



COOLING DEGREE-DAYS FOR SELECTED LOCATIONS IN NIGERIA

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ABSTRACT

"Degree-days" is used to quantify the duration and severity of hotness or coldness of a climate. Cooling degree-days is the accumulation positive differences between observed temperature and the base temperature.

From hourly dry-bulb temperature data for Ikeja (Lagos) and Ilorin for 15 years, average monthly and annual total cooling degree-days were computed for base temperatures varying from 24°C to 30°C for both locations. A mathematical model was also developed for cooling degree-days from the data for the two locations.

In addition, a typical one year dry-bulb temperature data were obtained for each of eleven other locations in Nigeria and cooling degree-days were calculated directly from the data and also from the mathematical model for cooling degree-days developed earlier from the data for Ikeja and Ilorin.

The annual total cooling degree-days for a base temperature of 24°C obtained from weather data were 298.9, 784.4, 951.7, 971.9, 989.6, 1012.5, 1022.7, 1051.5, 1076.3, 1225.2, 1431.4, 1803.6 and 1999.6 °C - days for Jos, Kaduna, Ibadan, Port-Harcourt, Benin, Calabar, Ikeja (Lagos), Ilorin, Enugu, Abuja, Kano, Maiduguri and Sokoto, respectively. Degree-days predicted using the mathematical model agreed quite well with the values listed above.

Cooling degree-days are useful in estimating the cost of cooling over a period of time.

1. INTRODUCTION

Man has learnt from experience that extremes of hot or cold weather are uncomfortable and unhealthy for him. In most places in the tropics, the only form of extreme temperature to be contended with is high temperature.

Before mechanical engineers perfected domestic refrigeration and comfort air conditioning, people suffered and died in some parts of the U.S.A during summer and some people who could afford to, moved from the southern states to the northern part of U.S.A during summer (Nagengast, 2000).

The rate of metabolic heat release from the human body depends largely on the physical activity engaged in by the person. If the ambient temperature is too high, the body has difficulty in dissipating heat and it may suffer harmful effects such as: diversion of blood from internal organs to the body surface, profuse perspiration and loss of some useful salts and minerals from the body and interference with normal sleep habits especially if the weather is also humid (Harris, 1983).

From studies carried out on subjects in the temperate zone, it was found that the ambient temperature should not exceed 30 °C for the body to be able to lose metabolic heat comfortably (Billington and Robert, 1982).

The concept of "degree-day" is used to quantify the duration and severity of hotness or coldness of a climate. It is an important climatic statistic useful in the estimation of the energy requirement for heating or cooling a building during a period of time. The total degree-days over a period of time is the accumulation of one-sided differences between a base value of temperature and the set of values of temperature which occur. The total heating degree-days is the sum of all positive differences between the base temperature (T_b) and the observed values of ambient temperature (T) i.e. ($T_b - T$) whereas, the total cooling degree-days is the accumulation of positive differences between the observed values of ambient temperature and the base temperature, i.e. $T - T_b$.

The degree-day was first applied to heating of building for human comfort by American Gas Association circa 1915 when it was discovered that no fuel was consumed when the daily mean outdoor temperature was greater than 18 °C (for an internal design

temperature of 21°C) and also that the fuel consumption on any day was proportional to the difference between the 24-hour mean outdoor temperature and 18°C (Billington and Robert, 1982). The outdoor temperature above which no heating is necessary (18°C in this case) is called the base temperature of heating degree-days and the heat gains from miscellaneous sources such as lights, people, machinery and solar radiation maintains the indoor temperature at the design value which is higher than the base temperature.

Erbs (1984) used twenty-year hourly data for nine locations in United States of America to compute cooling degree-days for base temperature values varying between 10 and 29°C . From ambient temperature cumulative distribution function model derived for the nine locations, Erbs also developed a model for computing monthly cooling degree-days.

Olorunmaiye and Ariyo (1998) used fifteen-year data for the Ikeja (Lagos) and Ilorin to develop cumulative distribution function model and cooling degree-day model applicable to southern Nigeria cities.

However, latent heat and solar radiation through windows constitute a large part of cooling load and they are not directly related to outdoor temperature. The concept of cooling degree-day is quite relevant to refrigeration load of freezers, refrigerators and cold storage rooms, where transmission heat gain as a result of temperature difference the ambient and the space being cooled and also the sensible portion of air change heat gain due to door opening and infiltration constitute a high percentage of the cooling load.

Like in the case of heating degree-days in which miscellaneous heat gains cause the base temperature to be below thermostat set point temperature, solar radiation and other internal gains can lead to appropriate values of base temperature for cooling degree-days being well below thermostat set point (Erbs, 1984). However the cooling load which occur when the ambient temperature is between the base temperature and the thermostat set point can be partly satisfied by ventilation with ambient air. In the case of refrigerators and freezers and cold storage rooms, such miscellaneous heat gains are minimal and the base temperature may be assumed to be approximately the same as the thermostat set point temperature.

Both heating and cooling degree-days are useful in estimating the energy required for heating or cooling a space over a period of time. A possible use of degree-days is for the

values obtained to serve qualitatively in characterizing a climate zone with respect to another (Biscarini et al 1995).

The aim of this work is to gather data for some locations in Nigeria and calculate cooling degree-days directly from the data. The model developed for cooling degree-days from the data for Ikeja (Lagos) and Ilorin will also be applied to all the locations to see how accurate it is.

2 METHODS OF CALCULATING COOLING DEGREE-DAYS

2.1 Calculation Directly from Data

Cooling degree-days (D_c) can be calculated directly from hourly dry-bulb temperature data using the expression

$$D_c = (1/24) \sum_{i=1}^n f(T_i) \quad (1)$$

where

$$f(T_i) = T_i - T_b \quad \text{if } T_i > T_b \quad (2a)$$

and

$$f(T_i) = 0 \quad \text{if } T_i \leq T_b \quad (2b)$$

In the expression above, T_i = hourly dry-bulb temperature in $^{\circ}\text{C}$, T_b = base temperature in $^{\circ}\text{C}$, n = number of hours in the period over which cooling degree-days is to be calculated.

2.2 Model for Cooling Degree-Days

The method discussed in section 2.1 is useful if long-term hourly dry-bulb temperature data are available. However, the direct computation of cooling degree-days from long-term hourly data is time consuming and expensive especially if such data are not available on diskette. Hence there is need to develop a model to simplify such calculations.

A temperature variable h defined by Erbs (1984) for developing models for probability density function and degree-days is given by

$$h = \frac{T_i - \bar{T}}{\sigma N^{1/2}} \quad (3)$$

Where T = mean dry-bulb temperature calculated as the arithmetic mean of all the hourly temperature during the period, σ = standard deviation of dry-bulb temperature and N = number of days in the period of time over which degree-days is to be calculated.

The model developed for calculating cooling degree-days from 15 - year data for Ikeja and Ilorin is given by (Olorunmaiye and Ariyo, 1998):

$$D = \sigma N^{3/2} [0.081546 - 0.5h_b + 0.11765 \ln \cosh (4.25h_b)] \quad (4)$$

$$\text{where } h_b = \frac{T_b - \bar{T}}{\sigma N^{1/2}} \quad (5)$$

All that is needed to apply equation (4) for calculating cooling degree-days for say a month is the average hourly dry-bulb temperature, standard deviation and number of days for that month.

3 RESULTS OF THE COMPUTATION FOR VARIOUS LOCATIONS

The selected locations in Nigeria for which results are presented here, are shown in Figure 1.

3.1 Ikeja (Lagos) and Ilorin

From the hourly dry-bulb temperature data for Ikeja and Ilorin for 15 years (19978-1992), the method discussed in section 2.1 was used to calculate cooling degree-days for the twelve months of the year for values of base temperature ranging from 24 to 30°C. The result is shown in Table 1 (Ariyo, 1997). It should be noted that this computation can be carried out for any desired valued of base temperature. However, in this work, cooling degree-days were calculated for base temperature varying between 24 and 30°C because the indoor design condition dry-bulb temperature for cooling load calculation for air conditioning is 24°C and 30°C is the ambient temperature that should not be exceeded if the body is to loose metabolic heat comfortably.

The monthly mean temperature and standard deviation of hourly dry-bulb temperature obtained from the 15 - year data from Ikeja and Ilorin are shown in Table 2 (Ariyo, 1997). These parameters are the needed input data for calculating monthly cooling degree days from

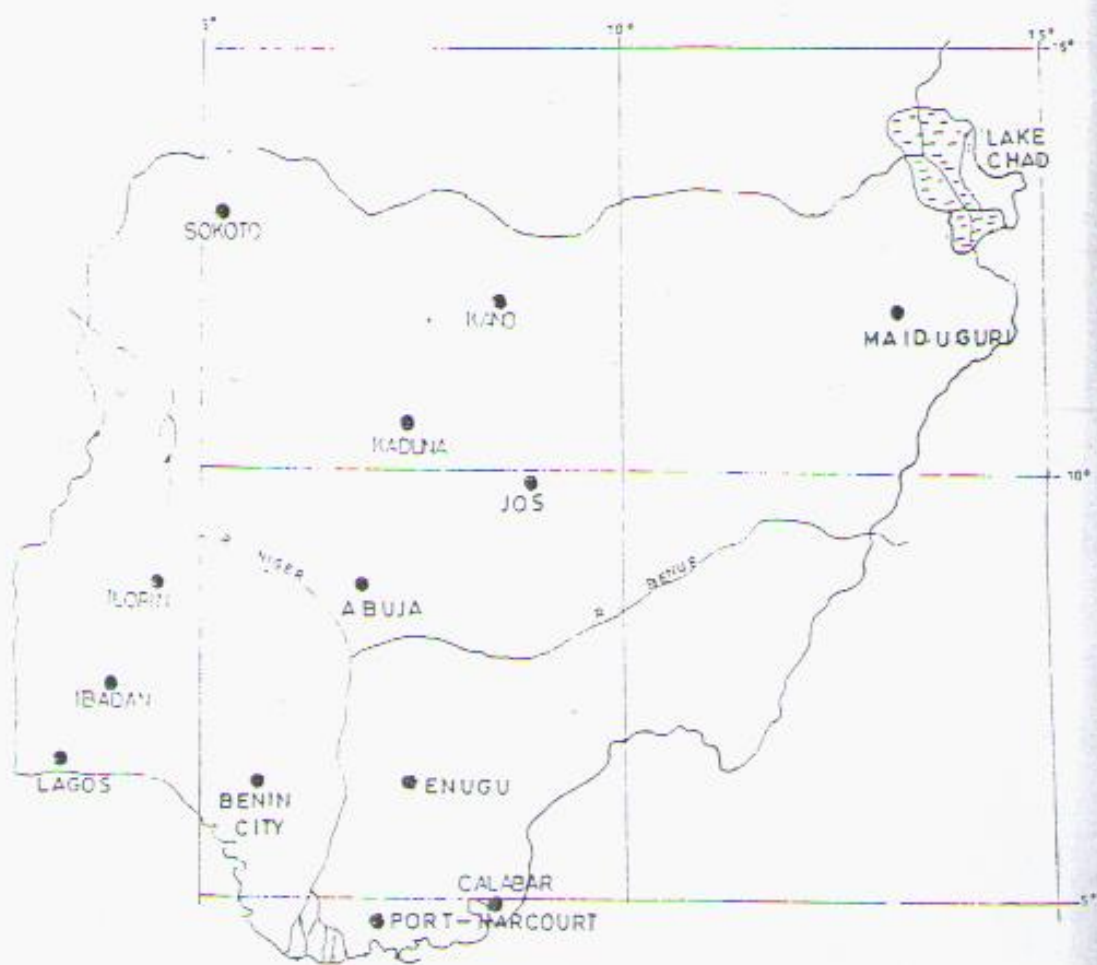


FIGURE 1 MAP OF NIGERIA SHOWING THE SELECTED LOCATIONS AND LATITUDES 5, 10, 15°N AND LONGITUDES 5, 10, 15°E

TABLE 1 COOLING DEGREE-DAYS ($^{\circ}\text{C-DAYS}$) CALCULATED FROM MEASURED DATA FOR IKEJA AND ILORIN.

Base Temp ($^{\circ}\text{C}$)	Place	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
24	Ikeja	98.1	119.8	139.7	129.9	104.3	62.1	36.8	36.7	44.8	68.4	90.8	91.3	1022.7
	Ilorin	99.7	134.2	156.4	128.9	97.8	65.3	39.2	34.2	43.7	68.4	96.1	87.6	1051.5
25	Ikeja	73.9	93.3	110.2	102.2	77.1	40.9	21.8	21.8	28.4	46.6	65.7	67.3	749.2
	Ilorin	80.7	111.8	129.6	104.3	75.6	47.4	25.9	21.8	30.5	51.8	77.0	69.8	826.2
26	Ikeja	54.5	69.7	82.9	76.7	54.2	25.8	11.9	11.6	17.3	31.2	46.4	48.8	531.0
	Ilorin	64.3	92.0	106.0	83.0	57.4	33.1	15.8	12.7	20.2	38.2	61.0	54.9	638.6
27	Ikeja	39.6	51.0	59.8	55.1	36.7	15.5	5.5	5.1	9.3	19.9	32.1	34.7	364.3
	Ilorin	50.2	74.8	86.0	65.2	42.3	21.6	8.4	6.4	12.2	27.1	47.5	42.2	483.9
28	Ikeja	27.9	36.9	42.1	38.4	23.8	8.4	2.0	1.7	4.0	11.3	21.0	23.6	241.1
	Ilorin	38.0	59.7	68.6	50.3	29.9	12.8	3.6	2.6	6.3	18.0	36.0	31.4	357.2
29	Ikeja	18.4	25.9	29.0	25.8	14.2	3.7	0.5	0.4	1.1	5.2	12.3	14.7	151.2
	Ilorin	27.7	46.6	53.6	37.5	19.7	6.4	1.1	0.8	2.6	10.8	26.1	22.2	255.1
30	Ikeja	10.7	17.0	18.8	16.0	7.2	1.2	0.1	0.0	0.1	1.6	5.9	7.7	86.3
	Ilorin	19.0	35.0	40.5	26.7	11.8	2.4	0.2	0.1	0.7	5.5	17.6	14.5	174.0

TABLE 2 MONTHLY-AVERAGE TEMPERATURE ($\overline{T}$, °C) AND STANDARD DEVIATION (σ) FOR
IKEJA AND ILORIN.

MONTH	IKEJA		ILORIN	
	$\overline{T}$	σ	$\overline{T}$	σ
January	26.9	2.9	26.2	4.3
February	28.2	2.7	28.4	4.2
March	28.5	2.4	28.9	3.7
April	28.3	2.3	28.2	3.2
May	27.3	2.0	26.9	2.8
June	25.9	1.6	25.7	2.4
July	24.8	1.5	24.5	2.0
August	24.9	1.6	24.3	2.0
September	25.2	1.7	24.7	2.4
October	26.0	2.0	25.6	2.9
November	27.0	2.4	26.7	3.8
December	26.7	2.7	25.8	4.2

the model in equation (4). The monthly cooling degree-days calculated using the model are shown in Table 3 (Ariyo, 1997).

3.2 The Other Eleven Locations

From one year weather data obtained for Kano (1985), Port-Harcourt (1990), Enugu (1989), Calabar (1990), Jos (1990), Kaduna (1989), Maiduguri (1985), Sokoto (1990), Ibadan (1992), Benin (1992) and Abuja (1994), the monthly mean temperature and standard deviation were calculated. The results are shown in Tables 4 and 5.

The problem of incompleteness of data available made it impossible to collect data for all the eleven place mentioned above for one particular year.

Table 6 shows the total amount cooling degree-days for a base temperature of 24°C calculated from weather data and model for the selected locations. More detailed results of the monthly cooling degree-days computed from weather data and the model can be found elsewhere (Olorunmaiye, 2000). Table 6 shows the arrangement of the locations in the ascending order of the magnitudes of their total annual cooling degree-days.

The percentage errors in the magnitudes of cooling degree-days predicted using the model are also shown. The months having maximum and minimum cooling degree-days are shown in the table.

The design month used for calculation of air conditioning cooling load is defined as the month having the highest mean maximum temperature among the four warmest months (Shoboyejo and Shonubi, 1974). For locations where such pieces of information as design month and elevation are available, they are shown in Table 6.

4. DISCUSSION OF RESULTS

The maximum difference for Ikeja and Ilorin between the total annual cooling degree days predicted using the model (Table 3) and results obtained from the weather data (Table 1) are 24.5 and 24.6°C - days respectively. From Table 1, it can be seen that the total annual cooling degree-days for Ikeja fell from 1022.7°C - days at a base temperature of 24°C to 86.3°C -days at a base temperature of 30°C , whereas that of Ilorin fell from 1051.5 to 174.0°C - days. Ilorin has higher cooling degree-days than Ikeja because of the clearer sky over Ilorin which causes more diurnal temperature swing at Ilorin than Ikeja.

TABLE 3 COOLING DEGREE DAYS ($^{\circ}\text{C-DAYS}$) CALCULATED FROM MODEL FOR IKEJA AND ILORIN.

Base Temp., $^{\circ}\text{C}$	Place	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
24	Ikeja	101.5	122.5	142.2	131.4	105.4	61.5	36.0	39.4	45.5	70.0	96.2	94.5	1046.1
	Ilorin	101.1	137.0	161.2	133.6	100.5	64.3	36.6	33.1	43.8	70.7	102.1	91.5	1075.5
25	Ikeja	77.3	97.1	113.5	103.6	77.8	37.8	18.2	21.0	25.9	46.5	71.2	70.5	760.4
	Ilorin	81.1	114.0	134.6	107.9	76.2	43.8	21.1	18.7	27.9	50.8	80.8	72.4	829.3
26	Ikeja	56.4	73.6	86.5	77.5	53.1	20.0	7.9	9.8	12.9	28.1	49.5	49.9	525.2
	Ilorin	63.7	92.8	109.7	84.3	55.1	27.9	11.2	9.8	16.6	34.9	62.2	56.1	624.3
27	Ikeja	39.3	53.0	62.4	54.5	33.1	9.1	3.1	4.1	5.8	15.5	32.2	33.5	345.6
	Ilorin	49.0	73.8	87.2	63.5	37.9	16.6	5.6	4.9	9.5	23.0	46.6	42.5	460.1
28	Ikeja	26.2	36.0	42.1	35.5	18.7	3.8	1.2	1.6	2.5	8.0	19.5	21.5	216.6
	Ilorin	37.0	57.3	67.3	46.0	24.9	9.5	2.7	2.3	5.2	14.7	34.0	31.7	332.6
29	Ikeja	16.8	23.1	26.6	21.5	9.8	1.5	0.4	0.6	1.0	3.9	11.2	13.2	129.6
	Ilorin	27.5	43.4	50.5	32.0	15.7	5.2	1.3	1.1	2.8	9.1	24.2	23.2	236.0
30	Ikeja	10.5	14.1	15.9	12.3	4.9	0.6	0.2	0.2	0.4	1.9	6.2	7.9	75.1
	Ilorin	20.1	32.2	36.9	21.6	9.6	2.8	0.6	0.5	1.5	5.5	17.0	16.8	165.1

TABLE 4 MONTHLY AVERAGE TEMPERATURE ($\bar{T}$, °C) STANDARD DEVIATION (σ) FOR KANO, PORT-HARCOURT, ENUGU, CALABAR AND JOS.

Month	Kano		Port-Harcourt		Enugu		Calabar		Jos	
	$\bar{T}$	σ	$\bar{T}$	σ	$\bar{T}$	σ	$\bar{T}$	σ	$\bar{T}$	σ
Jan.	23.6	4.5	26.9	2.8	24.3	4.9	27.4	2.2	20.2	5.2
Feb.	22.9	4.5	27.5	3.2	27.5	4.5	28.4	2.7	19.8	5.1
Mar.	29.9	4.0	29.5	3.6	28.5	3.3	29.4	2.8	22.2	5.1
Apr.	30.7	3.8	27.9	2.7	28.8	2.9	28.2	2.3	24.0	3.7
May	31.4	3.9	26.9	2.1	26.7	2.4	27.0	1.9	21.9	2.7
June	28.5	3.3	26.2	2.0	26.1	2.1	26.4	1.6	20.9	2.3
July	25.6	4.0	24.5	1.2	25.2	2.0	24.4	0.9	19.8	2.0
Aug.	26.1	2.9	24.7	1.5	24.9	1.8	24.8	1.1	20.0	2.2
Sept.	26.3	3.1	25.1	1.9	25.4	2.1	25.2	1.5	20.6	2.9
Oct.	27.90	4.4	25.8	2.1	26.2	2.5	25.7	1.9	21.7	3.8
Nov.	25.0	5.0	26.5	2.3	27.2	3.6	26.5	2.0	21.4	4.8
Dec.	21.4	4.2	26.3	2.5	25.8	4.5	26.7	2.0	21.1	5.0

TABLE 5 MONTHLY AVERAGE TEMPERATURE ($\bar{T}$, °C) STANDARD DEVIATION (σ) FOR KADUNA, MAIDUGURI, SOKOTO, IBADAN, BENIN AND ABUJA.

Month	Kaduna		Maiduguri		Sokoto		Ibadan		Benin		Abuja	
	$\bar{T}$	σ	$\bar{T}$	σ	$\bar{T}$	σ	$\bar{T}$	σ	$\bar{T}$	σ	$\bar{T}$	σ
Jan.	19.8	4.4	25.6	4.7	26.2	4.8	25.8	3.8	26.3	4.1	27.7	4.6
Feb.	23.0	4.4	24.0	4.7	26.0	3.9	28.6	4.3	28.8	4.0	28.0	4.3
Mar.	27.9	4.7	31.1	5.0	28.8	3.4	28.7	3.2	28.8	3.0	30.3	3.4
Apr.	28.7	4.3	32.0	4.6	34.4	3.1	27.7	3.0	27.8	2.5	30.7	3.3
May	26.0	3.3	33.1	3.6	32.5	2.3	26.8	2.4	27.0	2.5	28.9	2.4
June	25.1	2.8	30.8	3.1	31.6	2.7	25.1	2.1	25.3	2.0	28.1	2.4
July	24.1	2.6	27.3	2.9	27.1	2.3	24.1	1.5	24.0	1.1	25.9	2.0
Aug.	23.1	2.0	27.2	2.3	27.5	2.2	23.8	1.6	24.2	1.4	26.0	2.5
Sept.	23.9	2.7	27.6	3.0	28.7	2.6	24.4	1.8	24.9	1.8	26.5	2.5
Oct.	24.5	3.7	28.8	4.0	30.5	2.9	25.7	2.7	25.7	2.4	27.6	2.9
Nov.	24.6	5.0	26.7	5.3	29.0	4.6	26.2	3.0	26.5	3.1	26.5	4.4
Dec.	22.8	4.6	22.4	4.9	27.5	5.3	27.2	3.3	27.2	3.5	26.3	4.9

TABLE 6 TOTAL ANNUAL COOLING DEGREE-DAYS FOR A BASE TEMPERATURE OF 24°C COMPUTED FROM DATA AND MODEL, PERCENTAGE ERROR, MONTHS OF MAXIMUM AND MINIMUM D_c, DESIGN MONTHS AND ELEVATION FOR SELECTED LOCATIONS

Place	Elevation, m	Design month	Total Annual D _c for T _b = 24°C (°C-days)			Month for Maximum D _c	Month for Minimum D _c
			Data	Model	% Error		
Jos	1284.7	March	298.9	274.2	8.3	April	July
Kaduna	645.0	March	784.4	771.9	1.6	April	January
Ibadan	227.1	February	951.7	986.0	3.6	March	August
Port-Harcourt	19.5	February	971.9	1002.8	3.2	March	July
Benin	77.7	March	989.6	1027.1	3.8	March	July
Calabar	61.9	March	1012.5	1000.6	1.7	March	July
Ikeja	39.3	March	1022.7	1046.1	2.3	March	August
Ilorin	305.4	March	1051.5	1075.5	2.3	March	August
Enugu	141.4	March	1076.3	1079.5	0.3	March	August
Abuja	* N.A	N.A	1225.2	1200.3	2.0	March	August
Kano	472.1	April	1431.4	1137.8	20.5	May	December
Maiduguri	353.6	April	1803.6	1823.0	1.1	May	December
Sokoto	350.5	April	1999.6	2028.6	1.5	April	February

* N.A. = Not Available.

The months of maximum cooling degree-days fell within March to May for the selected locations. For each place it was the month occurring before rainfall becomes regular. In some places these months of maximum cooling degree days also coincides with the design month.

Abuja and the locations in the southern part of Nigeria have their month of minimum cooling degree-days occurring in July or August during the rainy season whereas the places in the northern part of the country have their months of minimum cooling degree-days occurring within December to February which are harmattan months when the weather is cold, dry and dusty.

The design month for the northern hemisphere is usually taken as July (Jones, 1980). In the CARRIER software package for computing air conditioning cooling load, this assumption of July being the design month was made to generate dry-bulb temperature profiles. However the results in Tables 1-6 show that such assumption is not right for locations in Nigeria. This is because July is in the rainy season and there is a lot of cloud cover which reduces the intensity of solar radiation.

The percentage errors in the values of total annual cooling degree-days are less than 5% except for Jos (8.3%) and Kano (20.5%). This shows that the model developed is quite good and applicable throughout Nigeria. The agreement between the model and the results calculated directly from the data might have been better if long-term weather data had been used for the eleven location instead of one year data.

5. CONCLUSIONS

The running cost of refrigerators, freezers and cold storage rooms per annum can be expected to increase in the order in which the places are arranged in Table 6, i.e. Jos having the lowest and Sokoto having the highest. For each place, the running cost of refrigerators, freezer and cold storage rooms are expected to vary from month to month and be proportional to monthly values of cooling degree-days. However, the running cost of air conditioning systems may not be directly proportional to cooling degree-days because latent heat component of the cooling load may be significant and it is not reflected in cooling degree-days.

The model for cooling degree-days developed from long-term weather data of Ikeja and Ilorin has been found to be suitable for places all over Nigeria.

The severity and duration of hotness of the selected locations have been quantified and presented.

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REFERENCES

- Ariyo, D.O. Model for Ambient Dry-Bulb Temperature and Relative Humidity Statistics Related to Building Cooling Loads for Ilorin and Ikeja. M.Eng. Project Report, Dept. of Mechanical Engineering, University of Ilorin, Ilorin, Nigeria, 1997.
- Billington, N.S and Robert, B.M. Building Services Engineering: A Review of its development, Pergamon Press, Oxford, 1982.
- Biscarini, M., Lorusso, A. and Maraziti, F. "Degree-days and Energy Saving, Analysis of a Method of Calculation for an Optimal Microclimate in Livestock Buildings" Vol. 38, No. 4, pp. 1207-1212, 1995.
- Erbs, D.G. Models and Applications for Weather Statistics Related to Building Heating and Cooling Loads, Ph.D. Thesis, Dept. of Mechanical Engineering, University of Wisconsin-Madison, 1984.
- Harris, N.C. Modern Air Conditioning Practice, Mc Graw-Hill Book Company, New York, 1983.
- Jones, W.P. Air Conditioning Applications and Design, Edward Arnold, London, 1980.
- Nagengast, B. "It's a Cool Story! Refrigeration and Air Conditioning in the 20th century", Mechanical Engineering, pp. 56-63, May 2000.
- Olorunmaiye, J.A. and Ariyo, D.O. "The Relationship Between Cooling Degree-days and Base Temperature for Southern Nigeria Cities", AMSE Modelling, Measurement & Control Vol. 66 No. 1 pp. 21-31, 1998.
- Olorunmaiye, J.A. Computation of Cooling Degree-Days for Nigerian Cities TR No. 2000 - 01, August 2000.
- Shoboyejo, A.B.O. and Shonubi, F.A. "Evaluation of Outside Design Conditions for Air Conditioning System Design in Nigeria". The Nigerian Engineer Vol. 9 No.1, pp5-11, 1974.