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HEAT TRANSMISSION OF A REFERENCE AND PRACTICAL CONTAINER UNDER SUBTROPICAL CONDITIONS

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1. Introduction

Under tropical and subtropical conditions the heat of transmission through insulated container walls is influenced by radiation. The cooling capacity of the container must be chosen conformable to the maximum heat load. This report compares the transmission of a reference and a practical container under South-Italian conditions.

2. Container

The reference container has insulated walls all over, with a K-value of 0,4 $W/(m^2.K)$. The practical container has top and bottom k-values of 0,1, side walls 0,7 and front and rear wall 0,4. The length, width and height are respectively 12 m, 2,5 m and 2,5 m. The inside temperature is -20^oC. The orientation of the container is north-south (rear - front) and north-west/south-east.

3. Ambient climate

The air velocity around the container gives a convective heat transfer of 15 $W/(m^2.K)$. The adsorption coefficient is 1 because the radiation has already been corrected for the reflection. Table 6 shows the climate conditions.

4. Method of calculation

To calculate the temperature inside the wall a step-by-step numerical solution was used of the Binder-Schmidt type (see Arpaci, Conduction heat transfer,, Addison-Westley, Reading, 1966, p. 515).

The surface temperature was calculated every time step from a heat balance over the surface. The surface temperature equalls:

$$T_{surf} = (J + \alpha : T_{air} + \frac{\lambda}{\Delta x} T_1)/(\alpha + \frac{\lambda}{\Delta x})$$

where

J	W/m^2	radiation
α	$W/(m^2 \cdot K)$	heat transfer (convective)
T_{air}	^oC	air temperature
λ	$W/(m \cdot K)$	thermal conductivity of insulation material

Δx	m	distance from surface to first nodal point
T_1	^oC	temperature of first nodal point, one time step back.

5. Results

5.1. Ambient temperature and transmission through the bottom

The ambient temperature varies between 30 and 40^oC. The temperature in the container is -20^oC. The minimum heatflow corresponds with a temperature difference of 50 K and the maximum heatflow with 60 k. The influence is 20% according to the lowest temperature difference. From table 1 to 2 it follows that the calculated difference is 19,5%.of walls not facing the sun. The reference container behaves better than the practical container. The difference between maximum and minimum heat flow through the bottom is only 13%. This can be explained by the thickness of the insulation and the corresponding time lag of 3 to 4 hours.

5.2. Effect of radiation on total transmission

Without sunshine the mean total transmission of the reference container is 2841 W. The mean daily total transmission with sunshine is 3268 W. The effect of radiation is only 15%. The maximum heat flow is 4000 W, thus 41% more than the mean total transmission without radiation.

5.3. Effect of orientation

Studying table 5 it is clear that the effect of the orientation of the container is neglectable.

Only the maximum heat flow of the practical container in the north-south orientation is much higher than in the north-west/south-east orientation;

3999 - 3847 = 152 W.

The difference of the reference container is only 61 W and reversed as well.

5.4. Reference and practical container

There is no real difference between the transmission of the reference and the practical container.

Table 1. Heat flows in W through walls of a reference container. Orientation north-south

time in hour	top	east	west	bottom + north + south	total
0	609	609	609	863	2689
1	600	600	600	850	2650
2	591	591	591	837	2610
3	585	585	585	829	2583
4	588	588	588	833	2597
5	639	783	594	842	2857
6	729	1008	603	854	3194
7	837	1104	615	871	3427
8	951	1110	627	888	3576
9	1065	1059	639	905	3668
10	1185	972	651	922	3730
11	1281	867	660	935	3743
12	1329	738	672	952	3691
13	1338	684	750	969	3741
14	1305	693	900	982	3879
15	1218	702	1038	990	3948
16	1110	699	1131	990	3930
17	1005	693	1182	982	3861
18	888	684	1167	969	3708
19	798	672	1011	952	3433
20	705	660	768	935	3068
21	648	648	648	918	2862
22	636	636	636	901	2809
23	624	624	624	884	2756
24	612	612	612	867	2703

Table 2. Heat flows in W through walls of a reference container. Orientation north-west/south-east

time in hour	top	east side	west side	bottom	total
0	609	732	732	609	2682
1	600	725	725	600	2650
2	591	714	714	590	2610
3	585	706	706	585	2583
4	588	706	710	587	2593
5	639	917	717	594	2867
6	729	1170	728	602	3231
7	837	1261	743	615	3456
8	951	1218	757	627	3553
9	1065	1112	772	639	3589
10	1185	899	786	650	3521
11	1281	797	826	660	3565
12	1329	812	942	672	3755
13	1338	826	1069	684	3917
14	1305	837	1174	692	4009
15	1218	844	1246	699	4008
16	1110	844	1268	699	3922
17	1005	837	1207	692	3742
18	888	826	1098	684	3496
19	798	812	964	672	3246
20	705	797	840	660	3003
21	648	782	782	647	2861
22	636	768	761	635	2801
23	624	754	754	624	2756
24	612	732	732	612	2688

Table 3. Heat flows (in W) through walls of practical container. Orientation north-south

time in hours	top	east	west	bottom	north + south	total
0	186	1038	1038	165	253	2682
1	176	1025	1025	161	250	2639
2	168	1010	1010	158	246	2594
3	165	1005	1005	158	243	2578
4	158	1007	1007	156	244	2574
5	156	1470	1020	153	247	3048
6	156	1800	1040	153	251	3402
7	161	1916	1059	153	256	3547
8	173	1893	1080	153	261	3562
9	191	1790	1100	156	266	3505
10	210	1623	1119	156	271	3381
11	233	1443	1140	158	275	3251
12	263	1209	1160	161	280	3075
13	287	1179	1344	165	285	3262
14	302	1190	1610	168	288	3560
15	315	1203	1833	168	291	3812
16	315	1200	1976	171	291	3955
17	308	1185	2043	173	288	3999
18	293	1166	1983	173	285	3902
19	276	1145	1629	173	280	3505
20	255	1128	1205	173	275	3038
21	233	1106	1106	171	269	2887
22	213	1085	1085	171	265	2821
23	198	1065	1065	168	260	2758
24	186	1046	1046	165	255	2700

Table 4. Heat flows in W through walls of a practical container. Orientation north-west/south-east

time in hour	top	north-east	south-west	south-east	north-west	bottom	total
0	186	1035	1035	126	126	165	2673
1	176	1025	1025	125	125	161	2640
2	168	1010	1010	123	123	158	2595
3	165	1005	1005	121	121	158	2577
4	158	1007	1007	121	122	156	2575
5	156	1413	1020	158	123	153	3023
6	156	1730	1040	201	125	153	3408
7	161	1794	1059	217	128	153	3513
8	173	1704	1080	209	130	153	3451
9	191	1533	1100	191	133	156	3307
10	210	1190	1119	155	135	156	2966
11	233	1140	1194	137	142	158	3007
12	263	1158	1391	140	162	161	3278
13	287	1179	1556	142	184	165	3515
14	302	1194	1704	144	202	168	3715
15	315	1203	1790	145	214	168	3837
16	315	1196	1800	145	218	171	3847
17	308	1185	1680	144	208	173	3700
18	293	1166	1515	142	189	173	3481
19	276	1145	1316	140	166	173	3219
20	255	1128	1155	137	145	173	2994
21	233	1106	1106	134	134	171	2888
22	213	1089	1085	132	131	171	2822
23	198	1068	1068	130	130	168	2762
24	186	1046	1046	126	126	165	2697

Table 5. Maximum and minimum heat flows

container type	orientation	heat flow in W maximum	minimum
reference		3948 (15)	2583 (3)
		4009 (14)	2583 (3)
practical		3999 (17)	2574 (4)
		3847 (16)	2575 (4)

figures between ( ) give the time

Table 6. Radiation on walls of a container under South-Italian conditions, and ambient temperature

time in hour	ambient temp. °C	radiation in W/m²				
		top	east-side	west-side	north-side	south-side
0	32	0	0	0	0	0
1	31	0	0	0	0	0
2	30,4	0	0	0	0	0
3	30	0	0	0	0	0
4	30,3	0	0	0	0	0
5	31	100	400	0	350	0
6	32	200	600	0	550	0
7	33	340	650	0	550	0
8	34	470	600	0	450	0
9	35	600	500	0	300	0
10	36	750	350	0	0	0
11	37	830	200	0	0	50
12	38	850	0	0	0	200
13	39	830	0	150	0	300
14	39,6	750	0	350	0	400
15	40	600	0	500	0	450
16	39,7	470	0	600	0	450
17	39	340	0	650	0	350
18	38	200	0	600	0	240
19	37	130	0	300	0	100
20	36	0	0	0	0	0
21	35	0	0	0	0	0
22	34	0	0	0	0	0
23	33	0	0	0	0	0
24	32	0	0	0	0	0

Wageningen, 13 april 1982

GvB/MJ