Frequency of occurrence of a certain air temperature at various sites in the Czech Republic

V. Šleger, P. Neuberger

Faculty of Engineering, Czech University of Life Science Prague, Prague, Czech Republic

Abstract

Šleger V., Neuberger P., 2010. **Frequency of occurrence of a certain air temperature at various sites in the Czech Republic**. Res. Agr. Eng., *56*: 127–137.

The present paper analyses the problem of calculation of the average number of hours in a year during which air temperature is lower than a preselected limiting level. A method for estimating the number of hours in situations where only the minimum, average, and maximum daily temperature data are available has been suggested and tested. The work encompassed 30 sites in the Czech Republic at different altitudes and with different average temperatures, using weather data from the 1961–2000 period. The results are presented in the tabular form. It is shown that interdependence exists between the number of hours with temperatures lower than a preselected limiting level and the average yearly temperature at the specific site. For instance, temperatures below 15°C during a typical year at a site with an average yearly temperature θ_{yr} (°C) within the range of 2.8°C to 9°C can be expected (coefficient of determination 0.986) for a time τ (h) calculated from the quadratic equation $\tau = -12.992 \times \theta_{yr}^{2} - 116.6 \times \theta_{yr} + 8{,}483$.

Keywords: climatic conditions; weather data; altitude; regression function

Climatic conditions at a site are among important input parameters when assessing the efficiency and effectiveness of an heating/cooling facility at that site. Air temperature data are particularly relevant in this context (Šleger et al. 2009).

Design climatic conditions for the Czech Republic can be found, e.g., in the Czech/European Standard ČSN EN 12831 (2005) or in the ASHRAE Handbook – Fundamentals (2005), summarizing data collected from 4,422 stations especially in the USA and Canada, as well as from other countries worldwide. However, the data have been compiled based on old or short measuring series and do not match each other enough from the time and/or space aspects. Although not impossible, collecting new and, at the same time, long-run and detailed data from the Czech Hydrometeorological Institute (Prague) would be a very expensive project, requiring the processing of a large volume of data, which are often difficult to obtain.

The present paper analyses the problem of calculation of the average number of hours in a year during which air temperature is lower than a preselected limiting level. The work encompassed 30 sites in the Czech Republic at different altitudes and with different average temperatures, using weather data from the 1961–2000 period.

MATERIAL AND METHODS

Climatic conditions at specific areas were assessed based on daily meteorological data over the period from January 1, 1961 to December 31, 2000, obtained from the non-governmental organization "National

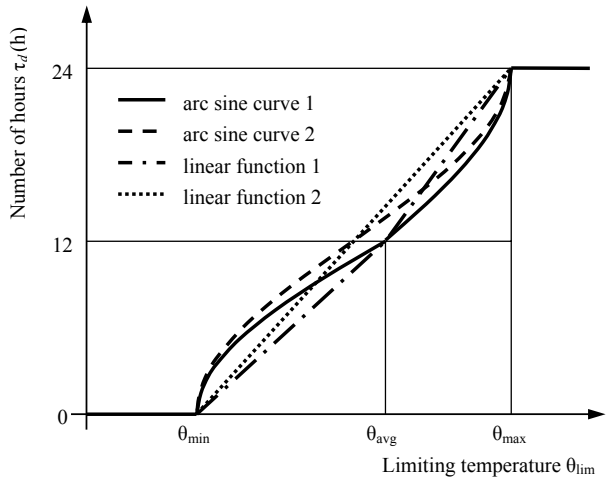

Fig. 1. Four methods for estimating the number of hours with temperatures lower than a predefined limiting level during a day

Climate Programme for the Czech Republic" (NKP). The maximum, minimum, and average daily temperatures collected from 30 weather stations are available in the electronic format. The maximum and minimum daily air temperatures were determined by using extreme thermometers. The average daily temperature was calculated from data measured in predetermined time points (at 7 a.m., at 2 p.m., and at 9 p.m.).

Weather stations performing continuous measurements at fixed sites (as far as possible) were selected. All of them lie within the Czech Republic between 48.8° and 50.8° north latitude at altitudes from 158 to 1,324 m.

Considering a typical temperature development during the day (Květoň 2001), the number of hours during which air temperature is lower than the predetermined limiting level can be estimated. Now, if the limiting temperature is higher than the maximum daily temperature, air temperature is lower than the limiting level for 24 h of the day, whereas if the limiting temperature is lower than the minimum daily temperature, air temperature is never lower than the limiting level that day.

A problem only occurs if the limiting level lies between the maximum and minimum daily temperatures. It is suggested that the actual interdependence between the number of hours with lower temperatures during the day τ_d (h) and the limiting temperature θ_{lim} (°C) lying within this range can be fitted with 4 different functions defined in Table 1, as shown in Fig. 1.

In 2 variants, see arc sine curve 2 and linear function 2, the number of hours with temperatures lower than the limiting level is calculated based on the minimum θ_{min} (°C) and maximum θ_{max} (°C) daily temperatures solely, whereas in the other 2 variants, i.e. arc sine curve 1 and linear function 1, the average daily temperature θ_{avg} (°C) is also taken into account and it is assumed that temperatures lower than the average level occur for 12 h during the day.

The four functions were tested on data of 2005, a year for which hourly air temperature data collected by the weather station at the Czech University of Life Sciences in Prague (Czech Republic) are available at http://meteostanice.agrobiologie.cz.

The function with the lowest absolute and relative errors was then used to calculate the number of hours with temperatures lower than 55 selected limiting levels (from –21°C to 33°C) over the entire

Table 1. Definition of the functions suggested

Estimate variant	Relationship validity range	
	$\theta_{min} \le \theta_{lim} \le \theta_{avg}$	$\theta_{avg} < \theta_{lim} \le \theta_{max}$
Arc sine curve 1	$\tau_d = \frac{24}{\pi} \times \arcsin\left(\frac{\theta_{lim} - \theta_{avg}}{\theta_{avg} - \theta_{min}}\right) + 12$	$\tau_d = \frac{24}{\pi} \times \arcsin\left(\frac{\theta_{lim} - \theta_{avg}}{\theta_{max} - \theta_{avg}}\right) + 12$
Arc sine curve 2	$\tau_d = \frac{24}{\pi} \times \arcsin\left(\frac{2 \times \theta_{lim} - \theta_{max} - \theta_{min}}{\theta_{max} - \theta_{min}}\right) + 12$	
Linear function 1	$\tau_d = 12 \times \frac{\theta_{lim} - \theta_{min}}{\theta_{avg} - \theta_{min}}$	$\tau_d = 12 \times \frac{\theta_{lim} - \theta_{avg}}{\theta_{max} - \theta_{avg}} + 12$
Linear function 2	$\tau_d = 24 \times \frac{\theta_{lim} - \theta_{min}}{\theta_{max} - \theta_{min}}$	

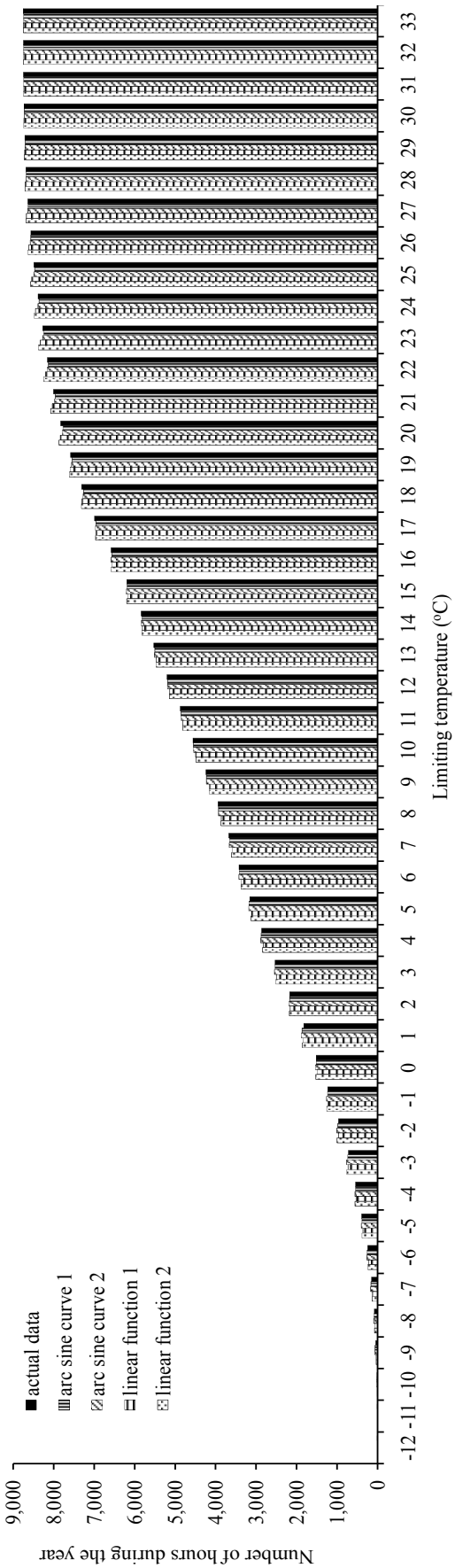

Fig. 2. Number of hours in 2005 during which air temperature at the Prague-Suchdol weather station was lower than the limiting level

Fig. 3. Differences between the estimated numbers of hours during a year with temperatures lower than the limiting level and the actual (observed) data

Table 2. Average numbers of hours in a year with temperatures lower than the limiting level

Weather station	Lysá hora	Churáňov	Červená	Svratouch	Přimda	Kostelní Myslová	Husinec	Ústí nad Orlicí	Velké Meziříčí	Liberec	Cheb	Havlíčkův Brod	Město Albrechtice Žáry	Ondřejov	Tábor
Limiting temperature (°C)	altitude (m)														
	1324	1118	750	737	742	569	536	452	452	398	471	455	483	518	438
	average temperature (°C) 1961–2000														
	2.8	4.4	5.7	5.9	6.0	7.1	7.3	7.3	7.4	7.4	7.4	7.4	7.5	7.6	7.7
33	8766	8766	8766	8766	8766	8765	8762	8764	8764	8765	8764	8764	8765	8764	8761
32	8766	8766	8766	8765	8765	8764	8758	8762	8760	8763	8761	8762	8764	8760	8755
31	8766	8766	8765	8764	8764	8760	8751	8759	8755	8759	8755	8757	8762	8755	8746
30	8766	8765	8763	8762	8762	8753	8742	8752	8745	8753	8745	8748	8758	8745	8732
29	8766	8764	8760	8759	8756	8742	8728	8738	8728	8743	8728	8734	8752	8730	8712
28	8766	8762	8755	8752	8748	8724	8706	8717	8703	8724	8703	8714	8738	8708	8680
27	8765	8757	8745	8740	8733	8696	8674	8687	8669	8698	8671	8682	8718	8676	8637
26	8762	8750	8728	8721	8710	8660	8629	8645	8616	8661	8627	8637	8688	8629	8580
25	8756	8737	8702	8692	8676	8609	8572	8586	8549	8610	8569	8577	8644	8567	8509
24	8747	8717	8663	8649	8629	8541	8497	8510	8468	8543	8497	8502	8580	8488	8420
23	8732	8686	8607	8590	8567	8455	8406	8418	8368	8459	8411	8407	8496	8388	8318
22	8707	8641	8532	8512	8488	8346	8299	8309	8250	8357	8310	8295	8389	8271	8200
21	8670	8581	8435	8412	8390	8219	8174	8182	8117	8237	8190	8163	8257	8136	8066
20	8620	8503	8317	8294	8273	8075	8034	8036	7969	8099	8051	8014	8106	7983	7913
19	8549	8404	8173	8148	8132	7909	7867	7868	7804	7939	7892	7842	7929	7803	7737
18	8460	8283	8010	7982	7974	7722	7677	7677	7616	7753	7709	7647	7724	7598	7543
17	8349	8142	7815	7786	7784	7506	7456	7459	7404	7538	7505	7429	7485	7367	7322
16	8214	7976	7589	7565	7567	7263	7205	7210	7163	7292	7266	7180	7212	7100	7071
15	8051	7785	7336	7311	7316	6984	6927	6928	6897	7014	6994	6904	6909	6802	6789

Table 2. to be continued

Weather station	Lysá hora	Churáňov	Červená	Svratouch	Přimda	Kostelní Myslová	Husinec	Ústí nad Orlicí	Velké Meziříčí	Liberec	Cheb	Havlíčkův Brod	Město Albrechtice Žáry	Ondřejov	Tábor
Limiting temperature (°C)	altitude (m)														
	1324	1118	750	737	742	569	536	452	452	398	471	455	483	518	438
	average temperature (°C) 1961–2000														
	2.8	4.4	5.7	5.9	6.0	7.1	7.3	7.3	7.4	7.4	7.4	7.4	7.5	7.6	7.7
14	7860	7562	7055	7024	7036	6672	6615	6621	6614	6705	6692	6599	6577	6486	6483
13	7642	7312	6741	6709	6728	6342	6285	6291	6307	6371	6364	6275	6229	6162	6160
12	7393	7026	6410	6373	6401	6003	5939	5947	5984	6018	6022	5944	5874	5817	5827
11	7114	6709	6069	6030	6057	5648	5587	5596	5657	5656	5664	5601	5514	5476	5484
10	6805	6367	5723	5675	5705	5295	5229	5242	5327	5289	5300	5252	5152	5129	5146
9	6473	6014	5390	5324	5352	4950	4879	4901	5002	4929	4948	4909	4808	4793	4815
8	6137	5651	5060	4979	5005	4621	4535	4565	4679	4577	4598	4573	4475	4465	4495
7	5790	5278	4733	4649	4666	4304	4204	4245	4361	4244	4260	4251	4149	4148	4184
6	5427	4905	4424	4331	4337	4000	3874	3935	4046	3913	3930	3935	3819	3843	3877
5	5076	4530	4126	4022	4021	3696	3546	3620	3733	3578	3596	3617	3488	3539	3555
4	4729	4164	3827	3719	3712	3392	3210	3305	3419	3241	3252	3299	3160	3218	3230
3	4389	3811	3530	3406	3389	3077	2873	2988	3094	2883	2905	2961	2825	2888	2897
2	4060	3459	3229	3091	3056	2753	2537	2653	2739	2503	2522	2611	2474	2546	2541
1	3723	3099	2919	2761	2709	2401	2182	2282	2344	2109	2110	2230	2113	2186	2151
0	3370	2701	2569	2391	2344	2014	1810	1876	1947	1709	1681	1821	1754	1804	1732
–1	2988	2310	2191	1995	1936	1628	1479	1511	1579	1352	1327	1451	1421	1440	1372
–2	2623	1950	1833	1636	1546	1297	1185	1197	1252	1054	1037	1147	1138	1138	1077
–3	2260	1607	1497	1313	1224	1031	954	943	987	837	815	910	902	895	846
–4	1916	1294	1201	1038	958	815	769	746	778	659	640	714	715	702	671

Table 2. to be continued

Weather station	Lysá hora	Churáňov	Červená	Svratouch	Přimda	Kostelní Myslová	Husinec	Ústí nad Orlicí	Velké Meziříčí	Liberec	Cheb	Havlíčkův Brod	Město Albrechtice Žáry	Ondřejov	Tábor
Limiting temperature (°C)	altitude (m)														
	1324	1118	750	737	742	569	536	452	452	398	471	455	483	518	438
	average temperature (°C) 1961–2000														
	2.8	4.4	5.7	5.9	6.0	7.1	7.3	7.3	7.4	7.4	7.4	7.4	7.5	7.6	7.7
–5	1582	1036	942	816	743	633	617	589	615	521	504	565	565	547	532
–6	1274	811	736	622	577	488	495	465	487	416	399	452	441	424	427
–7	1004	634	572	476	447	376	397	367	390	329	316	366	338	328	347
–8	773	495	439	357	338	289	318	287	313	261	249	299	258	252	284
–9	595	381	333	268	250	222	256	225	250	205	197	240	194	191	230
–10	448	291	246	199	183	167	206	172	198	159	154	193	145	141	184
–11	340	213	179	145	133	121	161	131	155	121	117	154	107	101	148
–12	252	155	130	101	95	86	125	96	121	92	89	122	77	71	117
–13	185	111	91	68	65	60	96	68	95	70	66	97	53	46	93
–14	133	78	64	45	44	41	72	48	74	52	50	75	38	30	74
–15	95	52	43	28	30	27	53	33	58	39	36	58	26	19	57
–16	66	35	30	17	18	17	38	23	44	28	26	45	18	12	44
–17	45	22	20	10	11	11	27	16	33	19	18	34	12	7	34
–18	29	13	13	6	7	6	19	11	25	13	12	25	7	4	26
–19	18	8	8	4	4	4	13	7	18	8	8	18	4	3	19
–20	12	5	5	2	2	2	9	5	13	5	5	12	2	1	13

Table 2. to be continued

Weather stations	Třeboň	Kralovice	Valašské Meziříčí	Praha Ruzyně	Klatovy	Lučina	Mošnov	Kuchařovice	Holešov	Hradec Králové	Doksany	Semčice	Olomouc Slavonín	Brno uřany	Žatec
	altitude (m)														
Limiting temperature (°C)	429	468	334	369	430	300	251	334	224	278	158	234	225	241	201
	average temperature (°C) 1961–2000														
	7.7	7.7	7.9	8.0	8.1	8.2	8.4	8.6	8.7	8.7	8.7	8.8	8.9	8.9	9.0
33	8762	8763	8763	8762	8759	8763	8761	8760	8762	8758	8757	8760	8760	8760	8755
32	8757	8760	8760	8758	8753	8760	8757	8755	8757	8749	8750	8753	8755	8755	8746
31	8750	8754	8753	8751	8743	8754	8748	8746	8748	8736	8739	8742	8745	8744	8731
30	8738	8745	8743	8738	8729	8743	8733	8728	8732	8716	8720	8723	8727	8726	8708
29	8717	8730	8724	8719	8706	8726	8711	8702	8706	8687	8694	8697	8698	8697	8676
28	8687	8706	8697	8693	8673	8698	8678	8665	8670	8648	8658	8662	8659	8657	8632
27	8648	8672	8658	8654	8629	8659	8634	8616	8620	8594	8607	8610	8606	8603	8575
26	8593	8625	8604	8601	8572	8604	8573	8550	8551	8527	8539	8544	8535	8528	8501
25	8524	8563	8532	8531	8501	8530	8492	8466	8464	8442	8456	8458	8444	8437	8412
24	8438	8482	8441	8445	8414	8437	8393	8361	8361	8339	8358	8355	8334	8323	8309
23	8335	8387	8333	8341	8310	8326	8278	8236	8240	8224	8244	8239	8206	8192	8191
22	8216	8272	8208	8220	8190	8197	8145	8093	8101	8089	8114	8101	8067	8040	8052
21	8079	8140	8064	8081	8056	8046	7995	7933	7941	7937	7960	7945	7906	7874	7893
20	7927	7988	7900	7923	7903	7880	7823	7752	7756	7768	7787	7768	7723	7683	7715
19	7751	7813	7714	7740	7729	7692	7633	7548	7549	7572	7592	7566	7514	7467	7512
18	7553	7617	7504	7532	7530	7479	7417	7316	7321	7349	7371	7332	7279	7221	7282
17	7334	7391	7266	7295	7306	7236	7176	7053	7060	7096	7124	7068	7019	6945	7024
16	7081	7137	6999	7025	7047	6964	6902	6763	6767	6811	6849	6775	6731	6645	6736
15	6802	6851	6700	6726	6759	6657	6600	6446	6458	6503	6551	6462	6422	6331	6425

Table 2. to be continued

Weather stations	Třeboň	Kralovice	Valašské Meziříčí	Praha Ruzyně	Klatovy	Lučina	Mošnov	Kuchařovice	Holešov	Hradec Králové	Doksany	Semčice	Olomouc Slavonín	Brno uřany	Žatec
Limiting temperature (°C)	altitude (m)														
	429	468	334	369	430	300	251	334	224	278	158	234	225	241	201
	average temperature (°C) 1961–2000														
	7.7	7.7	7.9	8.0	8.1	8.2	8.4	8.6	8.7	8.7	8.7	8.8	8.9	8.9	9.0
14	6497	6538	6375	6408	6446	6326	6273	6117	6131	6180	6229	6137	6092	5997	6096
13	6176	6215	6033	6073	6108	5976	5927	5772	5792	5844	5896	5801	5759	5663	5755
12	5837	5877	5676	5726	5757	5613	5577	5427	5454	5500	5553	5461	5429	5327	5413
11	5497	5537	5322	5374	5401	5252	5232	5090	5121	5157	5208	5119	5106	5003	5067
10	5160	5194	4972	5023	5043	4896	4890	4765	4793	4824	4864	4783	4779	4689	4720
9	4829	4853	4634	4683	4702	4551	4557	4454	4472	4498	4528	4456	4465	4383	4392
8	4506	4527	4303	4353	4369	4228	4240	4149	4165	4184	4205	4144	4164	4087	4067
7	4187	4202	3981	4030	4038	3905	3923	3849	3863	3875	3882	3835	3876	3800	3740
6	3865	3888	3672	3705	3706	3590	3608	3556	3560	3560	3551	3517	3584	3515	3410
5	3537	3573	3354	3387	3367	3269	3287	3255	3258	3248	3217	3201	3287	3224	3065
4	3205	3242	3037	3068	3027	2948	2970	2952	2952	2923	2876	2868	2970	2915	2712
3	2872	2902	2711	2728	2685	2628	2644	2634	2617	2583	2519	2521	2635	2591	2356
2	2525	2538	2366	2376	2317	2301	2300	2298	2259	2227	2151	2147	2281	2250	1996
1	2157	2149	1997	1995	1934	1957	1930	1944	1880	1857	1776	1736	1904	1886	1644
0	1769	1738	1616	1611	1552	1600	1549	1577	1505	1473	1398	1348	1534	1521	1309
–1	1430	1375	1292	1283	1225	1299	1236	1256	1194	1150	1089	1049	1217	1206	1032
–2	1132	1089	1027	1023	962	1054	990	992	952	895	857	817	961	944	802
–3	895	864	825	814	759	861	799	776	762	703	680	646	760	739	631
–4	700	680	666	646	598	714	646	601	608	555	542	511	596	577	503

Table 2. to be continued

Weather stations	Třeboň	Kralovice	Valašské Meziříčí	Praha Ruzyně	Klatovy	Lučina	Mošnov	Kuchařovice	Holešov	Hradec Králové	Doksany	Semčice	Olomouc Slavonín	Brno uřany	Žatec
	altitude (m)														
Limiting temperature (°C)	429	468	334	369	430	300	251	334	224	278	158	234	225	241	201
	average temperature (°C) 1961–2000														
	7.7	7.7	7.9	8.0	8.1	8.2	8.4	8.6	8.7	8.7	8.7	8.8	8.9	8.9	9.0
–5	547	534	539	513	474	588	521	464	487	440	434	404	473	448	401
–6	434	420	431	408	376	477	421	359	396	351	349	326	376	349	324
–7	345	328	346	323	300	390	342	276	323	280	283	258	298	269	257
–8	281	258	277	260	242	320	276	211	261	222	231	204	235	205	206
–9	230	199	223	206	194	263	220	157	209	172	189	161	182	154	165
–10	185	155	176	161	152	218	178	115	167	133	153	125	139	112	130
–11	151	116	139	122	121	179	143	81	131	101	123	96	103	81	102
–12	122	87	108	91	95	146	113	57	103	76	98	74	77	57	80
–13	99	64	82	70	73	119	88	40	78	56	78	56	58	41	62
–14	79	48	61	52	56	96	67	28	58	40	62	41	43	29	49
–15	62	35	43	37	42	75	50	18	42	29	48	32	31	20	37
–16	50	24	30	26	31	58	37	12	29	20	37	23	22	14	28
–17	39	17	21	17	23	44	27	8	21	14	27	16	16	9	21
–18	29	11	15	12	15	34	21	5	15	9	20	11	11	6	14
–19	22	7	10	8	10	26	16	3	10	6	14	7	8	4	9
–20	16	4	7	5	6	19	12	2	7	4	9	5	6	2	5
–21	12	2	5	3	4	15	8	1	5	3	5	2	4	1	3

40-year period at all of the 30 weather stations. The least squares method was applied to fit the large volume of resulting data with a quadratic regression dependence of the number of hours on the average yearly temperature of the specific site. Only such regression functions whose coefficient of determination (correlation coefficient squared) was higher than 0.8 were considered significant.

RESULTS AND DISCUSSION

The calculated estimates in comparison with actual data measured by the Prague-Suchdol, Czech Republic weather station in 2005 are shown in Fig. 2. Very good results were obtained with all the four functions used.

The true values are best fitted by the arc sine function passing through the minimum, average, and maximum daily temperature levels (arc sine curve 1). The absolute error of the estimate is higher than 24 h only six times among the 46 values (Fig. 3), i.e. at 17°C to 21°C (the relative error, however, is lower than 0.7%) and, furthermore, at 1°C, where this function led to the maximum absolute deviation of 53 h (relative error 3%).

The average absolute difference between the estimate and the true value is lower than 14 h for this function, while the same difference for the arc sine function passing through the minimum and maximum levels only (arc sine curve 2) is 16.4 h, for the linear function passing through the minimum, average, and maximum daily temperature levels (line-

Table 3. Interdependence between the yearly number of hours with temperatures lower than the limiting level and the average yearly temperature

Limiting temperature (°C)	Quadratic regression function τ (h), θ_{yr} (°C)	Coefficient of determination (–)	Limiting temperature (°C)	Quadratic regression function τ (h), θ_{yr} (°C)	Coefficient of determination (–)
31	$\tau = -1.395\times\theta_{yr}^2 + 12.32\times\theta_{yr} + 8741$	0.822	10	$\tau = 3.431\times\theta_{yr}^2 - 381.61\times\theta_{yr} + 7862$	0.988
30	$\tau = -2.285\times\theta_{yr}^2 + 19.68\times\theta_{yr} + 8727$	0.874	9	$\tau = 6.123\times\theta_{yr}^2 - 411.47\times\theta_{yr} + 7593$	0.988
29	$\tau = -3.420\times\theta_{yr}^2 + 28.29\times\theta_{yr} + 8711$	0.901	8	$\tau = 8.580\times\theta_{yr}^2 - 435.43\times\theta_{yr} + 7302$	0.989
28	$\tau = -4.700\times\theta_{yr}^2 + 36.68\times\theta_{yr} + 8697$	0.919	7	$\tau = 9.584\times\theta_{yr}^2 - 439.38\times\theta_{yr} + 6952$	0.989
27	$\tau = -6.282\times\theta_{yr}^2 + 46.35\times\theta_{yr} + 8682$	0.932	6	$\tau = 8.502\times\theta_{yr}^2 - 417.02\times\theta_{yr} + 6528$	0.988
26	$\tau = -7.970\times\theta_{yr}^2 + 54.53\times\theta_{yr} + 8670$	0.941	5	$\tau = 7.308\times\theta_{yr}^2 - 396.32\times\theta_{yr} + 6122$	0.985
25	$\tau = -9.686\times\theta_{yr}^2 + 60.30\times\theta_{yr} + 8664$	0.951	4	$\tau = 5.391\times\theta_{yr}^2 - 369.77\times\theta_{yr} + 5710$	0.982
24	$\tau = -11.030\times\theta_{yr}^2 + 59.29\times\theta_{yr} + 8671$	0.958	3	$\tau = 3.615\times\theta_{yr}^2 - 348.77\times\theta_{yr} + 5322$	0.978
23	$\tau = -11.838\times\theta_{yr}^2 + 50.33\times\theta_{yr} + 8690$	0.965	2	$\tau = 2.654\times\theta_{yr}^2 - 342.51\times\theta_{yr} + 4983$	0.975
22	$\tau = -12.386\times\theta_{yr}^2 + 37.18\times\theta_{yr} + 8707$	0.970	1	$\tau = 3.013\times\theta_{yr}^2 - 354.60\times\theta_{yr} + 4685$	0.972
21	$\tau = -12.596\times\theta_{yr}^2 + 19.10\times\theta_{yr} + 8724$	0.975	0	$\tau = 6.207\times\theta_{yr}^2 - 395.75\times\theta_{yr} + 4427$	0.968
20	$\tau = -12.865\times\theta_{yr}^2 + 0.85\times\theta_{yr} + 8726$	0.979	–1	$\tau = 11.623\times\theta_{yr}^2 - 445.73\times\theta_{yr} + 4143$	0.968
19	$\tau = -13.094\times\theta_{yr}^2 - 18.11\times\theta_{yr} + 8709$	0.982	–2	$\tau = 17.222\cdot\theta_{yr}^2 - 488.92\times\theta_{yr} + 3852$	0.969
18	$\tau = -13.718\times\theta_{yr}^2 - 33.81\times\theta_{yr} + 8666$	0.984	–3	$\tau = 20.253\times\theta_{yr}^2 - 491.77\times\theta_{yr} + 3461$	0.972
17	$\tau = -14.176\times\theta_{yr}^2 - 52.43\times\theta_{yr} + 8607$	0.985	–4	$\tau = 21.285\times\theta_{yr}^2 - 467.54\times\theta_{yr} + 3027$	0.971
16	$\tau = -14.184\times\theta_{yr}^2 - 77.60\times\theta_{yr} + 8542$	0.986	–5	$\tau = 20.118\times\theta_{yr}^2 - 416.35\times\theta_{yr} + 2555$	0.970
15	$\tau = -12.992\times\theta_{yr}^2 - 116.60\times\theta_{yr} + 8483$	0.986	–6	$\tau = 17.745\times\theta_{yr}^2 - 351.85\times\theta_{yr} + 2084$	0.967
14	$\tau = -10.913\times\theta_{yr}^2 - 164.25\times\theta_{yr} + 8413$	0.986	–7	$\tau = 14.440\times\theta_{yr}^2 - 281.17\times\theta_{yr} + 1646$	0.959
13	$\tau = -7.808\times\theta_{yr}^2 - 220.96\times\theta_{yr} + 8333$	0.986	–8	$\tau = 11.164\times\theta_{yr}^2 - 215.16\times\theta_{yr} + 1261$	0.942
12	$\tau = -4.138\times\theta_{yr}^2 - 279.42\times\theta_{yr} + 8221$	0.986	–9	$\tau = 8.668\times\theta_{yr}^2 - 164.80\times\theta_{yr} + 964$	0.911
11	$\tau = -0.215\times\theta_{yr}^2 - 335.10\times\theta_{yr} + 8069$	0.987	–10	$\tau = 6.430\times\theta_{yr}^2 - 121.61\times\theta_{yr} + 718$	0.858

ar function 1) it is 29.9 h, and for the simples linear function, which only passes through the minimum and maximum daily temperature levels (linear function 2) it is 35.2 h.

At lower temperatures (in the winter season) the differences are mostly positive for the arc sine function, in other words, the calculated number of hours with low temperatures is higher than the actual value. This implies that the true energy consumption for heating would be lower. The reverse is true of days with higher temperatures: the differences are negative, i.e. the estimated number of hours is lower than the true value. Hence, the actual number of hours with temperatures lower than the limiting level is higher and so the actual power consumption for ventilation or cooling would once again be lower than the calculated value.

Table 2 includes the average yearly numbers of hours with temperatures lower than 55 limiting levels (from –21°C to 33°C) determined based on 1961–2000 data at 30 sites in the Czech Republic. The data in the table can be used to assess the frequency of occurrence of a certain air temperature at sites at different altitudes and with different average yearly temperatures.

CONCLUSION

A method for estimating the number of hours during which air temperature is lower than a preselected limiting level in situations where only the minimum, average, and maximum daily temperature data are available has been suggested and tested. If the limiting temperature (θ_{lim}) lies between the minimum (θ_{min}), and average (θ_{avg}) temperatures, the number of hours (τ_d) with temperatures lower than the limiting level during one day is calculated by using the equation

$$\tau_d = \frac{24}{\pi} \times \arcsin\left(\frac{\theta_{lim} - \theta_{avg}}{\theta_{avg} - \theta_{min}}\right) + 12$$

(all temperatures in °C). If the limiting temperature lies between the average and maximum (θ_{max}) daily temperatures, the relationship:

$$\tau_d = \frac{24}{\pi} \times \arcsin\left(\frac{\theta_{lim} - \theta_{avg}}{\theta_{max} - \theta_{avg}}\right) + 12$$

(temperatures in °C) is applied.

This method was applied to calculate the data, and a table of average numbers of hours in a year with temperatures lower than 55 limiting levels (from –21°C to 33°C) was set up based on meteorological data (1961–2000) for 30 sites within the Czech Republic. Statistical analysis revealed that significant interdependence, given in Table 3, exists between the average number of hours (τ) in a year with temperatures below the limiting level (from –10°C to 31°C) and the average yearly temperature (θ_{yr}).

The results can be used when calculating the power demands of heating/cooling facilities in agricultural and other buildings at sites with average yearly temperatures between 2.8°C and 9°C.

References

ČSN EN 12831, 2005. Tepelné soustavy v budovách – Výpočet tepelného výkonu (Heating systems in buildings – Method for calculation of the design heat load). Prague, Czech Office for Standards, Metrology and Testing.

ASHRAE Handbook – Fundamentals, 2005. American Society of Heating, Refrigerating and Air-Conditioning Engineers. Atlanta, USA, Ashare.

Květoň V., 2001. Normály teploty vzduchu na území České republiky a vybrané teplotní charakteristiky období 1961–2000 (Climatological normals of air temperature of the Czech Republic in the period 1961–1990 and selected air temperature characteristics of the period 1961–2000). Prague, Czech Hydrometeorological Institute.

Šleger V., Neuberger P., Polák M., 2009. Feasibility of using heat-recovery exchangers in livestock buildings at a site at a specific altitude with specific average outdoor air temperature. Infrastructure and ecology of rural areas, *7*: 47–56.

Received for publication February 15, 2010
Accepted after corrections April 23, 2010

Corresponding author:

Doc. Ing. Vladimír Šleger, CSc., Czech University of Life Science Prague,
Faculty of Engineering, Kamýcká 129, 165 21 Prague 6-Suchdol, Czech Republic
phone: + 420 224 383 173, e-mail: sleger@tf.czu.cz