Compilation of Monthly World Weather Data and Transformation into Hourly Basis for the Calculation of Air-Conditioning Load at an Arbitrary Location in the World

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Abstract- *Weather data at thousands of stations throughout the world are compiled for air-conditioning load calculation using a personal computer. Several selected sources of weather data are introduced. Major sources among them are the publication by the British Meteorological Office and the magnetic tape compiled by the Japan Meteorological Agency. Since solar radiation is not included in the major sources, it is supplemented from the other sources. Consequently, two files named BMO and JMA are compiled. A computer program for calling the designated station from the files is developed. As the weather data in the files are on monthly basis, an estimation method of hourly data from monthly data is presented. Solar radiation for cooling load calculation is also estimated. Sample calculation is illustrated.*

Introduction

Since HASP/ACLD, the simulation program of unsteady state air-conditioning load through a year, was released from SHASE (the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan) in 1971, it has been given the status as the standard program for air-conditioning load calculation in Japan. SHASE also developed the framing of standard weather data required for HASP/ACLD in 1973. According to the framing, standard weather data called "Typical Year" with 8760 hourly data for each of the seven weather elements has been developed for 25 cities around Japan so far.

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Though HASP/ACLD was coded by FORTRAN, the demand of the BASIC version increased as the performance of a personal computer enhanced. The BASIC version of HASP/ACLD named MICRO-HASP was released in 1980. MICRO-PEAK, which calculates design and average air-conditioning load based on the periodical steady assumption using hourly weather data during a day, was also developed in 1984.

This report relates the compilation of world weather data so as to make them available for MICRO-PEAK/1987, the current version of MICRO-PEAK. The compilation may also be effective for the other programs if calculating the air-conditioning load under periodical steady condition.

Source Data

The source data introduced here are as follows:

1. the publication by the British Meteorological Office (1973~1980) (D1),
2. magnetic tapes compiled by the Japan Meteorological Agency (D2),
3. the report on the world solar radiation distribution published by the University of Wisconsin (George O.G. Lof et al. 1966) (D3),
4. BIN solar radiation data by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) (D4),
5. solar radiation observations at Japan Weather Observatories (D5).

Among these sources, D1 and D2 are the major sources as both of them have air temperature and relative humidity. The other three sources D3~D5 relates to solar radiation.

Supplementation for Lacking Weather Elements to D1 and D2

The weather elements required for ordinary air-conditioning load calculation are air temperature, humidity, solar radiation, wind direction, wind speed and cloud cover. In these weather elements, D1 and D2 have air temperature and relative humidity. D2 has additional three elements; i.e., wind direction, wind speed and cloud cover. Since both D1 and D2 are lacking in solar radiation, it is supplemented from that at the nearest station in D3, D4 or D5 with the correction of solar altitude difference between the stations in D1 or D2 and D3, D4 or D5. Wind direction, wind speed and cloud cover for D1 station are cited from those at the nearest station in D2 with the restriction that the height difference between the stations must be within 300[m].

Number of the Stations in BMO and JMA files

D1 and D2 contain about 2400 and 2000 stations, respectively. The monthly weather data are compiled for all of these stations. More than 3700 independent stations remain even excluding the overlapped stations in D1 and D2. Computer files based on D1 and D2 are named BMO and JMA, respectively. In order to minimize the memory size as much as possible, BMO and JMA are filed as the compact random files. Consequently, each of them is filed within the memory size of 1.1 mega bytes, i.e., within the 2HD floppy disk capacity. Number of the stations in each of the six continents filed in BMO and JMA are listed in TABLE 1. The distribution of the stations filed in BMO and JMA are illustrated in Fig.1 and Fig. 2, respectively.

TABLE 1 Number of the Stations in BMO and JMA

Continent	BMO stations(%)	JMA stations(%)	Over-lapped*
Europe	632 (27)	265 (13)	133
Asia	319 (13)	804 (40)	135
Africa	546 (23)	289 (14)	161
N. America	625 (26)	232 (11)	158
S. America	121 (5)	261 (13)	43
Oceania	139 (6)	171 (8)	48
Total	2382 (100)	2022 (100)	678

* Number of D1 stations within ±5' longitudinal and latitudinal distance from D2 stations

Data contents for each of the stations in BMO and JMA

The following data are included for each of the stations in BMO and JMA:

1. monthly mean of daily maximum temperature T_m [℃]
2. monthly mean of daily minimum temperature T_n [℃]
3. monthly maximum temperature T_{me} [℃]
4. monthly minimum temperature T_{ne} [℃]
5. monthly mean of daily maximum relative humidity RH_m [%]
6. monthly mean of daily minimum relative humidity RH_n [%]
7. monthly precipitation amount P_A [mm]
8. number of the precipitation days in a month P_D [d]
9. frequent wind direction in a month WD [36 directions]
10. monthly mean wind speed WV [m/s]
11. monthly mean of cloud amount CC [%]
12. frequent wind direction at 0, 6, 12 and 18 o'clock(GMT) in a month WD_h [36 directions]
13. mean wind speed at 0, 6, 12 and 18

o'clock(GMT) in a month WV_h [m/s]

14. mean cloud amount at 0, 6, 12 and 18 o'clock(GMT) in a month CC_h [%]
15. monthly mean of daily global solar radiation TH_d [cal/m^2].

Selection of the Designated Station

A computer program is developed that calls the nearest several stations(candidate stations) in BMO and JMA to the designated latitude and longitude input by an operator. Since the designated station is not always included in BMO or JMA, the computer program projects on CRT key information concerning candidate stations for assisting the operator in selecting the most suitable station in place of the designated station.

Conversion from monthly Values to Hourly Values

Although weather data in BMO and JMA are on monthly basis, MICRO-PEAK needs hourly weather data. Therefore, the methods for estimating hourly values during a day are developed here.

(1) Temperature

Hourly temperatures for an average day of each month are generated from T_m, T_n, the expected times t_m and t_n when T_m and T_n occur and the assumed curves connecting them. Although varying from day to day, t_n and t_m for a representative day during a month can be assumed at sunrise and 1.5 hour after solar noon, respectively.

Daily maximum and daily minimum temperatures corresponding to the given frequency levels such as 5%, 10% and 20% are estimated from T_m, T_n, T_{me} and T_{ne} by assuming their distributions are normal. Then hourly temperatures through the day for design cool-

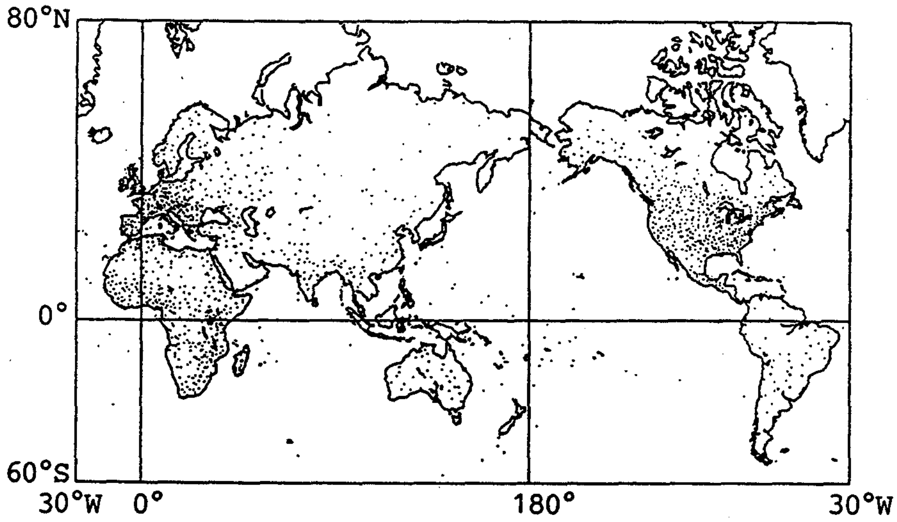

Fig. 1 Stations Filed in BMO

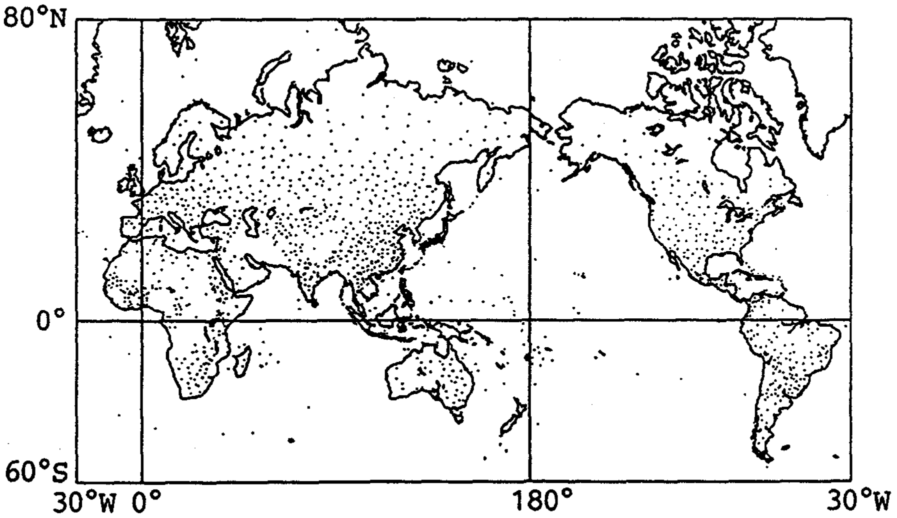

Fig. 2 Stations Filed in JMA

ing and design heating load calculation are generated as the same method as used for an average day.

(2) Solar Radiation

Hourly global solar radiation for an average day is calculated from TH_d in BMO or JMA using the relation between daily and hourly insolation (Collares et al. 1979). Then global solar radiation is divided into direct and diffuse components using the relation between global and diffuse solar radiation (Udagawa et al. 1979).

For estimating solar radiation on a clear day, which is necessary for design cooling load calculation, the multiple regression equation predicting the transmittance of the atmosphere(P) on a clear day is deduced by least square method from the observations at 14 stations around Japan and 17 stations around the United States and Canada (Akasaka et al. 1992). The equation is written as follows:

$$P = 0.91 - 0.003\ V_p - 0.23\ sin\ h_0 \qquad (1)$$

where V_p[mmHg] is the vapor pressure of the atmosphere and h_0 is solar altitude at solar noon. Global solar radiation at solar noon can be calculated using the P value from equation(1). Subsequent calculations for obtaining hourly direct and diffuse components of the day from the noon value are the same as those for an average day.

(3) the Other Weather Elements

Humidity ratio at t_n and t_m can be calculated from T_m, RH_n and T_n, RH_m, by the assumption that the expected occurrence times of RH_m and RH_n are the same as those of T_n and T_m, i.e., t_n, t_m. The values other than those at t_n and t_m are calculated by interpolating them using the same curves as used for the interpolation of hourly temperature.

Since BMO and JMA include the values of cloud amount, wind direction and wind speed at 6, 12, 18 and 24 o'clock GMT(Greenwich Mean Time), hourly values are obtained by interpolating them. Subsequently, hourly nocturnal radiation is calculated from temperature, humidity ratio and cloud amount.

TABLE 2 Monthly Weather Data for Adelaide
(Latitude:34.56S,Longitude:138.35E,Height from Sea Level:42m), Australia in BMO

month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
T_m [℃]	30.0	30.0	27.2	22.8	18.9	16.1	15.0	16.7	18.9	22.8	26.1	28.3
T_n [℃]	16.1	16.7	15.0	12.8	10.0	8.3	7.2	7.8	8.9	10.6	12.8	15.0
T_{me} [℃]	42.2	40.6	37.8	31.7	25.6	20.0	19.4	22.8	27.2	33.3	37.2	40.6
T_{ne} [℃]	10.6	10.6	9.4	7.8	5.6	3.3	2.8	3.3	3.9	5.0	7.2	8.9
RH_m [%]	38	41	45	55	67	76	76	69	60	51	43	39
RH_n [%]	31	32	36	45	56	65	63	57	52	42	36	32
P_A [mm/month]	20	18	25	45	68	76	66	66	53	43	28	25
P_D [d/month]	5	5	5	10	13	15	16	16	13	10	8	6
WD [0~36]	23	23	16	5	4	4	4	3	22	22	22	22
WV [m/s]	4	4	4	3	4	3	4	4	4	5	4	5
CC [%]	41	39	45	50	61	57	60	59	54	51	51	61
WD_h at 0 GMT*	23	14	18	5	2	4	4	2	1	1	4	22
WV_h at 0 GMT	3	3	3	4	3	3	3	4	4	5	4	4
CC_h at 0 GMT	52	43	50	55	66	60	65	61	54	54	57	69
WD_h at 6 GMT	23	23	23	22	2	4	3	2	24	23	22	22
WV_h at 6 GMT	6	5	6	5	5	5	5	6	6	6	6	6
CC_h at 6 GMT	37	38	45	53	69	65	66	63	58	52	51	51
WD_h at 12 GMT	23	23	23	22	2	4	4	2	24	23	22	22
WV_h at 12 GMT	4	3	3	3	3	2	3	3	3	3	4	4
CC_h at 12 GMT	36	40	42	45	57	51	56	54	51	46	48	52
WD_h at 18 GMT	23	23	23	22	2	4	4	3	24	23	22	22
WV_h at 18 GMT	3	2	3	2	3	3	3	3	3	3	3	3
CC_h at 18 GMT	38	32	41	45	53	55	54	57	54	51	47	44
TH_d [cal/m^2]	691	601	487	426	233	197	209	286	397	479	600	662

* Greenwich Mean Time

Air-Conditioning load Calculation Program and a Sample Calculation

MICRO-PEAK calculates hourly air-conditioning load on a typical day for each month as well as for the frequency levels(TAC) 5%, 10% or 20% of hourly heating and cooling load. The former load is used for the estimation of energy consumption during the month, whereas the latter is used for determining the sizes of air-conditioning apparatus. Since the program includes hourly weather data for 25 cities in Japan as a random file, weather data of a selected station from BMO or JMA must be converted into the same format as the random file. Sample calculation is shown below.

Monthly weather data for Adelaide read from BMO is shown in TABLE 2. Hourly values estimated from the values in TABLE 2 for design heating load at frequency level(TAC) 5% are shown in Fig.3 and Fig.4. The hourly values for design cooling load at frequency level(TAC) 5% are also illustrated in Figs.6 and Fig.7. While the hourly values for average air-conditioning load in May are shown in Figs.9 and Fig.10. Figs.12 and Fig.13 illustrate the hourly values for December. Local mean time including summer time is taken into account in Figs.3 to 14. Design and average heat loads for an imaginary 12 story building located in Adelaide are computed by MICRO-PEAK/1987. The object area for the computation is the north perimeter zone of the 8th floor (hatched area in Fig.15, 324m²). Details required for the computation is shown together with the plan. The air-conditioning loads per unit floor area are illustrated in Fig.5, Fig.8, Fig.11 and Fig.14, corresponding to the weather data shown above. Air-conditioning loads by mechanical ventilation (20m³ per person) are not added to the values in the figures. The addi-

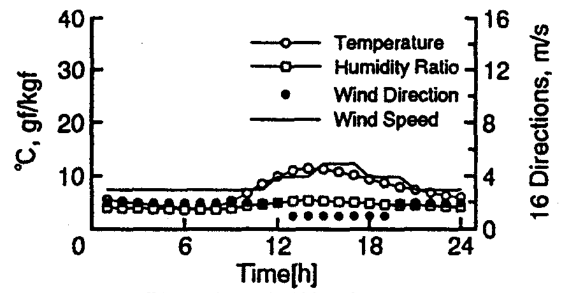

Fig. 3 Hourly Weather Data for Design Heating Load (1)

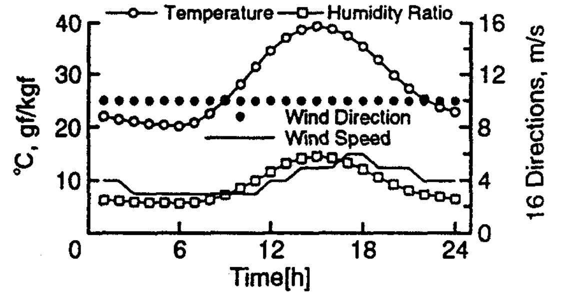

Fig. 6 Hourly Weather Data for Design Cooling Load (1)

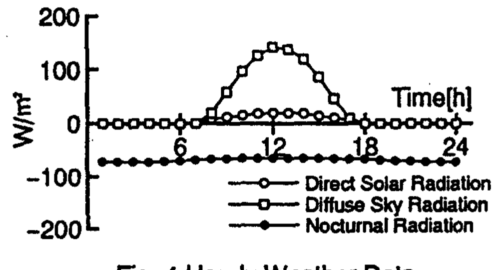

Fig. 4 Hourly Weather Data for Design Heating Load (2)

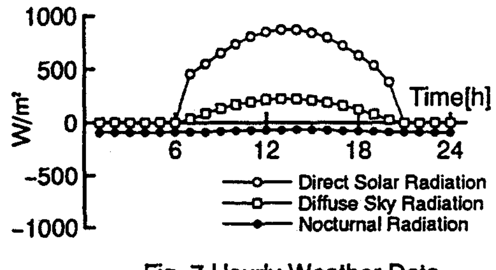

Fig. 7 Hourly Weather Data for Design Cooling Load (2)

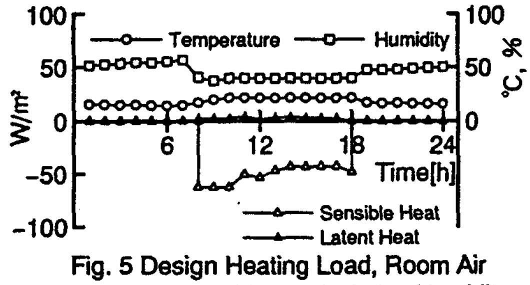

Fig. 5 Design Heating Load, Room Air Temperature and Room Relative Humidity

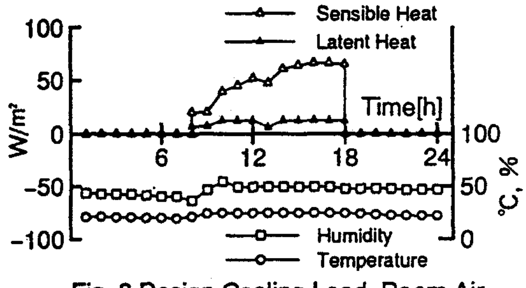

Fig. 8 Design Cooling Load, Room Air Temperature and Room Relative Humidity

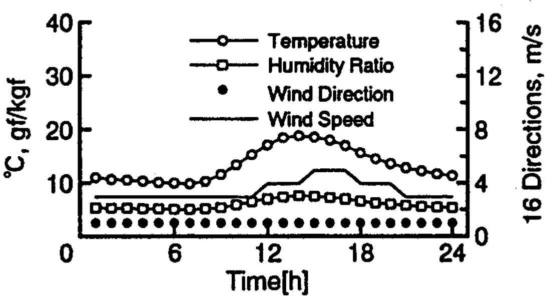

Fig. 9 Hourly Weather Data for May (1)

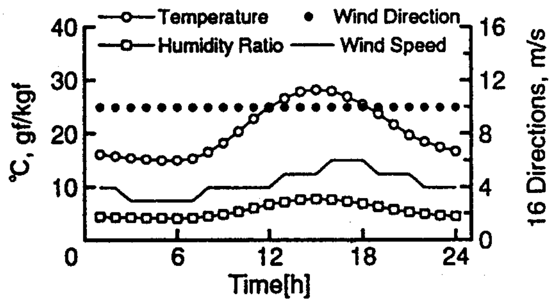

Fig.12 Hourly Weather Data for December (1)

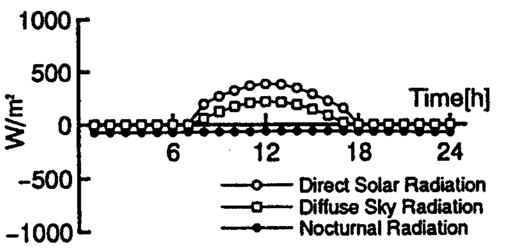

Fig.10 Hourly Weather Data for May (2)

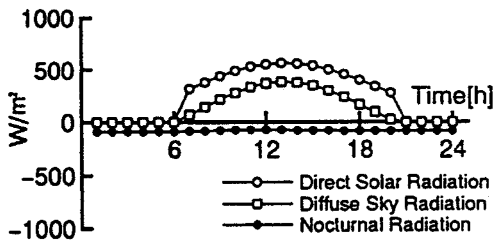

Fig.13 Hourly Weather Data for December (2)

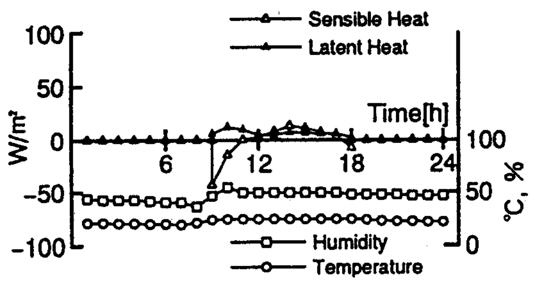

Fig.11 Average Heat Load, Room Air Temperature and Room Relative Humidity for May

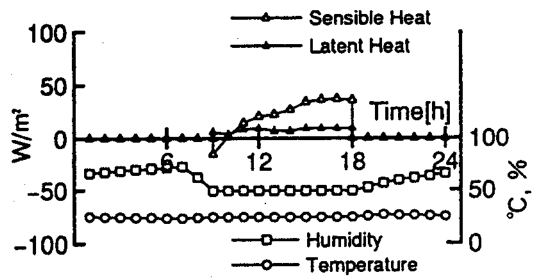

Fig.14 Average Heat Load, Room Air Temperature and Room Relative Humidity for December

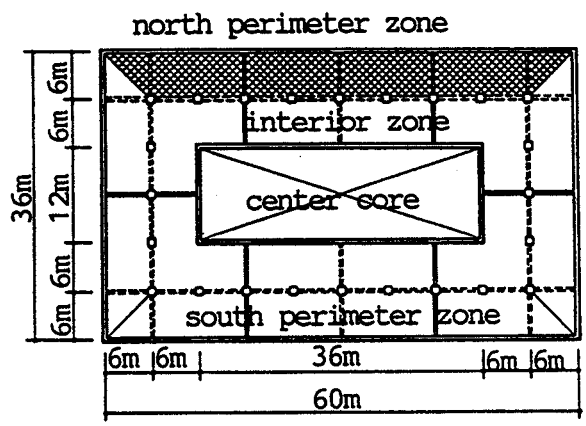

Fig.15 Sample Plan for Air-Conditioning Load Calculation

Object area is north perimeter zone(hatched area). The skin is composed of 86[m^2] of 165[mm]-thick concrete wall, 66[m^2] of 325[mm]-thick concrete wall and 70[m^2] of 8[mm]-thick glass window with interior blind. Projection of eaves over the windows is 1.5[m]. Floor height and ceiling height are 3.6[m] and 2.6[m], respectively. Occupant density is 0.2[person/m^2 (floor area)]. The density of artificial lighting is 20[W/m^2 (floor area)]. Air-conditioning system is operated from 9 to 18 o'clock with one hour pre-operation in the case of design load calculations. Room conditions for design heating load, design cooling load and average load are 22℃, 40% and 26℃, 50% and 25℃, 50%, respectively.

tional maximum sensible and latent loads by mechanical ventilation are 24, 9W/m^2 for design heating load, whereas 18, 14W/m^2 for design cooling load.

Conclusions

(1) Monthly world weather data files named BMO and JMA are compiled.

(2) Hourly values for temperature, solar radiation, nocturnal radiation, humidity ratio, wind direction and wind speed during a day can be calculated at any location around the world filed in BMO or JMA.

(3) Both of design and average air-conditioning loads can be computed from the hourly weather data if the computations are under periodical steady condition.

(4) Example air-conditioning load computations by MICRO-PEAK/1987 for a building in Adelaide are illustrated.

Acknowledgement

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