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Microclimate within the National Institute of Meteorology and Hydrology Archive Repository during the Warm Half-Year

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Abstract. Climatic changes observed in the last few decades have an adverse effect on microclimatic conditions within premises of libraries, art gallery repositories and museum storages, as well as in archive repositories within governmental and public institutional buildings. The registered outdoor air temperature increase leads to raising of premises indoor air temperature, too. More and more frequently internal air temperature overreaches the appropriate values for safe and sustainable safekeeping of archive collections. Because of that maintaining of suitable and stable air temperature and humidity conditions are of crucial importance for long lasting and correctly archive units storing within storage rooms. In contrast, any disturbance of stability at microclimatic conditions within premises leads to more rapid structural deterioration of stored archive units. Based on an experiment carried out in the premise of meteorological archive of the National Institute of Meteorology and Hydrology (NIMH) the temperature and humidity conditions during the warm half-year (19.05–30.11.2003) were investigated. Peculiarities in the diurnal course (of hourly values) and monthly course (of the average diurnal values) of air temperature, relative humidity, moisture content and enthalpy in the NIMH archive repository on the background of those of the environment were investigated. Dependencies between average diurnal values of the outside air parameters and those inside the NIMH building (air temperature, relative humidity, air moisture content and enthalpy within the premise) were obtained as well.

KEY WORDS: climatic changes, microclimate within buildings, archive repositories, temperature and humidity conditions into the archive premises.

1 Introduction

Maintaining of a suitable and stable microclimatic regime within archive repositories premises in public buildings is of mainly importance for the long lasting storage of archive units in appropriate condition. The microclimate within

archive repositories is formed under the influence of external meteorological factors, construction (technical) parameters of buildings and internal heat and moisture emissions in the premises, caused by different origins (heat from lighting devices, moisture emissions from service personnel, etc.). Due to the fact that buildings technical parameters remains constant after its construction finished, the external meteorological factors play an essential role of microclimate formation within the archive repositories premises. Additionally within the buildings, during winter months, in order to reduce outdoor environment adverse influence, various technical equipments (central heating, air conditioning systems, etc.) are used. In contrary, neglecting of regulatory requirements regarding microclimatic conditions in archival repositories causes to occurrence of irreversible deformations of the materials from which the archival units are made, to the appearance of microbiological structures (molds, fungi, etc.) and their premature aging. On the other hand climate changes that are observed at last few decades also leads to change of the climatic conditions in our country, in Sofia respectively, and at the cryptoclimate within such type of special premises as well. The comparative analysis carried out for external air temperatures for two climatic periods 1961–1990 and 1991–2020 showed that the temperature norm for Sofia during the warm half-year in the second period has increased by 1.2°C compared to the first one period. Regarding to the air relative humidity, no significant changes in the norm for the two periods is observed. That means – the external environment in our capital Sofia is changing and getting warmer because of climate change, as in the same time the relative humidity is changing insignificantly.

2 Cryptoclimate of the NIMH Archive Repository

The main meteorological factors that form the microclimate in buildings (cryptoclimate) are the temperature and humidity of the outside air, speed and direction of the wind (cooling effect due to the ventilation of the building), solar radiation falling on the facades and penetrating within the premises through the windows. Additionally to this impact, it is added the influence of heating and air conditioning systems, which, however, consumes an additional significant amount of energy. So that the building design and its optimal exploitation are again directly dependents on the microclimatic features of the place where the building is located. However, adverse climatic changes can significantly decrease the building's energy efficiency, complicate the operation of these systems and increase the costs of maintaining a suitable and stable microclimate within buildings.

2.1 Aim of the study

The main goal of present study is to determine the actual temperature-humidity conditions within the archive storage of National Institute of Meteorology and Hydrology (NIMH), caused by changes of external weather conditions nowa-

days. Modern climate models show that in the not-too-distant future, winters in our country are expected to be warmer and with a under normal amount of snow cover, as in the same time the summers will generally have more hot days and longer dry periods. All this changes in the background of more frequent observation of extreme weather events – intense rainfall, powerful storms and prolonged heat waves. The comparative weather analysis carried out for the warm half-year during the experiment showed that the experimental period (May–November 2003) was with 1.6°C warmer than the norm for these warm half-year months based on data from the period 1961–1990, and with relative humidity of 68% which is around the normal value. The summer of 2003 was warmer with 2.7°C above respective normal and with relative humidity around the normal (only 2% below this one for the period 1961–1990). This fact allows us to consider the experimental period as informative one for future warm half-years (and especially for the summer), caused by current climate change.

2.2 Experimental data

The period of the experimental work carried out, within the premise of NIMH archive storage includes the warm half-year of 2003 (from May till the end of November). The measurements were carried out daily (three times a day) during the working hours of the archive storage premise, and during the rest of the time the data from self-recording devices in the premise were used, which allowed us to obtain information about the continuous diurnal (24-hour) course of the indoor air temperature and its relative humidity. The measurements of air temperature and relative humidity were carried out with aspiration psychrometer GOST 6353-52 type and self-recording thermograph (with a bimetallic plate) and hygrograph, both located at a representative place in the archive storage premise. The meteorological information about the outside air was obtained from the hourly synoptic observations (at every three hours) at the Central Meteorological Station – Sofia, again for all these months of warm half-year (May-November 2003). The data for air temperature and relative humidity, atmospheric pressure and partial pressure of water vapor were used. This allowed us to calculate moisture content and enthalpy (heat content) of the outdoor air in Sofia during the period of experiment.

2.3 About the building where archive repositories premises is located

The archive storage premise of NIMH is located within the central building of the institute and is situated on its first floor. The building was built in 1976 and represents a massive, monolithic and reinforced concrete structure, with brick external walls. The archive room has a floor on the ground and its roof is of flat warm type. The orientation of the main facade of the archive room is ESE, and it is glazed with a compact double-glazed window, with wooden frames. The building, and in particular the archive repository premise, was not designed specifically for an archive, at in this case its multi-functionality is used.

2.4 Air temperature during the experiment

The analysis carried out of the collected experimental data showed that the average hourly values of the outdoor air temperature (averaged for respective month) varied in range from 3.9°C (in November) to 28.6°C (in August) during these experimental months of 2003. At the same time, the average diurnal (24 hours) values of the outdoor air temperature varied between 0.4°C (November 14) and 26.7°C (August 30). The comparative analysis showed that the average monthly values of outdoor air temperature during the warm half-year of 2003 were higher than the normal (for months from May to August and in November, Table 1 and Table 2), with up to 3.2°C deviation (August and June). The autumn was relatively cold with temperature values close to normal (1961-1990), but under them with deviation up to 0.8°C in September (Table 1 and Table 2). This allows us to characterize these months of the experiment period as quite warm in terms of temperature. These environmental parameters influenced the microclimate in the archive premise during the 2003 experiment.

Table 1. External air 1961–1990 climatic norms for temperature (T_N, °C) and relative humidity (f_N, %)

Month	**May**	**June**	**July**	**August**	**September**	**October**	**November**
T_N	14.7	17.8	19.8	19.5	16.1	10.7	5.1
f_N	67	67	63	62	65	69	77

The air temperature in the premises of the buildings is one of the main parameters of the microclimate within them. The mode of its change mainly determines how comfortable and appropriate for safekeeping of archive items the microclimate in buildings is. According to the Bulgarian building legislation and Regulations for storage of public archival collections [1], the air temperature during the warm half-year within archival repositories, where paper documents are collected must be in the range of 16.0°C to 18.0°C.

For the correct and long-lasting storage of the archival units, the stability of the microclimate within the archival premises is of crucial importance as well.

Table 2. Average monthly values of temperature (T_{out}, °C), relative humidity (f_{out}, %), moisture content (d_{out}, g/kg) and enthalpy (i_{out}, kJ/kg) of the external air during 2003

Month	**May**	**June**	**July**	**August**	**September**	**October**	**November**
T_{out}	17.7	21.0	21.5	22.7	15.3	10.3	6.6
f_{out}	66	67	60	59	67	77	81
d_{out}	8.5	10.9	10.0	10.2	7.5	6.4	5.3
i_{out}	36.2	45.4	46.9	48.7	34.4	26.6	20.0

2.4.1 Air temperature in the NIMH archive

The analysis of the collected experimental data showed that the mean hourly values (averaged for respective month) of the indoor air temperature in the archive repository (T, °C) varied in the range of 15.9°C (in November) to 23.8°C (in August) during these warm half-year of the experimental year 2003. Their average diurnal values varied between 13.8°C (October 17) and 24.5°C (July 2 and 25) from the experimental period. From the chart presented for June 2003 (Figure 1), it can be seen that the amplitude of air temperature fluctuations within this room is very small (about 1.0°C). The diurnal course in the room is highly smoothed and with a very small diurnal amplitude (Figure 1) – the temperature regime meets the requirements for stability within a similar type of premises [1] – with a deviation from the average values up to 1°C within a day. In Table 3 the average monthly values of temperature, relative humidity, moisture content and heat content (enthalpy) of the internal air during 2003 experiment are shown. The chart of the course of average diurnal values of the temperature (Figure 2) shows that the course during the month in the archive repository generally follows that one of the temperature of the outside air.

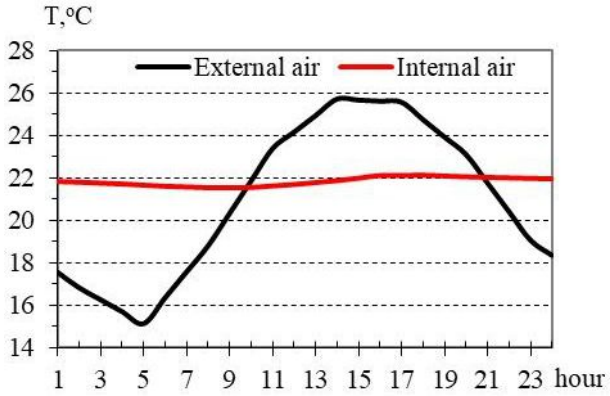

Figure 1. Diurnal course of the air temperature (T, °C) within NIMH archive, June.

Table 3. Average monthly values of temperature (T_{int}, °C) and relative humidity (f_{int}, %), moisture content (d_{int}, g/kg) and entalphy (i_{int}, kJ/kg) of the internal air during 2003

Month	**May**	**June**	**July**	**August**	**September**	**October**	**November**
T_{int}	18.4	21.8	23.2	23.6	20.2	17.2	16.4
f_{int}	59	60	55	54	51	53	54
d_{int}	8.3	10.4	10.4	10.5	8.1	7.0	6.7
i_{int}	39.6	48.5	49.7	50.5	40.8	35.1	33.4

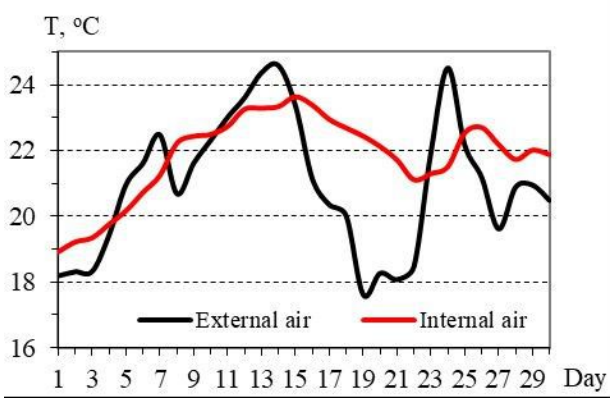

Figure 2. Average diurnal values of air temperature (T, °C) within NIMH archive, June.

2.5 Relative air humidity during the experiment

Conducted primordial analysis of the external air relative humidity data, received by Central Meteorological Station in Sofia showed that its mean hourly values (averaged for respective month) varied in the range from 38% (in August) to 90% (in November) during these warm half-year of 2003. The average diurnal values of this meteorological parameter for outdoor air varied between 43% (August 14) and 97% (October 16 and 17, November 4). The average monthly values of outdoor air relative humidity were around the norm during this experimental period (Table 1 and Table 2). They show that during July and August 2003 they were around 3% below the month normal for the period 1961-1990 (i.e. relatively dry summer), and above the normal during the autumn (especially in October and November). These environmental humidity conditions have an influence on the microclimate within the NIMH archive repository during the experimental year 2003. According to the Bulgarian building legislation and Regulations for safekeeping of public archival collections [1], air relative humidity during the warm half-year within archival repositories, where paper documents are collected must be in the range of 45% to 55%.

2.5.1 Relative humidity within the NIMH archive

The comparative analysis carried out of experimental data showed that the relative humidity of the indoor air (f, %) in the archive repository (averaged hourly values) varied in the range from 51% (in September) to 61% (in June) during the experiment. The average diurnal values of relative humidity of the air within this premise varied between 46% (September 4) and 66% (November 29) during the experimental period of 2003 warm half-year.

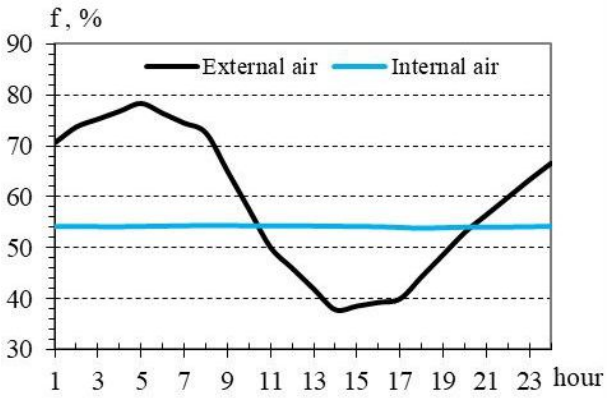

Figure 3. Diurnal course of the air relative humidity (f, %) within NIMH archive, August.

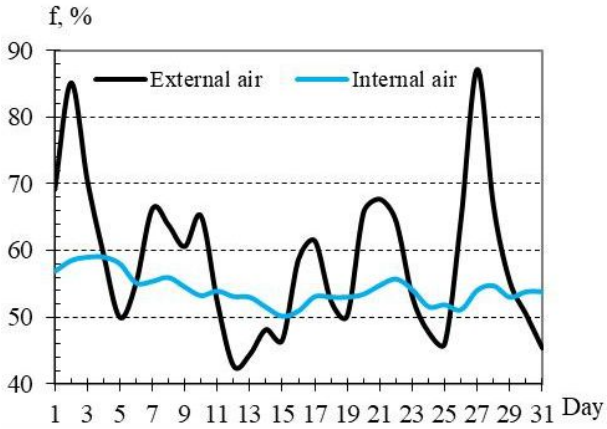

Figure 4. Average diurnal values of air relative humidity (f, %) within NIMH archive – August.

From the presented chart (Figure 3) it can be seen that amplitude in the fluctuations of air relative humidity values (averaged hourly values for respective month) is insignificant (around 1%). The chart for course of relative humidity average diurnal values during the month (Figure 4) shows that this one within the archive repository generally follows that one of the relative humidity of the outside air as well as their fluctuations are smaller. The average monthly values of relative humidity for indoor air are above the required normative interval during May and June (Table 3) and they are within it during the other months of experimental period. According to the regulatory requirements, the relative humidity of the indoor air in archive repositories has to be from 45% to 55% [1].

2.6 Moisture content of the air during the experiment

The air moisture content (d, g/kg) represents a ratio of the mass of water vapor contained in it to the mass of dry air and is determined by the formula [2]:

$$d = \frac{R_d}{R_V}\left(\frac{e}{p-e}\right) \times 10^3, \tag{1}$$

where R_d [3–5] is the gas constant of dry air (287.0529 J/kg K), R_V (462 J/kg K) is the gas constant of water vapor, p (mbar) is the atmospheric pressure, and e (mbar) is the partial pressure of water vapor in the air. Averaged for respective month hourly values for outdoor air moisture content during the 2003 experiment ranges from 4.9 g/kg (in November) to 11.5 g/kg (in June). These one for the air within archive repository changes from 6.4 g/kg (in November) to 10.7 g/kg (in July and August). The average diurnal values of moisture content of the air outside varied from 2.8 g/kg (November 12) to 13.2 g/kg (June 15), for the air inside the archive repository – from 5.3 g/kg (October 20) to 12.6 g/kg (July 3 and 4). The average monthly values of moisture content of the air outside changes from 5.3 g/kg (in November, Table 2) to 10.9 g/kg (in June), for the archive repository – from 6.7 g/kg (in November, Table 3) to 10.5 g/kg (in August). The analysis shows that the average values of air moisture content for the entire experimental period were 8.4 g/kg for the outside air and 8.8 g/kg in the archive premise. From the chart of the diurnal course of moisture content hourly values in the premise in October 2003. (Figure 5) it can be seen that course within repository is smoother and of smaller amplitude (about 0.4 g/kg). The chart for the course of moisture content average diurnal values (Figure 6) shows that the course in the archive repository generally follows that of the moisture content of the outside air.

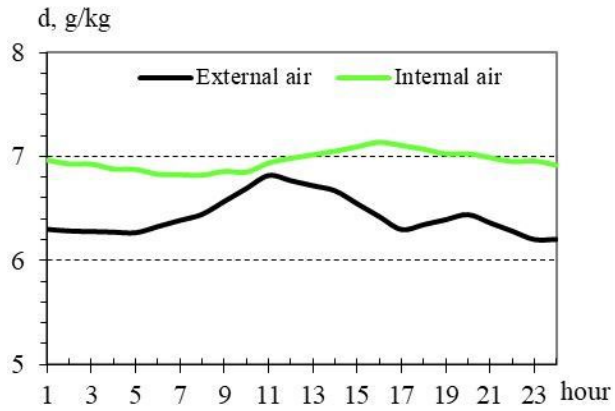

Figure 5. Diurnal course of moisture content of the air (d, g/kg) within NIMH archive – October 2003.

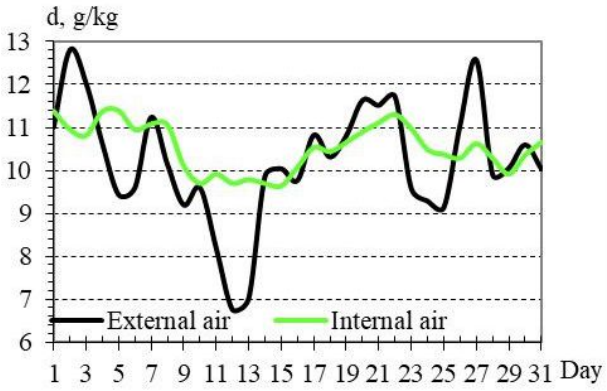

Figure 6. Average diurnal values of air moisture content (d, g/kg) within NIMH archive – August.

2.7 Enthalpy of the air during the experiment

Enthalpy (heat content) of the air is a complex parameter that takes into account the fact that moist air contains additional and hidden heat of phase transitions from the water vapor in it (heat of condensation). The enthalpy of air (i, kJ/kg) is a thermodynamic function of state, representing the sum of internal energy of the gas and work done by it during isobaric expansion to the occupied volume. The heat content of the air can be calculated according to the formula [2]:

$$i = c_p T + (L + c_n T) d \times 10^{-3}\,, \tag{2}$$

where c_p is the specific heat capacity of dry air [6] at constant pressure (1.005 kJ/kg K), c_n – the specific heat capacity of water vapor (0.716 kJ/kg K) in the air at a saturation pressure and temperature 0°C, L [7] – latent heat of vaporization (2500.9 kJ/kg) at 0°C, d – the moisture content of the air (g/kg), and T (°C) the temperature of atmospheric air. The average monthly values of outside air enthalpy are changed from 20.0 kJ/kg (in November, Table 2) to 48.7 kJ/kg (in August) and this within the archive repository – from 33.4 kJ/kg (in November) to 50.5 kJ/kg (in August, Table 3). The average value of the air enthalpy for the period of the experiment are as follows: for the outdoor air – 36.9 kJ/kg and for the one in the NIMH archive repository – 42.5 kJ/kg. Averaged for respective month hourly outdoor air enthalpy values during the 2003 experiment ranged from 16.3 kJ/kg (in November) to 53.2 kJ/kg (in August). These one for the air within NIMH archive repository from 32.3 kJ/kg (in November) to 51.0 kJ/kg (in August). The average diurnal values of the enthalpy of the air outside varied from 7.6 kJ/kg (November 12) to 55.4 kJ/kg (July 3), those of the air inside archive repository – from 27.3 kJ/kg (October 18) to 56.7 kJ/kg (July 3).

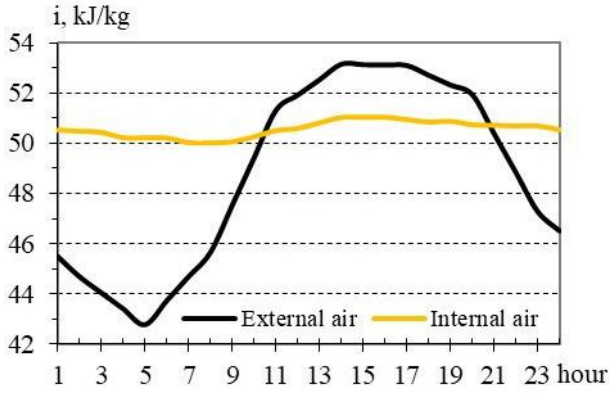

Figure 7. Diurnal course of enthalpy of the air (i, kJ/kg) within NIMH archive – August.

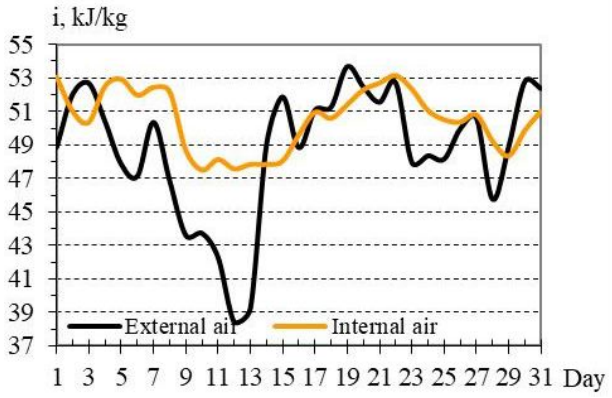

Figure 8. Average diurnal values of air enthalpy (i, kJ/kg) within NIMH archive - August.

From the chart for the air enthalpy daily course within the NIMH archive premise in August 2003 (Figure 7) it can be seen that this one within the repository is smoother and with smaller amplitude (about 2.0 kJ/kg). The chart of the course for average diurnal values of air heat content (Figure 8) shows that the course during the month in the NIMH archive generally follows that of the enthalpy of the outside air.

2.8 Relations between external air parameters and this within archive

Based on the experimental data and research carried out within NIMH archive, a diagnostic of the microclimate air parameters in the premise is made, as the first stage of the analysis.

However, meteorological information about the parameters of the outside air is

significantly more accessible and it is obtained regularly and daily, that is why, as a continuation of the research, a connection between the parameters of the outside air and those of the air in NIMH archive is found out, based on the collected experimental data. As the second step of analysis, the dependences were obtained between average diurnal values for various meteorological parameters of external air and this in the premise of the NIMH archive – for the temperature and relative humidity of the air, its moisture content and the enthalpy of the air in the building. They have a diagnostic character and allow to calculate these parameters of the air in the archive premise based on the average diurnal values of various meteorological parameters of the outside air. A linear regression dependence between outdoor air temperature and indoor air one of the NIMH archive repository was found out. They allow us using parameters of the outside air (they can be measured and predicted) to calculate the expected parameters (if the predicted temperature outside is used with phase lag of 2 days) of the indoor air. Its type for the average diurnal air temperature values in the archive repository is:

$$T_{\text{int}} = a_t T_{\text{out}} + b_t \,, \tag{3}$$

where $a_t = 0.42 \pm 0.01$, $b_t = 13.43 \pm 0.22$, at very high positive correlation with a Pearson correlation coefficient ($r = 0.928$) and confidence interval for r (CI; 0.924, 0.932) at confidence level (CL, 0.95; i.e. $\alpha = 0.05$). The analysis carried out show that the correlation coefficient is statistically significant at significance level $\alpha = 0.05$. Figure 9 presents a chart of average diurnal air temperature values calculated based on this dependency within the archive premise. In it, the measured value of the air temperature in the archive repository is marked with black and with red line – the average diurnal values calculated according to the obtained dependency. The very good coincidence of measured and calculated

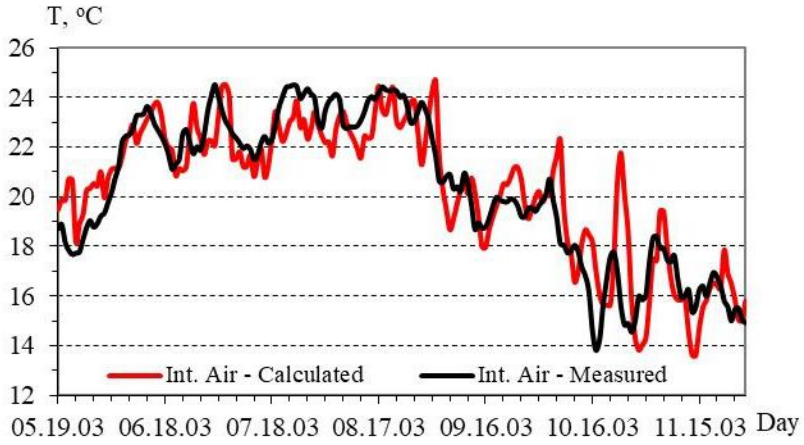

Figure 9. Average diurnal values of air temperature (T, °C) within NIMH archive.

values of the air temperature in the archive storage can be seen.

A diagnostic relationship, between the average diurnal values of outdoor air relative humidity and the relative humidity of the air in the premise of the NIMH archive is found out, as follow:

$$f_{\text{int}} = a_f f_{\text{out}} + b_f \,, \tag{4}$$

where $a_f = 0.15 \pm 0.03$, $b_f = 45.64 \pm 2.21$, with phase lag of one day and moderate positive correlation ($r = 0.373$) with CI (0.364, 0.382) at $\alpha = 0.05$. The analysis carried out show that the correlation coefficient is statistically significant at significance level $\alpha = 0.05$. Figure 10 shows the chart of air relative humidity average diurnal values within the NIMH archive premise, calculated according to this dependency. On this figure with black line are represented measured values of the relative humidity of the air in the archive repository and with blue line - the average diurnal values calculated according to the obtained dependency. From this figure can be seen that calculated values of air relative humidity roughly fitted in the measured values and they described only in average humidity regime of this premise.

A diagnostic dependency between average diurnal values of moisture content of external and internal air was found out. It allows us to calculate the moisture content of internal air, based on the same parameter of the outside air, as follow:

$$d_{\text{int}} = a_d d_{\text{out}} + b_d \,, \tag{5}$$

where $a_d = 0.67 \pm 0.02$, $b_d = 3.16 \pm 0.20$, with phase lag of one day and very high positive correlation for the archive one with a correlation coefficient ($r = 0.907$) and CI (0.903, 0.911) at $\alpha = 0.05$. The analysis carried out show that the correlation coefficient is statistically significant at significance level $\alpha = 0.05$.

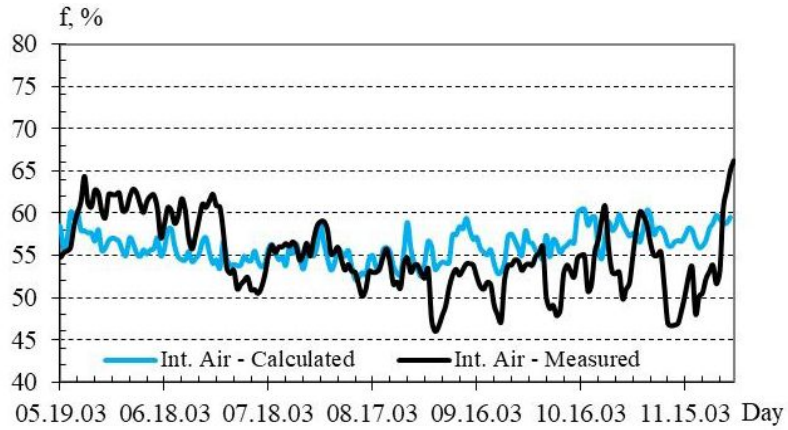

Figure 10. Average diurnal values of air relative humidity (f, %) within NIMH archive.

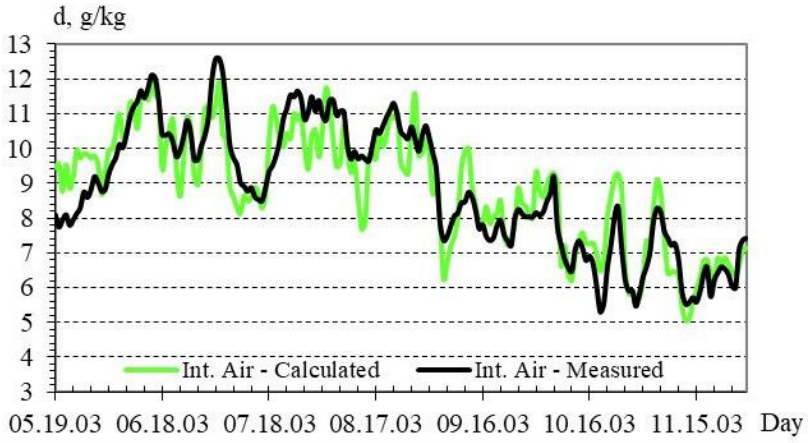

Figure 11. Average diurnal values of air moisture content (d, g/kg) within NIMH archive.

Figure 11 shows a chart of air moisture content average diurnal values within the archive repository calculated based on this dependency. On this chart with black line are represented the values of moisture content of the air measured within the archive premise and with green one - the average diurnal values calculated according to the obtained dependence. A good coincidence between measured and calculated average diurnal values of the moisture content within the NIMH archive can be seen (Figure 11).

A diagnostic relation between the average diurnal values of outdoor air enthalpy and the indoor air enthalpy of the NIMH archive repository is found out.

It allows us to calculate heat content (enthalpy) values of the air within the premise based on this of the external air heat content:

$$i_{\text{int}} = a_i i_{\text{out}} + b_i \,, \tag{6}$$

where $a_i = 0.59 \pm 0.02$, $b_i = 21.05 \pm 0.67$, with phase lag of 1 day at very high positive correlation for the archive with a correlation coefficient ($r = 0.926$) and CI (0.922, 0.930) at $\alpha = 0.05$. The analysis carried out shows that the correlation coefficient is statistically significant at significance level $\alpha = 0.05$. Figure 12 represents a chart of the air enthalpy average diurnal values, calculated based on this dependency in the archive repository of NIMH. On it, the values of air enthalpy calculated from the experimental data in the archive premise are shown with black line and the average diurnal values calculated according to the obtained dependency – with orange one. This figure shows very good coincidence between measured and calculated mean diurnal values of air enthalpy within NIMH archive repository.

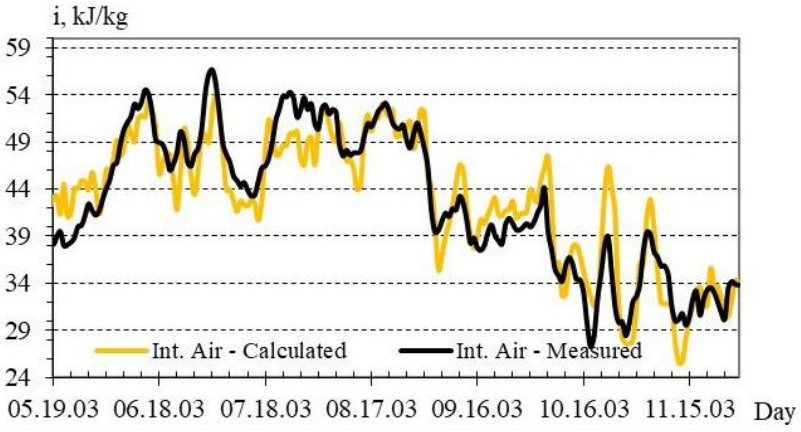

Figure 12. Average diurnal values of air enthalpy (i, kJ/kg) within NIMH archive.

3 Conclusions

As a result, from the analysis of collected data from experiment during the warm half-year of 2003 within the premise of NIMH archive repository, as well as from the calculations carried out, we can summarize obtained information, as follow:

Analysis for whole warm half-year during the experiment shows that the experimental period (May–November) was with 1.6°C warmer than the climatic normal for this time of the year, based on data from the period 1961–1990 and this allows us to consider this period as a representative of the warm half-years expected in the future for Sofia region.

The indoor air temperature hourly values (averaged for respective month) within the NIMH archive repository during the experimental period have varied from 15.9°C up to 23.8°C, as in the same time their values required for long lasting safekeeping are between 16.0°C and 18.0°C.

The relative humidity mean hourly values of the indoor air within archive premise have varied from 51% to 61% during the experimental months, as per the National Regulations and Ordinances their values have to be between 45% to 55%.

In the case of the NIMH archive premise, the average hourly values of temperature for the warm half-year during the main part of experiment are above the 18°C limit (from June to September, i.e. for Summer and beginning of Autumn), and they are within the required range only in May (Spring), October and November 2003 (last part of Autumn).

The air relative humidity is above the required upper limit of 55% at the beginning of the warm half-year (May, June) and it is within the required interval during the rest of the experimental time.

With purpose of safe and long-lasting storage of archival units within the archival repository of NIMH in good condition, it is strongly recommended to install a suitable designed air conditioning system in the premise (here the calculations of moisture content and heat content of the air with archive will be very helpful for its design). It is recommend to install and use permanently a pair of devices for measurement of the temperature and relative humidity of the air within the NIMH archive premise, with purpose of better control of microclimate parameters here as well.

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