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"TEST REFERENCE YEAR", WEATHER DATA FOR ENVIRONMENTAL ENGINEERING AND ENERGY CONSUMPTION IN BUILDINGS

BY

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"Test Reference Year", weather data for Environmental Engineering and Energy Consumption in Buildings

by

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The "Test Reference Year" (TRY) is a weather data collection with 8760 hourly weather registrations, containing a considerable number of weather parameters for each hour. It is intended, for a given location, to ideally represent the weather throughout a typical year, on the assumption that a typical year can be defined.

It's main purposes are to make it possible for architects, consulting engineers, and others to make use of computing programs for calculations of energy consumption and indoor climate by an entire year of weather data, and to make it possible to compare different projects throughout a whole year. The requirements on the qualities of a TRY are discussed, related to the use and present possibilities.

Paper to CIB-S-17 meeting, London, September 1975.

Introduction.

The calculation methods available today for calculation of indoor thermal climate and heating and cooling demands take into account the combined effect of many very different factors:

The architectural design of the building - windows, size, and orientation, sun shading

The building fabric - mass, thermal accumulation in each surface in a room

The effect of inner factors - inmates, ventilation, machines, other heat sources and influence upon them from e.g. outer factors, like illumination, or inner factors, like thermostatic controls etc.

The effect of external factors - climate, temperature, sun, wind, humidity etc.

The three factors first mentioned are determined by the building owner, the architect, and the consultants, but the future weather is still beyond our command. We can only have in view to dimension our buildings and systems in such a way that they, by means of the weather of the past, are optimized in use, in lifelength, and economically.

The climatologist furnish us with mean values, variances, diurnal variations, frequencies etc. for the individual climatic parameters, which can then be used for dimensioning.

For calculations of the combined effect of external climate upon the indoor climate of a building, however, such values are not sufficient. This is caused by the fact that the building incorporate time delays - the thermal accumulation - and non-linearities such as changing ventilation, changing illumination and thermostatic regulations. Use of the superposition principle by calculating the influence of each weather parameter independantly is therefore only in few cases permissible. The combined effect of many parameters must be calculated simultaneously. Furthermore, the different weather parameters influence various buildings to different degrees.

Main objects for "Test Reference Years".

Possible use of TRY related to energy calculation and indoor climate in a building:

A For a single project a calculation of indoor climate and/or energy consumption throughout a whole year, giving e.g. mean values or frequencies of temperatures per month, or during the working hours, etc.

The evaluation of the results must be based upon experience gained at earlier calculations, or upon standards or building codes.

B Comparison of two or more alternative projects. The comparison takes place utilising e.g. mean values or frequencies of temperatures, or energy consumption for heating or air conditioning. Such calculations can be used for cost-benefit analyses of modifications in a project.

Calculations with a TRY cannot be expected to give absolute extremes of any parameter, because that normally demands a special combination of excitations. Such events which appear 5 or lo times a year or more may readily be found.

The TRY shall, if possible, for all seasons contain such a variety of different weather situations that any building, regardless of construction, orientation, or use, will get reasonable different excitations to make it possible to get an overall impression of the performance of the construction or system during a typical year.

That means on the other hand that the calculations for a certain building or system for a large percentage of the Test Reference Year will render results that are not extreme nor interesting, but those results make it possible to establish frequencies or monthly or yearly sums or means that are a sound basis for evaluation of performance.

Furthermore, with many calculation methods the expences for problem formulation and manual data selection of buildings or systems by far exceed the expenses for computer time. The elimination of manual selection of interesting weather situations constitutes a considerable simplification and secures comparability with other calculations.

Requirements.

Determined by the prevalent use of TRY, calculation of energy consumption and indoor climate in buildings, the following requirements must be set:

I Some parameters must be mandatory, considered necessary for the purposes mentioned above, as DBT, humidity, radiation, wind, and a few others. (Appendix 2).

II The most important weather parameters for the purposes must possess

i) True frequencies, i.e. as near as possible a true mean value throughout longer periods, like each month, and at the same time a natural distribution of higher and lower values for single days.

ii) True sequencies, i.e. the weather situations must have a duration and follow each other in a way corresponding to often registrered courses at the location.

iii) True correlation between different parameters, i.e. temperature, radiation, cloud cover, wind, etc.

The fulfilment of i) could rather easily be accomplished by generation of a synthetic year, based on already available mean values, standard deviations etc.

However, so far ii) and iii) cannot be satisfied in this way, because many of the relations between individual parameters cannot yet be described mathematically.

It therefore seems necessary to use real, measured data, and through a selection procedure try to satisfy i) and ii). Then iii) will by itself be satisfied through the use of data measured simultaneously.

Selection procedures.

The simplest selection process is to chose a random year from the period for which sufficient weather data are available. For the users, however, such a year will possess very little attraction, even when it is accompanied by a detailed description of it's deviations from the normal or mean values for the location.

The users want to know how their constructions will act in a "typical" year or a "warm" or "cold" year, not in a random year.

Proposed ASHRAE method.

The next possibility will be to perform a manual selection from a very few data, e.g. the monthly mean temperatures only. In this way the user will know something about the chosen parameter, and nothing about others, like humudity or radiation.

The selection according to the proposed ASHRA method not yet published (appendix 3) tries to avoid years containing the most extreme months with respect to monthly mean temperature. This means the warmest or coldest January, February, etc. in the period from which the selection is made. The method is extremely easy and quick in use. In less than one hour one can select the year from 1o or 2o that can be used as TRY for the location, using only monthly mean temperatures for the period. Afterwards, of course, it is necessary to collect all weather data for the selected year, check them, fill in lacunes etc., a work that must be done whatever selection method has been used, as the Test Reference Year must contain all data, independently of which ones were used at the selection process.

Danish method.

The most elaborate selection methods incorporate a large number of data. This means that a computerized method for the selection has to be used. Even then it has been necessary to restrict the parameters chosen for the selection to those considered most important for use in the geographical area.

For the Danish Reference Year the daily mean temperature, the daily maximum temperature, and the daily sum of global radiation have been used, and for each of them a true monthly mean and deviation have been aimed at. In other climatic regions it might be more important to select according to wind or humidity.

Besides this mathematical, computerized selection, the monthly values of some 2o parameters have been checked manually, and if one of them has deviated more from the corresponding mean value for the 3o year period than the standard deviation, the month has been rejected.

A detailed description of the selection procedure used for the Danish Reference Year is given in [1]. An estimate of the cost in man-weeks and computer hours is given in appendix 4.

Although a TRY is selected for a restricted geographical area, like Denmark, there seems to be a possibility to expand the geographical area of validity. The feasibility of this expansion is still being investigated [2].

Building orientated selection.

Several authors have tried to select weather data for typical runs of days (2 to 1o days) for specified types of buildings, e.g. light-weight or heavy constructions [3]. The use of such data might be justified for very detailed computer programs, consuming much computer time, but they place the demand upon the user that he must be able to evaluate the validity of a data collection for a specific project.

Generally, however, it must be preferred to base the selection upon meteorological data only, unrelated to any specific building.

Occurence of extremes by Danish method.

The selection method used for the Danish Reference Year has a tendency to reduce the yearly extremes, simply because the selection is made month by month, and e.g. the highest daily mean temperature may occur anywhere during the months of June, July, or August, or even in May. However, observing the upper and lower 1o per cent fractiles, the picture is much better. Fig. 1 shows the number of sunny hours per day during the Reference Year, and 1o per cent and 2o per cent fractiles up and down. Table 3 states the number of days exceeding those fractiles, and, totally for the year, the numbers to be expected statistically.

Table 4 and 5 show similarly the values for the daily mean temperature and global radiation.

It is seen that although there are variations during the seasons, the general agreements are fairly good.

A similar test with a Finnish experimental Reference Year by the Danish method gave an average of 4 per cent of the days exceeding the 5 per cent fractiles for a 24 year period.

Experiences.

The Danish Reference Year has been in practical use for more than two years. It is used by many of the important consulting engineering firms, not only for the original purposes, but also for other completely different problems.

Many questions from the users are "whether such a year is really typical". An extensive use of a TRY demands a clear yes and a clear documentation from those who produces the TRY.

References:

1. Bo Andersen et al:
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2. Hans Lund:
The "Reference Year", a set of climatic data for environmental engineering. Paper no. A3 for "Second Symposium on the Use of Computers for Environmental Engineering", Paris, June 1974.

3. P.S. Scanes:
Climatic Design Data for Use in Thermal Calculations for Buildings - Estimated Clear Sky Solar Radiation versus Measured Solar Radiation. Building Science, Vol. 9, pp 219-226. Pergamon Press 1974.

			RY	1967
Temperature	YE	°C	o,1	o,4
(compared with 1931-6o)	ME		o,6	1,1
	MM		-2,6	3,3
			Dec.	March
Global radiation	YE	Wh/m^{2}day	2o	-158
(compared with 1959-69)	ME		189	221
	MM		346	-495
			March	Sept.
Ditto	YE	%	o,7	-5,6
	ME		9,9	13,3
	MM		3o	-28
			Dec.	Jan.
Sunny hours	YE	h/day	-o,4	-o,8
(compared with 1931-6o)	ME		o,9	o,9
	MM		-2,3	-2,3
			May	May

Table 1

Comparison between the Danish Reference Year (RY) and the year selected according to the proposed ASHRAE method, 1967. "Error" is the (absolute) difference between yearly or monthly mean and the corresponding value for 1931-6o, or 1959-69.

YE error in early mean

ME average error in monthly mean

MM maximum monthly error, and month.

TRY selected from	25 years	1o years
Average error in yearly mean. °C	o,4	o,4
Average error in monthly mean. °C	1,o	1,o
Average max. monthly error. °C	3,4	4,o

Table 2

Yearly and monthly error in TRYs (selected according to proposed ASHRAE method) compared with 3o years' monthly mean temperatures. Average for 9 cities in the U.S.A.

Danish Reference Year

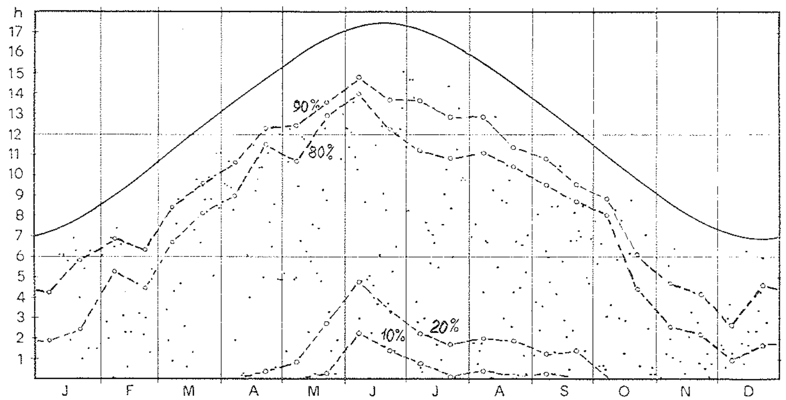

Fig. 1. • Sunshine hours, daily sum, Reference Year.

-o- Fractiles, 10% and 20%, based on the years 1959-69, Copenhagen.

— Length of day, hours.

Hours with clear sun are measured with an equipment which do not respond for very low solar altitudes.

Table 3. Sunshine hours, daily sum, number of days in the Reference Year exceeding fractiles from 1959-69.

	< 10%	< 20%	> 80%	> 90%
Jan.-March	/	/	26	14
April-June	12	19	15	3
July-Sept.	7	16	9	7
Oct.-Dec.	/	/	21	10
Total	19	35	71	34
Should be	18	37	73	37

The Danish Reference Year

compared with the period 1959-69 from which it has been selected.

Number of days in the Reference Year exceeding fractiles from 1959-69.

Table 4. Daily Mean temperature

	< 10%	< 20%	> 80%	> 90%
Jan.-March	3	9	12	5
Apr.-June	7	11	23	9
July-Sept.	0	8	24	14
Oct.-Dec.	9	17	17	11
Total	19	45	76	39
Should be	36	73	73	36

Table 5. Global Radiation, daily sum

	< 10%	< 20%	> 80%	> 90%
Jan.-March	9	15	29	14
Apr.-June	8	17	15	6
July-Sept.	8	18	14	8
Oct.-Dec.	3	14	22	14
Total	28	64	80	42
Should be	36	73	73	36

Appendix 3

PROCEDURE FOR SELECTING A TEST YEAR OF WEATHER DATA

RECOMMENDED BY ASHRAE

The term "test year" in this note means a selected calendar year whose actual hourly weather observations are to be used for comparing the computed energy requirements of different buildings in the same municipality or different heating and air conditioning systems in the same building. The weather in the test year is not to be considered sufficiently typical to yield reliable estimates of average energy requirements over several years.

All the desired weather data are readily available for only about ten years at most stations. The problem is to select one test year from amongst these ten, basing the selection on the 120 values of the monthly mean temperatures for the ten years. The principle of selection is to eliminate years containing months with extremely high or low mean temperatures until only one year remains.

To do this the extreme months must be arranged in order of their importance for energy comparisons. Hot Julys and cold Januarys are assumed to be the most important. All the months are ranked by alternating between the warm half (May to October) and the cold half (November to April) of the year, with the months closest to late July or late January given priority. The resulting order is given in the centre column below. If, in addition, it is assumed that hot summer months and cold winter months are more important than cool summer or mild winter months then the order of extreme months will be down the first column below from "Hottest July" to "Coolest April" and then down the last column from "Coolest July" to "Warmest April".

Hottest	July	Coolest
Coldest	January	Mildest
Hottest	August	Coolest
Coldest	February	Mildest
Hottest	June	Coolest
Coldest	December	Mildest
Hottest	September	Coolest
Coldest	March	Mildest
Warmest	May	Coolest
Coolest	November	Warmest
Warmest	October	Coolest
Coolest	April	Warmest

The first step is to mark all 24 extreme months and to count the number of marked months in each year.

If there is one and only one year remaining without any marked month, then this is the test year.

If there are two or more years remaining without any marked month then continue marking months starting with next-to-the-hottest July, then next-to-the-coldest January and so on down the first column above until only one year remains without any marked month.

If there is no year without a marked month and only one year with only one marked month, then this is the test year.

If there are two or more years with only one marked month, then note these months and whether they are hottest or coldest. Starting at the bottom of the right hand column of the table move upwards until you find one of the extreme months noted. This month is presumed less important than those higher in the table and the year containing it is the test year.

Similar rules could be followed when all years have two or more marked months but this will occur only rarely.

Appendix 4

Estimated demand of work for establishing Reference Years

Estimate given March 1974 to the Scandinavian Committee for Building Codes (NKB). (Revised dec. 74).

The following is based on the experiences gained by establishing the Danish Reference Year. This work started medio 1971, and is terminated through publishing the report about the Reference Year and the magnetic data tape early 1974.

The estimate is based mainly on the work made in 1973, because what is made earlier must be considered as unsuccessful experiments. It is therefore assumed in the estimate that the experiences gained in Denmark are utilized as far as possible.

A practical way to have the job done could be in each country to establish a working group of specialists as follows, and with an estimated load for establishing one Reference Year (two Reference Years):

a. 1 project leader. 4 weeks. Administration, editing, publishing.

b. 1 meteorologist. 4 (6) weeks. General evaluation of the single months (criterium A), regionalising of stations, selection of basis station.

c. 1 computer specialist. 6 (7) weeks. Implementation of programmes at the actual computer, administration of job runs, correction of errors in data.

d. 1 HVAC specialist. 6 (8) weeks. Selection of basis station, critical survey of data, especially data for moisture, both for the original data material and for the selected months for the Reference Year.

Estimated computer time on a big computer (corresponding to e.g. IBM 370/165) 1 (1.3) hours.

The estimate is based on selection of the data for the Reference Year from a period of minimum 10 years, maximum 30 years, and further that methods for selection, for error-detecting and for interpolation can be taken over generally unchanged from the Danish project.

Hans Lund