

Methods of selection of the outdoor air design temperature and enthalpy in the warm period of the year

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Abstract. The RF requirements “Technical safety regulations of buildings and structures”, with regard to the room microclimate, provide maintenance of the air temperature and relative humidity at the levels, which are comfortable for people living and accommodation therein. An important technological and economic role in designing of the systems of maintenance of the required thermal microclimate shall be attributed to the design parameters of the outdoor environment, as they affect the installation capacity of the systems aimed at maintaining the specified environmental conditions, the size of these systems and the area allowed to them in the building. The article proposes an approach to selection of the outdoor air design temperature and enthalpy of the warm period of the year, based on the year-to-year cumulated availability coefficient. Currently, the design values of each parameter are selected on the basis of a certain number of hours in an average multi-year time section, during which higher values of this parameter may be observed. This causes in some years a longer unavailability of the microclimate internal parameters and, importantly, deviations of actual values of these parameters from the calculated ones, leading to a prolonged discomfort of people who are present in the premises. To justify the proposed approach to the selection of the outdoor environment design parameters, provision has been made of processing the data of urgent meteorological observations got at the meteorological stations of Moscow and Hanoi over a period of 30 years. It has been shown, that in some years the duration of the temperature unavailability, instead of 200 hours per year, reaches up to 830h in Moscow and 418 hours in Hanoi, and instead of 400 h - 1130h in Moscow and up to 692 hours in Hanoi. The outdoor air enthalpy unavailability duration makes even more. The got results allowed to recommend for selection of the outdoor air design parameters in the warm period of the year the same approach, which is adopted in the Russian Federation for the winter period: the cumulated availability coefficients from year to year of 0.98 for unique and critical buildings and 0.92 for all other residential and public buildings.

1. Introduction

The design parameters of the outdoor environment play an important technological role in designing of systems of the required thermal indoor microclimate maintenance, because they determine the installation capacity of the systems, their size, location in the building where these systems are located [1], [2], [3], [4]. In addition, the design parameters significantly affect the economic performance of the building, both during its construction and operation [5], [6], [7], [8], [9].

The existing approaches to selection of the outdoor air design parameters have been formulated mostly after the IInd World War in the 60-ies of the last century, when the essential problem was to



minimize capital investments due to weak economics. Nowadays, the State faces the target of a sharp rise of the economy by its reversal from a raw material oriented one to another type, including the digital development.

To do this, the economic losses from excessive parameters of the indoor environment, which occurred in some years due to an insufficient capacity of the microclimate maintenance systems in the premises, shall be minimized. In the further text we will focus on a different approach to the probabilistic availability of temperature and enthalpy of the outdoor air. As this article is pointed to the design parameters of the warm period of the year, then the safety shall be understood as the summarized probability that the values of the parameter under investigation will not exceed the design ones. When choosing the design parameters for the external environment, different approaches may be used to estimate their availability. One approach is focused on the "availability of time", which is considered as a portion of the total time period accepted for consideration, when the parameter data do not exceed the design values. This availability may also be measured by a number of hours [10], when a parameter data exceed the calculated values, i.e. being determined by the time of unavailability. Another approach is the "availability from year to year". In this case, availability is understood as a total probability that the data of the parameter, which have been selected in each year according to certain rules, will not exceed the calculated value. That is, availability is considered as a portion of the years taken into consideration, when the parameter data do not exceed the design value [11].

During the past years, in our country, the design parameters of the outdoor air of the warm period of the year have been given in SNIIP "Heating, ventilation and air conditioning". SNIIP II-33-75 normalized parameters of the outdoor air according to three grades: "A", "B", "C". Herein, the parameters "C" for the warm period of the year have been approaching to their absolute maximum values. The design temperature of the parameters "A" corresponded to the average temperature of the hottest month at 13 o'clock.

It was believed, that within a year the parameter values, which are higher than these ones of the design temperature and enthalpy, have been observed for 400 hours and less. The values of temperature and enthalpy of the outdoor air have been determined according to "B": parameters as the arithmetic average between the values of "A" and "C" parameters with some correction down to 1.5 – 2.5 °C. It was declared that higher values than the design temperature by "B" parameters did not occur more than 220 hours on average per year, and the enthalpy, which overpass those of the design ones, occur during not more than 200 hours [12]. However, detailed studies of this duration [13] showed its variation in the range of 85 – 100 hours for different inhabited localities of the USSR.

Currently, the Tables of the building rules SP 131.13330.2012 indicate the design values only of the temperature, and the values of enthalpy are presented on maps, which is very inconvenient to use. Design "B" parameters for the warm period of the year have been reduced and converted to the declared unavailability duration of 200 hours, which is not conducive to the operation efficiency of various civilian technologies. Thus, in the Russian Federation, for a long time the selection of the design temperature and the enthalpy of the outdoor air in the warm period of the year is subject to an approach, which is based on the availability of time, i.e. estimation of a particular value corresponding to a given unavailability duration or, what is the same, a certain availability coefficient of the average multi-year time section.

It is interesting to note, that Vietnam adopted a more rigid approach to selection of design parameters of the outdoor environment in warm and cold periods of the year. The design combination of the outdoor air temperature and enthalpy shall be selected by the joint availability of the parameters, which make the availability area of the joint monitoring of both parameters equal to the required one [14], [15].

2. Method of selection of the outdoor air design parameters for the warm period of the year

In this cold country, a consistent maintenance of the required indoor parameters in winter is a vital task. For the cold period of the year, the approach to the choice of the design temperatures is based on the year- to- year availability coefficient. The temperature of the coldest five days is determined every

year. After that, e.g. 8 five day periods with the lowest temperatures are deduced from one hundred ones, the following 9th five day period is considered as the design one with 0.92 availability. It means that during selection of the design temperature of the cold period, provision shall not be made of determination of the number of hours per year on average multi-year section with the lowest monitored values, but all efforts are aimed at keeping you warm in any cold year. The answers to the questions “why five days” and “why 0.92 availability” have been already got [16, 17]. These answers satisfy, in particular, economic considerations, as well.

Nowadays, the design values of the outdoor air parameters in the warm period of the year became more meaningful not only because of the climate warming, but also due to the fact, that there are plenty of industries and technologies in civil buildings with a significant excess heat [18, 19]. These include entertaining, educational, office, commercial and other buildings with a long and a mass stay of people, as well as the use of heat-emitting equipment. People, who are staying in these buildings, can't remain indifferent to the indoor air temperature and humidity, which exceed the required limits during the most part of summer. The computers suffer from shutdowns, it is impossible to work on them. We are aware of cases, when in 2010 within more than a month, the design institutes of Moscow forced their staff to take time off, 1 department per day, because of insufficiency of the electrical power supplied to the building for each operating designer's PC, as well as operation of the air cooling split systems in the rooms. This is despite the fact, that a lot of working places were vacant because of the summer holidays in all departments. Of course, 2010 was a year with unprecedented ambient air temperature in Moscow. It may not be given as an example. That is why it's much more interesting to see what happens in the other years.

Selection of rules, which establish the choice of the outdoor environment design parameters, shall consider not only the statistical frequency of certain combinations of the parameters, but also the influence of frequency of their appearance on the economic performance of buildings and technologies housed in these buildings.

The target of this work is to suggest a common approach to the selection of the design temperature and enthalpy of outdoor air. When establishing the levels of the parameter availability, this work bases on the existing or formerly valid standards concerning this subject. Such targets, in particular, include determination of the values of the outdoor air temperature and enthalpy, which enable the same availability from year to year, as in the cold period of the year. For the buildings to be designed according to special specifications it is recommended to take 0.98 year-to-year availability, and 0.92 for the most part of the other buildings.

At the same time, as a rule for the selection of the outdoor air parameter values in each year, provision has been made of their correspondence to the declared durations in the building rules SP 131.13330.2012. That is, 200 hours for "B" parameters (with the time availability of 0.97) and 400 hours (with the time availability of 0.95) for "A" parameters. The values of the parameters with circa 100 hour unavailability have been examined in addition, since they existed in the Russian building rules before, as well as those of 35 and 50 hour unavailability used for certain types of buildings in Vietnam.

The present work analyzed the values of temperature and relative humidity we could get in two cities on the basis of the data, which have been measured with a three-hour interval at the weather stations of Moscow from 1984 to 2011 of the VDNKh station [20], of Hanoi (Vietnam) in 1970 – 1990 and 2005 – 2014.

In tables 1 and 2, to the left of the line, there are given data of the outdoor air temperature and enthalpy for 10 years with the absolute maximum highest values of these years.

The values of each parameter are given in table with the time availability of a given year. The coefficients of time availability are correlated to the parameter unavailability durations listed in the tables. In the last rows for each city there is indication of the average long-term values of each parameter, i.e., parameter values that match a specified time availability in the average multiyear section (within the total time taken for consideration). To the right of the line there is indication of the number of unavailability hours of an average long-term value in the year under investigation.

Table 1. Values of the outdoor air temperature, °C, of different time availability for 10 years with the highest extreme temperature and the unavailability duration of the average multiyear temperature of a specified year

Years	Time availability coefficient					
	K1	K=0.996	K=0.994	K=0.989	K=0.97	K=0.95
	Unavailability duration per year, h					
	0	35	50	100	200	400
Moscow						
2010	37.9/297	35.7/360	35.2/444	33.8/608	31.6/830	29.2/113
1996	34.2/21	29.8/38	28.6/45	27.0/81	25.3/198	23.3/407
2007	33.5/83	31.6/96	31.2/128	29.4/213	27.4/358	24.9/593
2011	33.3/42	30.5/69	30.1/105	28.9/216	27.5/383	25.3/684
1988	33.1/19	29.7/37	29.0/59	27.7/131	26.4/292	24.3/526
1998	33.0/21	29.7/40	29.3/61	27.7/121	25.7/225	23.2/403
1999	32.8/47	30.7/72	30.1/119	29.0/234	27.8/387	25.2/632
2008	32.6/11	29.0/22	28.3/41	26.7/77	24.8/160	23.0/370
2001	32.5/37	30.6/54	29.8/79	28.2/135	26.2/275	24.2/522
2002	32.3/54	30.4/72	29.9/111	29.0/182	26.9/360	25.1/655
average	31.3	29.6	28.8	27.3	25.4	23.2
Hanoi						
2009	40.2	36.1/55	35.8/89	35.2/174	34.4/359	33.4/684
1983	40.0	37.4/95	36.8/123	35.7/192	34.5/320	33.1/565
2010	39.7	37.9/152	37.5/185	36.6/257	35.1/418	33.6/692
1987	39.1	36.3/54	35.9/74	34.9/137	34.1/267	32.8/509
1988	39.1	35.6/28	35.2/46	34.5/97	33.7/228	32.7/459
2013	39.0	35.9/38	35.5/58	34.4/92	33.5/193	32.4/401
1982	38.9	35.7/34	35.3/49	34.2/81	33.1/151	31.8/294
2011	38.7	35.4/26	35.2/41	34.6/105	33.7/222	32.5/403
2012	38.6	36.8/82	36.3/108	35.5/180	34.4/325	33.2/610
2014	38.2	36.1/96.5	35.7/67	34.9/133	34.0/259	32.8/502
average	37.9	35.8	35.4	34.6	33.6	32.4

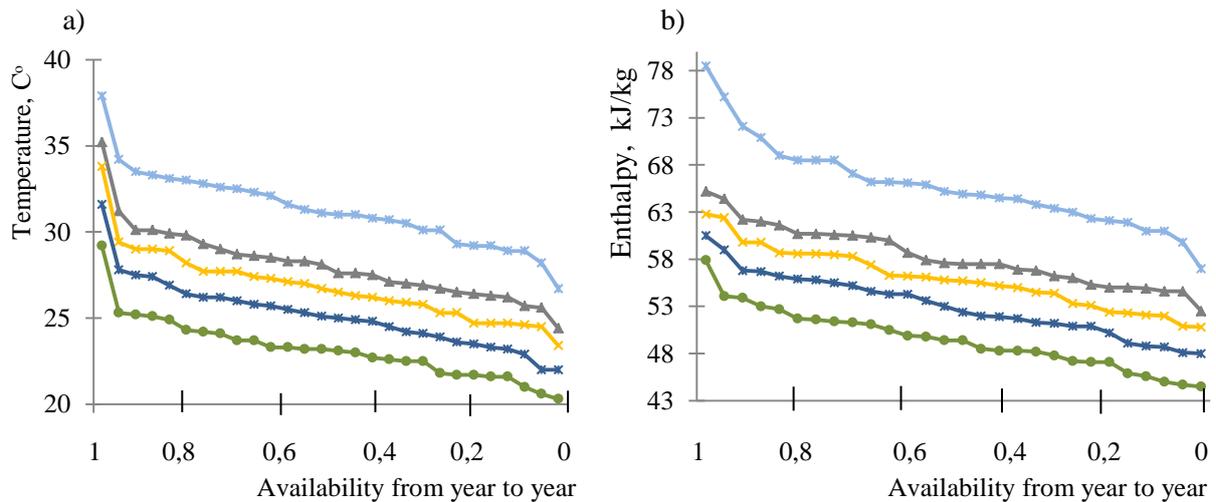
Table 2. Values of the outdoor air enthalpy, kJ/kg, various time availability within 10 years with the highest extreme enthalpy and unavailability duration of the long-term average enthalpy of a specified year

Years	Time availability coefficient					
	K=1	K=0.996	K=0.994	K=0.989	K=0.97	K=0.95
	Unavailability duration per year, h					
	0	35	50	100	200	400
Moscow						
2001	78.5/99	66.0/138	65.2/176	62.4/291	59.0/420	54.1/686
2010	75.2/166	65.2/192	64.4/269	62.8/469	60.5/743	57.9/1129
2007	72.1/48	63.4/79	62.2/109	59.8/189	56.7/350	53.0/628
1996	70.9/38	63.2/49	60.5/51	55.7/83	50.9/118	47.2/238
2008	69.0/41	63.4/64	62.0/81	58.6/141	55.5/259	50.5/434
2011	68.5/37	61.8/52	60.7/77	58.7/170	56.2/404	53.9/780
1991	68.5/36	62.5/49	60.6/68	57.4/111	54.6/230	49.4/378
1995	68.5/11	56.2/16	54.9/18	53.3/27	50.9/78	48.5/275
1990	67.1/9	57.5/18	54.6/26	50.9/39	48.0/51	44.5/135
2004	66.2/36	61.9/52	60.7/72	58.5/137	55.2/259	51.3/484
average	65.8	60.6	59.7	57.0	53.9	49.9

Continuation of Table 2						
Hanoi						
1981	130.3/89	102.4/96	98.6/112	95.0/152	91.1/212	88.3/372
1976	128.5/178	110.4/199	108.0/219	102.2/256	95.0/337	89.7/467
1984	116.5/54	97.4/60	95.9/77	93.3/120	90.7/199	88.4/370
2007	104.8/4	93.2/7	92.5/17	91.5/48	89.9/135	87.9/312
2013	103.5/26	95.4/38	94.5/51	93.0/119	91.4/259	89.4/497
1982	103.4/10	93.9/19	93.0/30	91.7/70	90.1/154	87.9/307
2014	102.6/0	96.5/109	96.1/175	95.3/325	93.9/583	92.0/951
2009	102.6/0	94.8/29	94.3/51	92.9/121	91.5/270	89.5/514
2010	102.5/0	96.7/72	95.7/95	94.2/236	93.0/451	91.2/781
1977	102.0/0	95.8/47	94.9/64	93.1/124	91.3/240	88.8/426
average	102.7	95.1	94.3	92.6	90.8	88.7

Figure 1 shows the graphs of the probability distribution functions, from year to year, of the maximum values of the outdoor air temperature and enthalpy with different time availability. These charts represent the growing rows of each parameter depending on the availability from year to year. As a 28 year row has been adopted for the city of Moscow, then each value is probable within 3.37 % of the years; for Hanoi the row makes 30 years, so each value is probable within 3.33 % of the years. The given charts show the variation of these parameters over the whole period, taken to consideration.

Noteworthy is the fact that in Hanoi the values of the outdoor air temperature and enthalpy are significantly higher than in Moscow. It is seen that, for example, the absolute maximum temperatures in Moscow in different years vary from 26.7 °C to 37.9 °C, the enthalpy maximum values change from 57 kJ/kg to 78.5 kJ/kg. In Hanoi the absolute maximum temperatures range from 36.0 °C to 40.2 °C, those of the enthalpy from 97.3 kJ/kg to 130 kJ/kg. These estimates indicate that in Moscow the temperature is subject to changes most of all, and in Hanoi – the outdoor air enthalpy. No matter which parameter value significantly changes from year to year, it is necessary to consider the probability of exceeding the outdoor air design parameter values in any year.



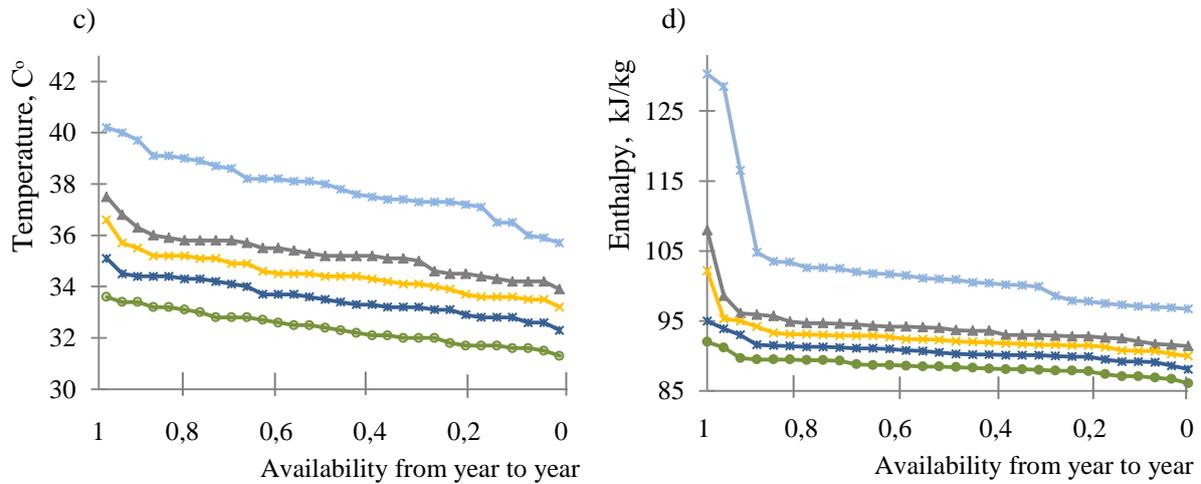


Figure 1. Distribution of probabilities of the outdoor air parameters, which meet the time availability, in the warm period of the year: — K=1; — K=0.994; — K=0.989; — K=0.977; — K=0.954
 a) temperature in Moscow b) enthalpy in Moscow; c) temperature in Hanoi; d) enthalpy in Hanoi

3. Results of selection of the design parameters and discussion

The table shows that neither in Moscow nor in Hanoi the presence of a high year parameter maximum does not guarantee its high values under different time availabilities. The highest values of temperature and enthalpy of the outdoor air are observed in different years. There are years when high values of the parameters greatly exceed the average long-term values of the same availability, but the monitoring time of these values is relatively short. There are also years with persistent high temperatures or the enthalpy of the outdoor air, though they are not the most extreme parameter values, but much higher than the multiyear average ones.

The question of whether to choose the design parameters based on the availability of each individual parameter or by a joint availability shall be left to economists. We note only, that the method of selection of the parameters by the joint security is more difficult, and the result of selection is more rigorous [15]. The results of selection by separate availability of the outdoor air parameters are given below.

To identify the design values of the temperature and the enthalpy, which meet the above requirements, the graphs of functions of the probability distribution of the maximum values of temperature and enthalpy of outdoor air with different time availability have been deprived of the values corresponding to year-to-year availabilities of 0.98 and 0.92 of the Table 3. The data of the Table 3 are compared with the valid design values of the outdoor air parameters. The actually valid design temperature of the outdoor air by “B” parameters is equal to 26 °C for the city of Moscow. When comparing this value with a temperature that meets the availability of 0.92 – 27.6 °C, there is an increase in the design value. This is due to the fact, that the proposed method takes into account the duration of the design temperature excess of the monitored values only of the "hottest" years. If we compare the design temperature of 29.1 °C, that meets a 100 h time unavailability, with a formerly normalized one of 28.5 °C, there the same dependence between them: when considering the availability from year to year, the design value rises. The building rules SNiP dated 1976 give “B” parameter values. For Moscow this temperature makes 38 °C and corresponds to the absolute maximum of 1 availability temperature, which is higher than all temperature values proposed for 0.98 year- to-year availability. It is interesting to note, that the designing of the museums, where provision shall be made of maintenance of the required optimal values of the outdoor air parameters and keeping the exhibits out of showcases, the design outdoor air temperature is taken equal to 35 °C. In the Table 3 it corresponds to 1 (time availability) and 0.98 (year- to- year availability).

Table 3. Values of the design temperature and enthalpy of the outdoor air with 0.92 and 0.98 year-to-year availability for Moscow and Hanoi

Availability from year to year	Time availability coefficient					
	$K=1$	$K=0.996$	$K=0.994$	$K=0.989$	$K=0.97$	$K=0.95$
	The year average unavailability duration, h					
	0	35	50	100	200	400
Moscow						
Design temperature, °C						
0.98	35.1	32.5	32.0	30.3	28.8	25.6
0.92	33.8	31.2	30.6	29.1	27.6	25.2
Design enthalpy, kJ/kg						
0.98	76.1	65.4	64.2	62.1	59.6	55.7
0.92	72.1	64.3	63.2	59.8	57.8	53.2
Hanoi						
Design temperature, °C						
0.98	40.0	37.6	37.1	36.1	34.6	33.4
0.92	39.8	37.3	36.6	35.6	34.3	33.2
Design enthalpy, kJ/kg						
0.98	129.3	105.0	101.0	96.5	94.2	91.5
0.92	124.5	101.3	97.3	95.0	93.4	90.9

With regard to the outdoor air enthalpy, it made 69.9 kJ/kg for “B” parameters, which is below the absolute maximum even with 0.92 year-to-year availability. The enthalpy of 68 kJ/kg is taken for designing of the museums. The designers justify the accepted level of the design temperature and enthalpy by the argument, that it shall be done "at the request of the customer", and don't bear in mind how often these parameter values are observed. For “B” parameters (200 hours of unavailability) the enthalpy given in SNiP dated 1976 and 1985 was taken equal to 54 kJ/kg, and for “A” parameters – 49.4 kJ/kg. As it is seen, these values are below those given in the Table 3, even at 0.92 year-to-year availability. The above relation of suggested values to the really used ones may be explained by the fact, that the SNiP of the previous years used as “B” parameters not the highest enthalpy but this one, which had been the highest during observation of the highest temperature. To justify the proposed values of the enthalpy, it should be noted that the meteorological observation data, which have been subject to investigations [20], include the following temperature-enthalpy combinations: 37.9 °C – 75.2 kJ/kg; 34.2 °C– 70.2 kJ/kg; 33.5 °C – 72.1 kJ/kg.

Thus, the proposed values of the outdoor air design parameters reflect quite accurately the recurrent probabilistic correlation of some values of the outdoor environment parameters. In the future, it is desirable to perform an economic evaluation of the design temperature and enthalpy of the outdoor air.

4. Conclusions

1. Since in some years the unavailability duration of individual values of temperature and enthalpy may differ very much from each other, the choice of the outdoor air design parameter values shall take into account their availability from year to year.
2. Processing of meteorological data shall be preferably carried out according to the results of the hourly measurements as for duration of the period under review not less than 30 years, otherwise, if the meteorological information has been obtained by the measurements with a three-hour interval, some parameter values, including the extreme ones, will be lost. In addition, the probability distribution function of a meteorological parameter value doesn't become smooth.
3. An increase in the design values of the outdoor air temperature and enthalpy will help to reduce the unavailability duration of the inner environment parameters in some years and to low the values of

excess of these inner environment parameters during observations of the outdoor air temperature and enthalpy, which are higher than the design values.

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