–1998	16
Mersin	34.36	36.49	5	1983–1998	16	1983–1998	16
Muğla	28.21	37.12	646	1983–1998	16	1981–1996	16
Muş	41.31	38.44	1283	1981–1998	18	1981–1998	18
Nevşehir	34.40	38.25	1260	1981–1998	18	1981–1998	18
Niğde	34.40	37.59	1208	1981–1998	18	1981–1998	18
Ordu	37.52	40.59	4	1981–1998	18	1981–1998	18
Rize	40.30	41.02	4	1983–1998	16	1981–1996	16
Samsun	36.20	41.17	44	1983–1998	16	1981–1996	16
Siirt	41.56	37.56	875	1981–1998	18	1981–1998	18
Sinop	35.10	42.02	32	1981–1998	18	1981–1998	18
Sivas	37.01	39.49	1285	1983–1998	16	1983–1998	16
Şanlıurfa	38.46	37.08	547	1983–1998	16	1980–1993	14
Tekirdağ	27.29	40.59	4	1983–1998	16	1983–1998	16
Tokat	36.54	40.18	608	1981–1998	17	1981–1998	18
Trabzon	39.43	41.00	30	1983–1998	16	1981–1996	16
Tunceli	39.32	39.06	979	1981–1998	18	1981–1998	18
Uşak	29.29	38.40	919	1981–1998	18	1981–1998	18
Van	43.41	38.28	1725	1983–1998	16	1981–1995	15
Yalova	29.16	40.39	2	1981–1998	18	1981–1998	18
Yozgat	34.49	39.50	1298	1983–1998	16	1983–1998	16
Zonguldak	31.48	41.27	136	1981–1998	18	1981–1998	18

Table 2
Cooling design conditions for Turkey

Province	Cooling DB/MWB (°C)										Daily range of DB (°C)
	0.4%		1%		2%		Max DB (°C)		StdID		
	DB	MWB	DB	MWB	DB	MWB	Mean	StdID	Mean	StdID	
Adana	36.4	21.2	34.9	21.5	33.8	21.9	40.5	1.2	40.5	1.2	11.0
Adapazarı	32.4	22.8	30.6	22.3	29.2	21.9	37.1	1.6	37.1	1.6	11.3
Adiyaman	39.4	21.5	38.3	21.3	37.2	21.1	42.0	1.6	42.0	1.6	14.4
Afyon	32.0	19.5	30.7	19.2	29.2	18.8	35.0	1.4	35.0	1.4	15.2
Ağrı	31.8	20.8	30.4	20.5	28.9	20.0	34.7	1.6	34.7	1.6	17.9
Aksaray	33.0	20.5	31.7	20.0	30.4	19.6	36.4	1.1	36.4	1.1	14.8
Amasya	34.5	19.8	32.6	19.4	31.0	19.0	39.5	1.5	39.5	1.5	15.5
Ankara	33.0	18.5	31.4	18.3	29.9	18.0	36.3	1.5	36.3	1.5	14.5
Antakya	35.0	20.8	32.9	21.0	31.5	21.6	40.5	1.6	40.5	1.6	9.0
Antalya	37.7	21.1	35.9	21.0	34.1	20.8	41.8	1.1	41.8	1.1	13.1
Ardahan	26.6	17.9	25.1	17.4	23.5	16.9	30.8	1.6	30.8	1.6	16.3
Artvin	30.0	18.4	27.8	18.0	26.1	17.6	36.5	2.0	36.5	2.0	9.4
Aydın	37.8	23.2	36.4	23.0	35.1	22.7	41.6	1.6	41.6	1.6	16.1
Balıkesir	34.6	21.8	32.7	21.4	31.3	21.1	39.1	1.8	39.1	1.8	12.9
Bartın	30.9	20.9	29.3	20.6	27.9	20.6	35.8	2.4	35.8	2.4	13.0
Batman	40.8	23.9	39.7	23.7	38.5	23.3	43.4	1.4	43.4	1.4	18.2
Bayburt	29.7	17.8	28.1	17.3	26.4	16.9	33.3	1.0	33.3	1.0	16.4
Bilecik	31.9	20.8	30.3	20.3	28.8	19.9	36.4	1.5	36.4	1.5	12.8
Bingöl	36.2	20.8	35.1	20.6	33.8	20.2	39.0	1.3	39.0	1.3	16.2
Bitlis	32.3	20.1	31.2	19.8	29.9	19.5	34.9	1.3	34.9	1.3	15.8
Bolu	30.6	19.4	28.9	19.3	27.3	19.0	35.4	1.7	35.4	1.7	14.7
Burdur	33.5	19.1	32.3	18.9	31.1	18.6	36.3	0.8	36.3	0.8	15.0
Bursa	33.5	20.4	32.0	20.3	30.7	20.1	37.7	1.6	37.7	1.6	13.7
Çanakkale	32.3	23.7	31.0	23.3	30.0	22.9	35.6	1.8	35.6	1.8	10.8
Çankırı	33.5	20.6	31.8	20.2	30.2	19.8	37.4	1.8	37.4	1.8	17.9
Çorum	32.2	18.8	30.4	18.3	28.8	17.9	35.9	1.4	35.9	1.4	17.6
Denizli	36.0	21.9	34.8	21.8	33.6	21.6	38.9	1.4	38.9	1.4	13.9

(continued on next page)

Table 2 (continued)

Province	Cooling DB/MWB (°C)						Daily range of DB (°C)		
	0.4%		1%		2%		Max DB (°C)		StdD
	DB	MWB	DB	MWB	DB	MWB	Mean		
Diyarbakır	39.7	22.3	38.7	22.0	37.5	21.7	42.1	1.2	17.1
Edirne	34.0	21.9	32.8	21.6	31.5	21.1	37.7	2.1	14.7
Elazığ	35.8	19.8	34.6	19.6	33.3	19.3	38.6	1.3	15.3
Erzincan	33.6	20.8	32.1	20.5	30.8	20.1	36.6	1.2	16.0
Erzurum	29.5	18.0	28.1	17.8	26.7	17.3	32.6	1.3	17.6
Eskişehir	32.4	18.4	30.7	18.2	29.2	17.9	35.9	1.7	17.1
Gaziantep	36.7	21.0	35.8	20.9	34.7	20.7	39.6	1.2	14.9
Giresun	27.7	22.6	26.8	22.7	26.0	22.5	31.4	2.0	6.1
Gümüşhane	32.2	18.4	30.0	17.9	27.9	17.6	36.3	2.0	15.0
Hakkari	32.0	20.1	30.9	19.8	29.8	19.3	34.6	1.6	12.4
İğdir	34.9	21.1	33.8	20.8	32.6	20.4	38.3	1.4	16.0
İskenderun	31.8	23.0	30.7	23.6	30.1	24.0	36.5	1.8	6.1
Isparta	32.6	19.6	31.3	19.3	30.1	18.9	35.1	1.0	15.8
İstanbul	30.4	21.9	29.2	21.6	28.1	21.4	34.6	2.1	9.0
İzmir	35.2	22.8	33.8	22.5	32.6	22.3	39.0	1.3	10.7
Kahramanmaraş	37.6	22.3	36.3	22.2	34.9	21.9	40.2	1.7	13.6
Karaman	33.3	19.4	32.0	19.2	30.7	18.9	36.7	1.1	16.3
Kars	28.5	20.1	27.0	19.6	25.5	19.3	31.8	1.4	16.6
Kastamonu	31.1	19.5	29.4	19.0	27.7	18.5	35.3	1.6	15.8
Kayseri	33.3	20.5	31.8	20.1	30.3	19.7	36.8	1.5	18.9
Kilis	37.7	19.6	36.5	19.5	35.3	19.2	40.8	1.7	15.3
Kırkkale	33.6	20.1	31.9	19.7	30.5	19.3	36.8	1.3	14.2
Kırklareli	33.4	21.8	31.9	21.3	30.6	20.9	37.3	2.3	13.4
Kırşehir	32.0	20.6	30.6	20.2	29.2	19.9	35.4	1.1	14.2
Kocaeli	32.3	22.1	30.7	21.7	29.4	21.4	36.6	1.6	10.3
Konya	32.7	19.0	31.3	18.8	30.0	18.6	35.5	1.1	14.1

(continued on next page)

Table 2 (continued)

Province	Cooling DB/MWB (°C)						Daily range of DB (°C)		
	0.4%		1%		2%		Max DB (°C)		StdD
	DB	MWB	DB	MWB	DB	MWB	Mean		
Kütahya	31.5	17.8	29.9	17.4	28.5	17.1	35.0	1.6	15.5
Malatya	36.0	20.7	34.7	20.3	33.4	20.0	39.2	1.7	14.5
Manisa	37.3	21.9	35.9	21.7	34.6	21.5	41.5	1.7	14.1
Mardin	36.5	20.5	35.5	20.4	34.4	20.1	39.4	1.1	10.4
Mersin	31.1	25.6	30.5	25.8	30.0	25.8	35.1	1.7	6.5
Muğla	35.5	20.7	34.2	20.5	33.0	20.3	38.2	1.4	13.8
Muş	34.2	20.6	33.0	20.3	31.7	19.9	37.4	1.3	17.0
Neveşehir	31.1	19.0	29.5	18.6	28.1	18.2	34.4	1.3	15.3
Niğde	31.4	19.3	30.1	19.0	28.9	18.7	34.8	1.3	14.8
Ordu	28.6	23.3	27.8	23.2	27.0	22.9	32.4	2.3	8.2
Rize	27.6	22.3	26.9	22.3	26.3	22.0	32.1	1.9	6.7
Samsun	27.8	22.6	27.0	22.8	26.3	22.7	32.2	1.5	7.3
Siirt	38.1	21.2	37.1	21.0	36.1	20.7	40.7	1.3	13.5
Sinop	27.4	21.1	26.5	21.1	25.6	20.9	30.4	1.2	6.3
Sivas	31.7	18.8	29.9	18.5	28.2	18.1	35.3	1.8	16.3
Şanlıurfa	40.0	22.1	39.1	21.7	38.0	21.4	42.5	1.2	14.2
Tekirdağ	29.1	22.9	28.0	22.8	27.2	22.6	33.9	1.5	9.1
Tokat	32.6	20.3	31.0	19.7	29.4	19.3	37.3	1.6	14.4
Trabzon	27.7	23.0	26.9	22.9	26.2	22.6	31.6	2.7	6.3
Tunceli	36.3	21.1	35.1	20.9	33.9	20.7	38.9	1.3	15.5
Uşak	32.8	19.7	31.6	19.4	30.4	19.2	35.8	1.4	14.8
Van	29.6	18.7	28.5	18.4	27.5	18.1	32.7	1.9	13.2
Yalova	30.2	22.8	29.0	22.7	28.0	22.5	35.0	2.1	11.4
Yozgat	30.0	19.7	28.4	19.4	26.8	19.0	33.2	1.5	13.5
Zonguldak	27.7	19.6	26.2	19.5	25.0	19.5	32.4	1.6	6.9

maximum dry-bulb temperatures usually occur between 12:00 and 16:00 h, the humidity ratio calculated at 14:00 h was used with hourly dry-bulb temperature observations to obtain mean coincident wet-bulb temperatures. The psychrometric equations given by the 1993 ASHRAE Handbook—Fundamentals [6] were used in the calculations.

The 1998 ASHRAE Handbook—Refrigeration, Systems and Applications [20] suggests that outdoor design temperatures for 0.4% should be used in refrigeration load calculations (cold storage design). However, in Turkey, monthly average dry-bulb temperature for the hottest month is used commonly in the design of cold stores, following [21]. These temperatures are given by the present authors in [22].

In this study, due to the lack of hourly wet-bulb temperature measurements, design wet-bulb temperatures were not calculated. However, in cooling load calculations, the use of design dry-bulb temperature with the design wet-bulb temperatures produce cooling loads significantly greater than the actual loads. Therefore, design dry-bulb temperatures should be used with the coincident wet-bulb temperatures in computing cooling loads for cooling applications, especially in air-conditioning. The design wet-bulb temperatures are used for evaporative cooling, cooling towers and fresh air ventilation system design [6,7].

The probability of occurrence of very extreme conditions can be required for the operational design of equipment to ensure continuous operation and serviceability [7]. The mean and standard deviation of the annual extreme maximum dry-bulb temperatures are given in Table 2 for 78 locations within Turkey. These data are based on the daily maximum and minimum temperature observations.

Another parameter needed in the calculation of thermal loads is the mean daily range of dry-bulb temperature, which is the mean of the difference between daily maximum and minimum temperatures for the hottest month. The last column of Table 2 presents the mean daily ranges. In Turkey, the maximum daily range of dry-bulb temperature is in Batman (18.2 °C), while Giresun and İskenderun have the minimum daily range (6.1 °C).

The envelopes that cover cooling design conditions calculated at 0.4, 1 and 2% frequency levels for 78 locations within Turkey are shown on a psychrometric chart in Fig. 1. Analysis of the chart reveals that Turkey has a non-uniform climate. The design data are scattered on the chart covering a broad area. Influence of different frequency levels can be seen from the figure. If more stringent design conditions (smaller frequency levels) are selected, the envelope shifts downward, indicating higher design dry-bulb temperatures. However, the picture is not so clear in the case of moisture content.

Counter maps of proposed cooling design dry-bulb temperatures and mean coincident wet-bulb temperatures at 0.4% frequency level is shown in Figs. 2 and 3, respectively. Maximum design dry-bulb temperatures occur in southeastern Turkey, whilst minimum temperatures are in the northeast. The design dry-bulb temperature may exceed 39 °C in the southeast where low humidity in the summer results in considerable solar radiation. The counters are close to each other around a line drawn from Siirt to Trabzon. This shows a rapid climate change in short distances due to mountainous nature of the landscape in these regions. As can be seen from Fig. 3, coincident wet-bulb temperatures do not change much. However, it is slightly higher for locations near the sea coasts (around 22–23 °C), compared with the eastern and the inner regions (around 19–20 °C). Similar trends are obtained in the case of other two frequency levels (1 and 2%), although there are changes in the values of the parameters considered.

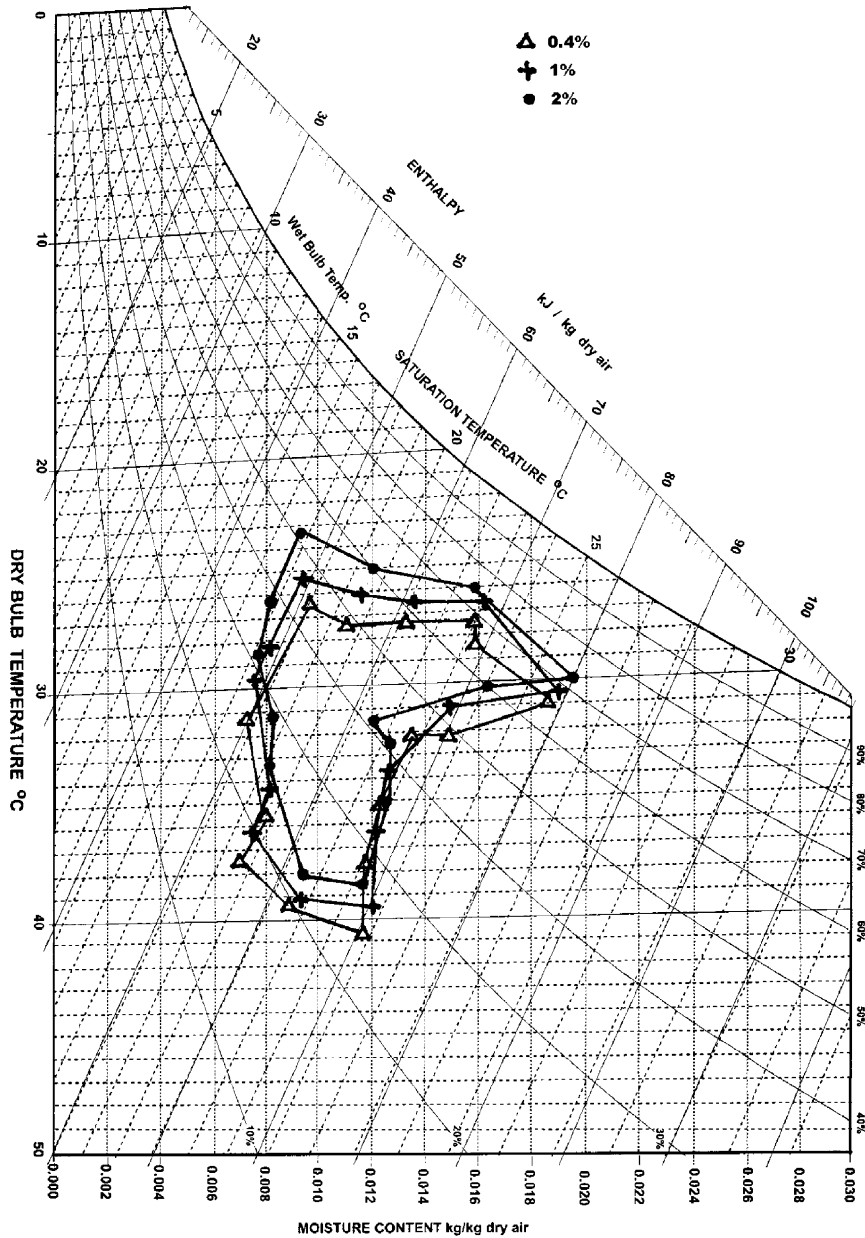


Fig. 1. The envelopes covering the cooling design conditions calculated at 0.4, 1 and 2% frequency levels for Turkey.

A comparison of the cooling design data provided in this study with the data available in the literature for Turkey is given in Table 3. TTMD [12] provides cooling design data obtained from hourly observations for four cities and ASHRAE [7] for eight Turkish locations. A good agreement is evident between the values given by ASHRAE [7], TTMD [12] and this study for design dry-bulb and coincident wet-bulb temperatures and maximum dry-bulb temperature. The small

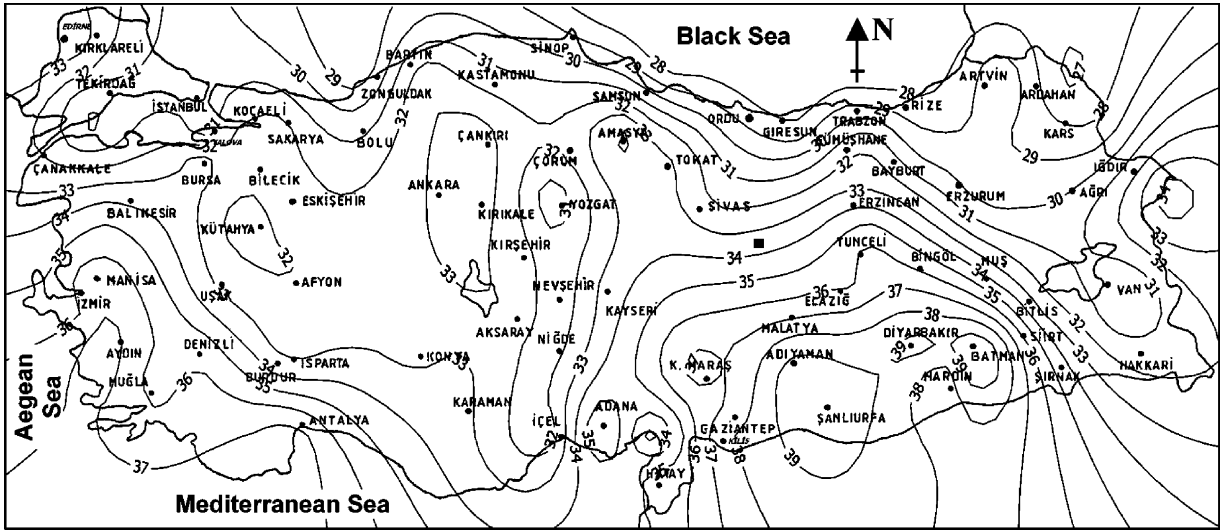


Fig. 2. The counter map of cooling design dry-bulb temperatures at 0.4% frequency level for Turkey.

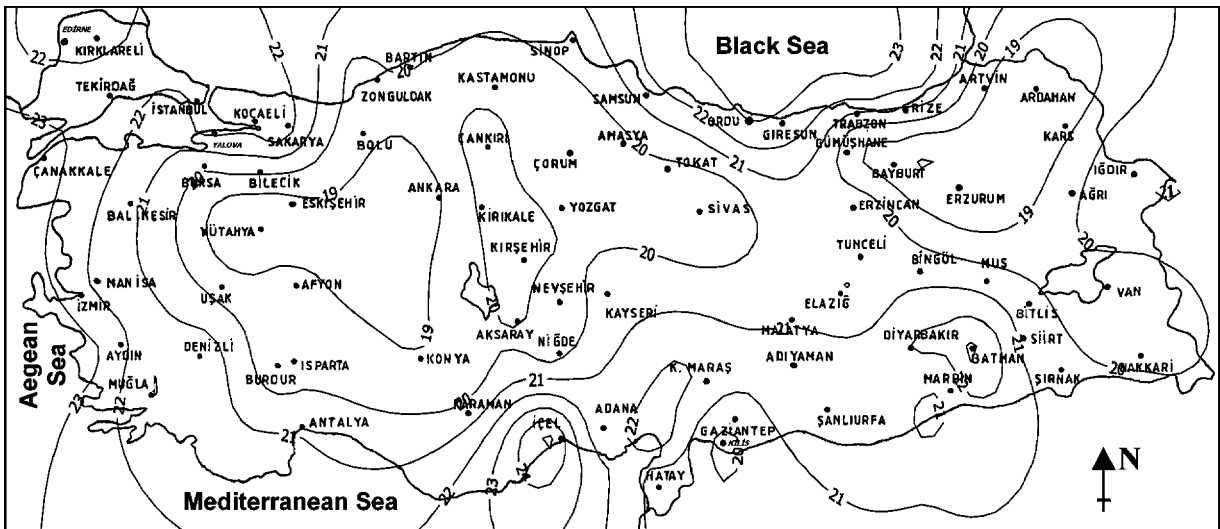


Fig. 3. The counter map of the mean coincident wet-bulb temperatures at 0.4% frequency level for Turkey.

differences between the design values could be due to the use of weather data measurements taken during different years, period of the record, and the methods used in processing the raw data. In the case of mean daily range, there are significant differences between the values given by TTMD [12], ASHRAE [7] and this study. The mean daily range of TTMD [12] is significantly smaller than that of the others.

4. Analysis of current cooling design conditions for Turkey

In Turkey, the weather data provided by MMO [10] and Ministry of Reconstruction and Settlement [11] are currently effective and used as outdoor design conditions in the calculation of cooling load. Table 4 compares the current cooling design data with the data obtained in this study. The annual frequency levels of the current cooling design dry-bulb temperatures were calculated using the database (Table 1) on which this study is based. For example, the current cooling design dry-bulb temperature is 38 °C for Adana. Analyzing the hourly dry-bulb temperature records between the years 1983 and 1998 (Table 1), the average number of hours (NOH) for which dry-bulb temperature exceeds this value was found to be 17 h. The corresponding annual frequency level was then calculated as 0.2%.

Annual frequency levels of the current cooling design dry-bulb temperatures for the locations within Turkey are between 0.0 and 3.09% (Table 4). The current design conditions usually overestimate cooling design dry-bulb temperature. For 69 of 78 locations, the frequency level of the current cooling dry-bulb temperature is smaller than the minimum frequency level (0.4%) proposed by the 1997 ASHRAE Handbook—Fundamentals [7]. This means that the specified dry-bulb temperature will be exceeded on average less than 35 h in a year. Moreover, those hours do not occur in sequence and thermal inertia of the building attenuates the peak loads if the building is not very light structured. Therefore, it can be concluded that the current cooling design temperatures are stringent and provide total protection. If the current cooling design data are used, an air-conditioning system will be oversized and will run at part load conditions most of the time. Furthermore in practice, an average safety margin of 5–10% is added to the cooling load based on the current design data. As a result of these, both initial and operational costs of the air-conditioning system will be high. Being a developing country, Turkey should modify the current cooling design data soon.

Only in four locations, the frequency level of the current cooling design dry-bulb temperature is between the levels (between 0.4 and 2%) proposed by the 1997 ASHRAE Handbook—Fundamentals [7]. In five locations (Amasya, Bingöl, Muş, Nevşehir and Tokat) the risk factor of the current cooling design dry-bulb temperature is too high. In these locations, the frequency level is higher than the maximum frequency level (2%) proposed by ASHRAE [7] and, an air-conditioning system designed using the current design data may not be able to provide indoor design conditions for more than 175 h in a year.

The current design wet-bulb temperatures are also generally higher than the coincident wet-bulb temperatures found in this study. Only in Hakkari, Kahramanmaraş, Kars, Muş, Nevşehir, Ordu and Tokat, the current design wet-bulb temperature is lower than the coincident wet-bulb temperature for at least one frequency level. For the remaining 71 locations, the current design wet-bulb temperature is higher than the coincident wet-bulb temperature.

Table 4 also shows the temperature difference between the current design data and the data recommended in this study. Temperature differences, both for dry-bulb and wet-bulb, are generally positive, indicating that the current design temperatures are generally higher than the data obtained in this study.

The current design data and the design data obtained in this study are shown together on a psychrometric chart in Fig. 4 for 0.4% frequency level. A comparison of the envelopes that cover the current design data and the data found in this study reveals that there are significant differences

Table 4
The frequency level of the current design conditions and comparison of them with the data obtained in this study

Location	Current		This study						Difference with current (°C)							
	DB	NOH (h)	FL (%)	WB	0.4%		1%		2%		0.4%		1%		2%	
					DB	MWB	DB	MWB	DB	MWB	ΔWB	ΔDB	ΔWB	ΔDB	ΔWB	ΔDB
Adana	38	17	0.2	26	36.4	21.2	34.9	21.5	33.8	21.9	1.6	4.8	3.1	4.5	4.2	4.1
Adapazari	35	8	0.09	25	32.4	22.8	30.6	22.3	29.2	21.9	2.6	2.2	4.4	2.7	5.8	3.1
Adiyaman	38	140	1.6	22	39.4	21.5	38.3	21.3	37.2	21.1	-1.4	0.5	-0.3	0.7	0.8	0.9
Afyon	34	9	0.1	21	32.0	19.5	30.7	19.2	29.2	18.8	2.0	1.5	3.3	1.8	4.8	2.2
Agrı	34	10	0.11	25	31.8	20.8	30.4	20.5	28.9	20.0	2.2	4.2	3.6	4.5	5.1	5.0
Aksaray	NA	-	-	NA ^a	33.0	20.5	31.7	20.0	30.4	19.6	-	-	-	-	-	-
Amasya	31	194	2.21	21	34.5	19.8	32.6	19.4	31.0	19.0	-3.5	1.2	-1.6	1.6	0.0	2.0
Ankara	34	22	0.25	20	33.0	18.5	31.4	18.3	29.9	18.0	1.0	1.5	2.6	1.7	4.1	2.0
Antakya	37	18	0.21	28	35.0	20.8	32.9	21.0	31.5	21.6	2.0	7.2	4.1	7.0	5.5	6.4
Antalya	39	21	0.24	28	37.7	21.1	35.9	21.0	34.1	20.8	1.3	6.9	3.1	7.0	4.9	7.2
Ardahan	NA	-	-	NA	26.6	17.9	25.1	17.4	23.5	16.9	-	-	-	-	-	-
Artvin	30	42	0.48	26	30.0	18.4	27.8	18.0	26.1	17.6	0.0	7.6	2.2	8.0	3.9	8.4
Aydin	40	9	0.11	26	37.8	23.2	36.4	23.0	35.1	22.7	2.2	2.8	3.6	3.0	4.9	3.3
Balikesir	37	10	0.11	25	34.6	21.8	32.7	21.4	31.3	21.1	2.4	3.2	4.3	3.6	5.7	3.9
Bartın	NA	-	-	NA	30.9	20.9	29.3	20.6	27.9	20.6	-	-	-	-	-	-
Batman	NA	-	-	NA	40.8	23.9	39.7	23.7	38.5	23.3	-	-	-	-	-	-
Bayburt	NA	-	-	NA	29.7	17.8	28.1	17.3	26.4	16.9	-	-	-	-	-	-
Bilecik	34	13	0.14	23	31.9	20.8	30.3	20.3	28.8	19.9	2.1	2.2	3.7	2.7	5.2	3.1
Bingöl	33	270	3.09	21	36.2	20.8	35.1	20.6	33.8	20.2	-3.2	0.2	-2.1	0.4	-0.8	0.8
Bitlis	34	13	0.14	22	32.3	20.1	31.2	19.8	29.9	19.5	1.7	1.9	2.8	2.2	4.1	2.5
Bolu	33	11	0.12	23	30.6	19.4	28.9	19.3	27.3	19.0	2.4	3.6	4.1	3.7	5.7	4.0
Burdur	36	2	0.03	21	33.5	19.1	32.3	18.9	31.1	18.6	2.5	1.9	3.7	2.1	4.9	2.4
Bursa	37	3	0.04	25	33.5	20.4	32.0	20.3	30.7	20.1	3.5	4.6	5.0	4.7	6.3	4.9

(continued on next page)

Table 4 (continued)

Location	Current		This study				Difference with current (°C)									
	DB	NOH (h)	FL (%)	WB	DB		MWB DB		MWB ΔDB		ΔWB ΔDB		ΔWB ΔDB			
					0.4%	1%	0.4%	1%	0.4%	1%	0.4%	1%	0.4%	1%		
Çanakale	34	12	0.14	25	32.3	23.7	31.0	23.3	30.0	22.9	1.7	1.3	3.0	1.7	4.0	2.1
Çankiri	37	4	0.04	23	33.5	20.6	31.8	20.2	30.2	19.8	3.5	2.4	5.2	2.8	6.8	3.2
Çorum	35	8	0.1	22	32.2	18.8	30.4	18.3	28.8	17.9	2.8	3.2	4.6	3.7	6.2	4.1
Denizli	38	10	0.12	24	36.0	21.9	34.8	21.8	33.6	21.6	2.0	2.1	3.2	2.2	4.4	2.4
Diyarbakır	43	1	0.01	23	39.7	22.3	38.7	22.0	37.5	21.7	3.3	0.7	4.3	1.0	5.5	1.3
Edirne	37	6	0.06	25	34.0	21.9	32.8	21.6	31.5	21.1	3.0	3.1	4.2	3.4	5.5	3.9
Elazığ	38	7	0.07	21	35.8	19.8	34.6	19.6	33.3	19.3	2.2	1.2	3.4	1.4	4.7	1.7
Erzincan	36	5	0.06	22	33.6	20.8	32.1	20.5	30.8	20.1	2.4	1.2	3.9	1.5	5.2	1.9
Erzurum	30	37	0.42	19	29.5	18.0	28.1	17.8	26.7	17.3	0.5	1.0	1.9	1.2	3.3	1.7
Eskişehir	34	14	0.16	22	32.4	18.4	30.7	18.2	29.2	17.9	1.6	3.6	3.3	3.8	4.8	4.1
Gaziantep	39	6	0.06	23	36.7	21.0	35.8	20.9	34.7	20.7	2.3	2.0	3.2	2.1	4.3	2.3
Giresun	29	14	0.16	25	27.7	22.6	26.8	22.7	26.0	22.5	1.3	2.4	2.2	2.3	3.0	2.5
Gümüşhane	33	27	0.3	23	32.2	18.4	30.0	17.9	27.9	17.6	0.8	4.6	3.0	5.1	5.1	5.4
Hakkari	34	11	0.13	20	32.0	20.1	30.9	19.8	29.8	19.3	2.0	-0.1	3.1	0.2	4.2	0.7
İğdir	36	19	0.21	25	34.9	21.1	33.8	20.8	32.6	20.4	1.1	3.9	2.2	4.2	3.4	4.6
İskenderun	37	1	0.01	29	31.8	23.0	30.7	23.6	30.1	24.0	5.2	6.0	6.3	5.4	6.9	5.0
Isparta	34	14	0.16	21	32.6	19.6	31.3	19.3	30.1	18.9	1.4	1.4	2.7	1.7	3.9	2.1
İstanbul	33	5	0.06	24	30.4	21.9	29.2	21.6	28.1	21.4	2.6	2.1	3.8	2.4	4.9	2.6
İzmir	37	13	0.14	24	35.2	22.8	33.8	22.5	32.6	22.3	1.8	1.2	3.2	1.5	4.4	1.7
K. Maraş	36	122	1.39	22	37.6	22.3	36.3	22.2	34.9	21.9	-1.6	-0.3	-0.3	-0.2	1.1	0.1
Karaman	NA	-	-	NA	33.3	19.4	32.0	19.2	30.7	18.9	-	-	-	-	-	-
Kars	30	15	0.17	20	28.5	20.1	27.0	19.6	25.5	19.3	1.5	-0.1	3.0	0.4	4.5	0.7
Kastamonu	34	8	0.09	22	31.1	19.5	29.4	19.0	27.7	18.5	2.9	2.5	4.6	3.0	6.3	3.5
Kayseri	36	4	0.05	22	33.3	20.5	31.8	20.1	30.3	19.7	2.7	1.5	4.2	1.9	5.7	2.3
Kilis	NA	-	-	NA	37.7	19.6	36.5	19.5	35.3	19.2	-	-	-	-	-	-

(continued on next page)

Table 4 (continued)

Location	Current		This study				Difference with current (°C)												
	DB	NOH (h)	FL (%)	WB	DB		MWB DB		MWB DB		MWB DB		MWB DB		MWB DB				
					0.4%	1%	0.4%	1%	0.4%	1%	0.4%	1%	0.4%	1%	0.4%	1%	0.4%	1%	0.4%
Kırkkale	NA	-	-	NA	33.6	20.1	31.9	19.7	30.5	19.3	-	-	-	-	-	-	-	-	-
Kırklareli	35	17	0.2	25	33.4	21.8	31.9	21.3	30.6	20.9	1.6	3.2	3.1	3.7	4.4	4.1	-	-	-
Kırşehir	35	3	0.03	21	32.0	20.6	30.6	20.2	29.2	19.9	3.0	0.4	4.4	0.8	5.8	1.1	-	-	-
Kocaeli	36	3	0.03	25	32.3	22.1	30.7	21.7	29.4	21.4	3.7	2.9	5.3	3.3	6.6	3.6	-	-	-
Konya	34	15	0.17	21	32.7	19.0	31.3	18.8	30.0	18.6	1.3	2.0	2.7	2.2	4.0	2.4	-	-	-
Kütahya	33	16	0.18	21	31.5	17.8	29.9	17.4	28.5	17.1	1.5	3.2	3.1	3.6	4.5	3.9	-	-	-
Malatya	38	11	0.13	21	36.0	20.7	34.7	20.3	33.4	20.0	2.0	0.3	3.3	0.7	4.6	1.0	-	-	-
Manisa	40	7	0.08	25	37.3	21.9	35.9	21.7	34.6	21.5	2.7	3.1	4.1	3.3	5.4	3.5	-	-	-
Mardin	38	13	0.15	23	36.5	20.5	35.5	20.4	34.4	20.1	1.5	2.5	2.5	2.6	3.6	2.9	-	-	-
Mersin	35	1	0.01	29	31.1	25.6	30.5	25.8	30.0	25.8	3.9	3.4	4.5	3.2	5.0	3.2	-	-	-
Mula	37	16	0.19	22	35.5	20.7	34.2	20.5	33.0	20.3	1.5	1.3	2.8	1.5	4.0	1.7	-	-	-
Muş	32	181	2.07	20	34.2	20.6	33.0	20.3	31.7	19.9	-2.2	-0.6	-1.0	-0.3	0.3	0.1	-	-	-
Nevşehir	28	209	2.39	17	31.1	19.0	29.5	18.6	28.1	18.2	-3.1	-2.0	-1.5	-1.6	-0.1	-1.2	-	-	-
Niğde	34	5	0.05	20	31.4	19.3	30.1	19.0	28.9	18.7	2.6	0.7	3.9	1.0	5.1	1.3	-	-	-
Ordu	30	9	0.1	22	28.6	23.3	27.8	23.2	27.0	22.9	1.4	-1.3	2.2	-1.2	3.0	-0.9	-	-	-
Rize	30	6	0.07	26	27.6	22.3	26.9	22.3	26.3	22.0	2.4	3.7	3.1	3.7	3.7	4.0	-	-	-
Samsun	32	2	0.02	25	27.8	22.6	27.0	22.8	26.3	22.7	4.2	2.4	5.0	2.2	5.7	2.3	-	-	-
Siirt	40	8	0.09	23	38.1	21.2	37.1	21.0	36.1	20.7	1.9	1.8	2.9	2.0	3.9	2.3	-	-	-
Sinop	30	2	0.02	25	27.4	21.1	26.5	21.1	25.6	20.9	2.6	3.9	3.5	3.9	4.4	4.1	-	-	-
Sivas	33	21	0.24	20	31.7	18.8	29.9	18.5	28.2	18.1	1.3	1.2	3.1	1.5	4.8	1.9	-	-	-
Şanlıurfa	43	2	0.02	24	40.0	22.1	39.1	21.7	38.0	21.4	3.0	1.9	3.9	2.3	5.0	2.6	-	-	-
Tekirdağ	33	2	0.02	25	29.1	22.9	28.0	22.8	27.2	22.6	3.9	2.1	5.0	2.2	5.8	2.4	-	-	-
Tokat	29	238	2.71	20	32.6	20.3	31.0	19.7	29.4	19.3	-3.6	-0.3	-2.0	0.3	-0.4	0.7	-	-	-
Trabzon	31	6	0.07	25	27.7	23.0	26.9	22.9	26.2	22.6	3.3	2.0	4.1	2.1	4.8	2.4	-	-	-
Tunceli	37	26	0.3	22	36.3	21.1	35.1	20.9	33.9	20.7	0.7	0.9	1.9	1.1	3.1	1.3	-	-	-
Uşak	35	8	0.09	22	32.8	19.7	31.6	19.4	30.4	19.2	2.2	2.3	3.4	2.6	4.6	2.8	-	-	-
Van	33	4	0.04	20	29.6	18.7	28.5	18.4	27.5	18.1	3.4	1.3	4.5	1.6	5.5	1.9	-	-	-
Yalova	NA	-	-	NA	30.2	22.8	29.0	22.7	28.0	22.5	-	-	-	-	-	-	-	-	-
Yozgat	32	10	0.12	20	30.0	19.7	28.4	19.4	26.8	19.0	2.0	0.3	3.6	0.6	5.2	1.0	-	-	-
Zonguldak	32	1	0.01	25	27.7	19.6	26.2	19.5	25.0	19.5	4.3	5.4	5.8	5.5	7.0	5.5	-	-	-

^a NA: Not available

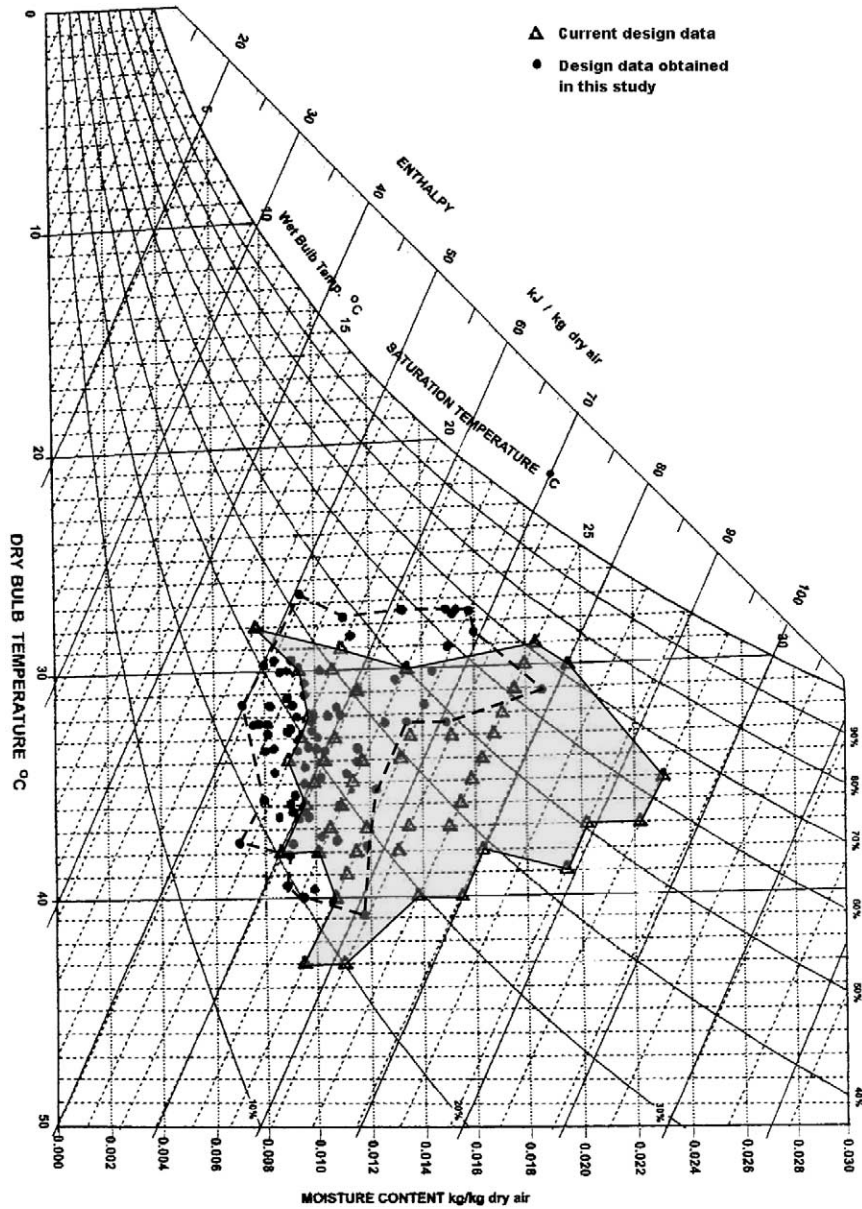


Fig. 4. Comparison of the current cooling design conditions for Turkey with the conditions obtained in this study at 0.4% frequency level.

between the two. First of all, the current design data covers a broader area on the chart. Secondly, the bottom border of the envelope for the current design data is lower than that of the present data (higher design dry-bulb temperatures). Thirdly, the current design data sit further right on the chart (higher moisture contents). These mean that the current design data will produce larger sensible and latent cooling loads than that of the present design data. When less stringent fre-

quency levels (1 and 2%) are chosen, the envelope for the present design data found in this study shifts upward, indicating smaller design dry-bulb temperatures (Figs. 5 and 6). The differences between the two will be larger.

To be able to evaluate the influence of the data presented in this paper, cooling load calculations of an existing three-storey office building located in Adana (36.59 latitude and 35.18 longitude

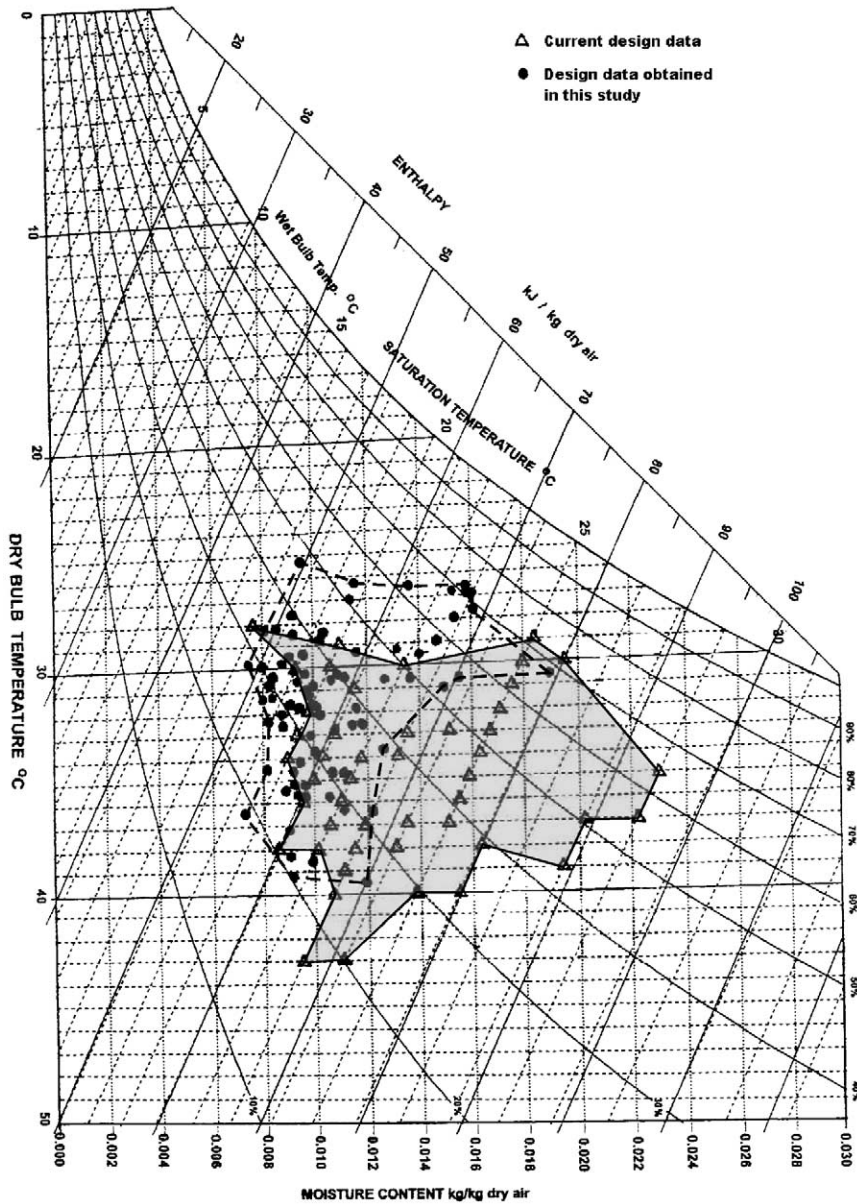


Fig. 5. Comparison of the current cooling design conditions for Turkey with the conditions obtained in this study at 1% frequency level.

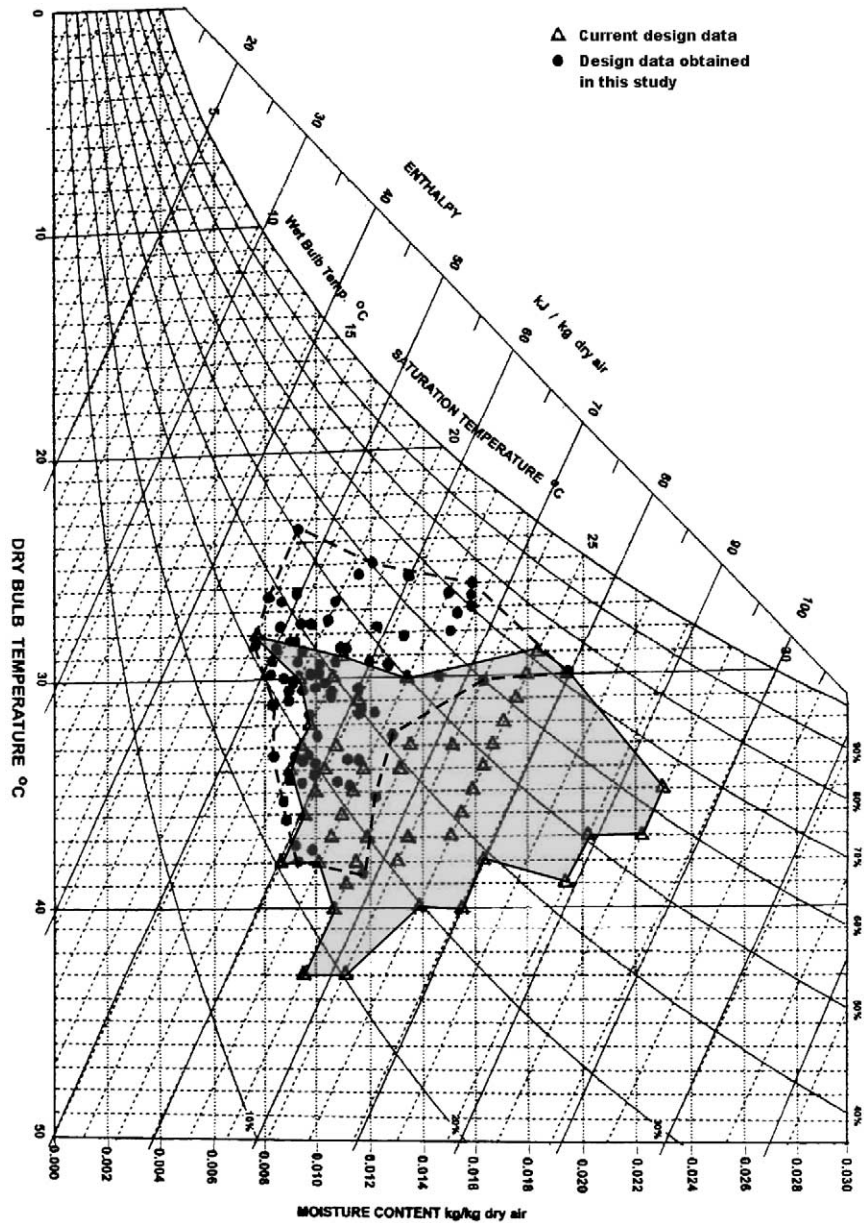


Fig. 6. Comparison of the current cooling design conditions for Turkey with the conditions obtained in this study at 2% frequency level.

and 20 m altitude) were carried out using both the current outdoor design data and the new data presented in this paper. The indoor design conditions selected were 26 °C dry-bulb temperature and 50% relative humidity. Table 5 provides some details of the building and Table 6 summarizes the results. The comparison is given only for the hour at which the maximum load occurs, that is, 16:00 h. The sum of the cooling load components that depend on the outdoor design conditions

Table 5
Some properties of the sample building

Element	Area (m ²)	U-factor (W/m ² K)
Outer walls	702.4	0.7
Windows (double glazed)	330.6	3.02
Total floors	1555.1	0.88
Roof (insulated)	610	0.38

Table 6
Cooling load of the sample building for 16:00 h

Outdoor design data	Cooling load (kW)			Difference (%)	
	Q_{out}	Q_{const}	Q_{tot}	Q_{out}	Q_{tot}
Currently-used	56.75	81.60	138.35	-	-
New (0.4%)	29.06		110.65	95.3	25.0
New (1%)	27.76		109.36	104.4	26.5
New (2%)	28.65		110.25	98.1	25.5

(Q_{out}) and that do not (Q_{const}) are given separately in Table 6, to be able to see clearly the influence of the outdoor design conditions on the cooling load.

As can be seen from Table 6, if the cooling load of the sample building is calculated using the current design data, the sum of the cooling load components that depend on the outdoor design conditions (Q_{out}) will be larger 95.3, 104.4 and 98.1% than the ones obtained using the data presented in this study for the frequency levels of 0.4, 1 and 2%, respectively. In the case of total cooling load (Q_{tot}), the difference is approximately 25%. This means that the resulting air-conditioning equipment for the sample building will be oversized approximately 25% and this, in turn, will increase the initial equipment cost and operating cost.

5. Conclusion

The existing data of outdoor design conditions for Turkey are old, not detailed and incomplete. In this study, new outdoor design conditions for cooling were determined for 78 locations within Turkey according to the format recommended by the 1997 ASHRAE Handbook—Fundamentals. Dry-bulb temperature corresponding to 0.4, 1 and 2% annual cumulative frequency of occurrence and the mean coincident wet-bulb temperature, the mean and standard deviation of the annual maximum dry-bulb temperatures, and the mean daily ranges were obtained for 78 weather stations. In these calculations, the hourly data measured during at least 13 years were used.

The cooling design data found in this study were compared with the existing design data. For this purpose, the frequency levels of the existing design dry-bulb temperatures were calculated using the database on which this study was based. It was found that the current cooling design

temperatures are generally stringent and provide total protection. An air-conditioning system will be oversized and run at part load conditions most of the time, if the current cooling design data are used. This will result in higher initial and operational costs of the air-conditioning system. Having limited energy resources, Turkey should use energy carefully. Therefore, the existing cooling design data should be modified by official bodies and designers should be able to choose different risk levels depending upon the project in hand.

Acknowledgements

The authors wish to express their gratitude to The State Meteorological Affairs General Directorate (DMİ) for providing meteorological data.

References

- [1] Turkey's energy yearbook. İstanbul: Uzman Publishing Inc.; 2001.
- [2] Kılış B. Utilization of natural gas in heating of buildings: saving possibilities and new alternatives (in Turkish). Ankara: Ankara Chamber of Industry, 1991.
- [3] Akdeniz AH. Economic analysis of alternative solutions in optimum selection of heating systems for buildings. PhD thesis, University of Ege, İzmir, Turkey, 1989. (In Turkish)
- [4] Üner M, İleri A. Typical weather data of main Turkish cities for energy applications. *International Journal of Energy Research* 2000;24:727–48.
- [5] Kreider JF, Rabl EA. Heating and cooling of buildings—design for efficiency. New York: McGraw-Hill Inc, 1994.
- [6] ASHRAE handbook—1993 fundamentals. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1993.
- [7] ASHRAE handbook—1997 fundamentals. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1997.
- [8] Hui CM. Energy performance of air-conditioned buildings in Hong Kong. PhD thesis, City University of Hong Kong, Hong Kong, 1996.
- [9] Lam JC, Hui SCM. Outdoor design conditions for HVAC system design and energy estimation for buildings in Hong Kong. *Energy and Building* 1995;22:25–43.
- [10] Özkul N. Applied cooling technique, publication no 115 (in Turkish). Ankara: Turkish Chamber of Mechanical Engineers, 1985.
- [11] Önen E. Ventilation and air-conditioning. Technical publication no 9 (in Turkish). Ankara: Press of Prime Ministry, Turkish Ministry of Reconstruction and Settlement, 1985.
- [12] Turkish weather data (in Turkish). Ankara: Technical Publication of Turkish Society of HVAC & Sanitary Engineers (TTMD), 2000.
- [13] Üner M. Obtaining and validating Typical Weather Data for Yearly Computer Simulation of Heating/Cooling Systems in Turkey. MSc Thesis, The Middle East Technical University, Ankara, Turkey, 1998.
- [14] Büyükalaca O, Bulut H, Yılmaz T. Analysis of variable-base heating and cooling degree-days for Turkey. *Applied Energy* 2001;69(4):269–283.
- [15] Bulut H, Büyükalaca O, Yılmaz T. Bin weather data for Turkey. *Applied Energy* 2001;70(2):135–155.
- [16] Richardson CW. Data requirements for estimation of weather generation parameters. *Transactions of the ASAE* 2000;43(4):877–882.
- [17] Al-Rabghi OM, Hittle DC. Energy simulation in buildings: overview and BLAST example. *Energy Conversion & Management* 2001;42:1623–1635.
- [18] Yılmaz T, Özgeren M, Gürçınar Y. Daily and yearly variation of humidity ratio. Proceedings of 10th National Thermal Science and Technique Conference, Ankara, Turkey, 1995 (in Turkish).

- [19] Yılmaz T, Bulut H. Expression of daily and yearly variation of meteorological parameters with equations for Şanlıurfa. Proceedings of 4th National Congress on Cooling and Air-Conditioning Techniques, Adana, Turkey, 1996 (in Turkish).
- [20] ASHRAE handbook—1998 refrigeration, systems and applications. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1998.
- [21] Savaş S. Cold storage and introduction to refrigeration systems (in Turkish). Bursa: University of Uludağ Press, 1987.
- [22] Bulut H, Büyükalaca O, Yılmaz T. Analysis of monthly average outdoor dry-bulb temperatures used in the calculation of thermal insulation in buildings. Proceedings of 13th National Conference on Thermal Sciences and Technologies, Konya, Turkey, 2001 (in Turkish).