



CONSERVATION
SUPPORT

Design phase simulation

KB National Library

Version 01
12-08-2022

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1 Introduction

The National Library in The Hague, The Netherlands, (KB) plans to build a new repository building. This new building will be a unique concept not shown in The Netherlands before, in which books are stored in containers in a fully automated and robotized passive storage. The example for this storage can be found in the Kooperative Speicherbibliothek located in Büron, Switzerland. The collection of the KB will be placed in a similar building on the outskirts of The Hague.

This report is meant for the final design phase. Changes are made to the design which are subsequently also copied into the simulation model to be tested. Furthermore, also a new position of the 'special sizes collection' is examined in this report.



2 Research questions

Out of the first simulation studies a realistic model for the passive repository was derived. In this report, the developed simulation model will be used to answer the following questions:

- How does the building behave after some design changes?
 - Concrete construction walls and concrete cladding on the outside
 - Average R_c value of $8.0 \text{ m}^2\text{K/W}$
 - Better real world air tightness by reducing the amount of doors
 - Changes to the robot design
- Where can the 'special sizes' collection best be stored?
 - Above the robotic system in the repository or
 - In the front building (at floor 3)
- Are additional measures needed to make the 'special sizes' collection area in the front building suitable?
 - Additional air flow between repository and collection area
 - Position on floor 2 instead of 3
 - Internal wall insulated to the extreme ($16 \text{ m}^2\text{K/W}$)
 - Half of return air fed through collection area by open connection
 - Half of return air fed through collection area by additional ducts
 - Create a separate climate zone for the collection area.

3 Design phase model

The optimized realistic model (20220106_KB_Metamorfoze_Simulation_Continuation.docx describes this model) is used. This model is changed slightly to match the current design; a comparison is made in this chapter.

The simulation model has the following specifications:

- Cladding made of concrete, not metal
- Additional zone on floor 3 of the working area, connected to the repository
- Average R_c is $8.0 \text{ m}^2\text{K/W}$, including thermal bridges due to attachment of cladding
- Minor changes in dimensions
- No more pallets, everything in crates

The results of this model are as follows (simulation calculation period 2001 – 2020, simulation assessment period 2006 – 2020 because of time needed to come into equilibrium).

When comparing stratification for the previous model (table 1) and the current model (table 2), differences are only very small and not significant. The behavior over the height is similar in both models.

Table 1: Results of optimized realistic model, stratification

	WA pallet	WA corr	M pallet	M corr	M crate	BW corr	BW crate
Minimum [°C]	-0.07	-0.53	-1.09	-1.06	-1.08	-0.51	-0.48
Maximum [°C]	2.76	1.84	3.89	3.28	4.21	2.03	1.59

* WA = near Working Area, M = Middle, BW = near Back Wall, corr = in corridor, crate = in crate section

Table 2: Results of design phase model, stratification

	WA crate	WA corr	M crate	M corr	M crate	BW corr	BW crate
Minimum [°C]	-0.03	-0.48	-1.08	-1.07	-1.10	-0.52	-0.50
Maximum [°C]	2.76	1.83	3.88	3.22	4.11	2.01	1.56

* WA = near Working Area, M = Middle, BW = near Back Wall, corr = in corridor, crate = in crate section

When comparing temperature and relative humidity values for previous (table 3) and current model (table 4), results are a bit different. The current model shows less seasonal and short changes, so it is more stable. The only exception can be found close to the working area: where the collections area and repository are connected, changes in RH are a bit higher.

In general, the current model is slightly cooler ($-0.1 \text{ }^\circ\text{C}$) and slightly more humid ($+0.8 \text{ \%RH}$) than the previous model. This is mainly caused by more thermal buffering on the outside, by having a concrete façade with large thickness. The effect could be even larger by using titanium oxide as an outer layer of the concrete (see e.g. <https://phys.org/news/2013-07-pavement-titanium-oxide-air-pollution.html>).



Table 3: Results of optimized realistic model, on 5 locations

	Temperature [°C]						Relative Humidity [%RH]					
	Min	Max	Av	S-	S+	Short	Min	Max	Av	S-	S+	Short
Front area low	14.7	19.2	16.3	1.4	1.6	0.45	38.6	47.0	42.9	4.1	3.8	0.37
Front area high	13.9	20.0	16.4	2.2	2.3	0.54	39.0	45.7	42.5	3.3	3.0	0.27
Middle	11.6	17.8	14.6	2.7	2.5	0.55	45.0	50.6	48.0	2.8	2.5	0.19
Back side low	10.0	18.5	14.4	3.4	3.1	0.83	45.2	51.3	48.5	3.1	2.7	0.24
Back side high	10.3	20.0	15.1	4.0	3.6	0.89	42.9	48.7	46.0	2.9	2.6	0.23

Table 4: Results of design phase model, on 5 locations

	Temperature [°C]						Relative Humidity [%RH]					
	Min	Max	Av	S-	S+	Short	Min	Max	Av	S-	S+	Short
Front area low	14.6	19.1	16.3	1.3	1.5	0.43	39.3	47.5	43.6	4.1	3.7	0.36
Front area high	14.1	19.9	16.5	2.0	2.1	0.51	36.8	48.0	42.7	5.3	4.6	0.63
Middle	11.5	17.7	14.6	2.6	2.4	0.56	45.9	51.3	48.8	2.7	2.5	0.18
Back side low	9.8	18.4	14.3	3.3	2.9	0.83	46.1	52.0	49.3	3.0	2.7	0.22
Back side high	9.9	19.9	15.0	3.9	3.6	0.91	44.1	49.5	46.9	2.7	2.5	0.21

The energy usage for heating and dehumidification is estimated in tables 5 and 6. The current model needs slightly more heating. This is due to a lower temperature in the repository; the working area needs to be heated 2.5 % more when compared to the previous model.

Table 5: Energy requirements for optimized realistic model

Variant	Capacity needed			Yearly usage		
	Heating	Humidification	Dehumidification	Heating	Humidification	Dehumidification Or dilution*
New basic	25 kW	-	0.16 kg/h*	75.3 MWh	-	1,400 kg*

* = assumed dehumidification by dilution, caused by low oxygen system

Table 6: Energy requirements for design phase model

Variant	Capacity needed			Yearly usage		
	Heating	Humidification	Dehumidification	Heating	Humidification	Dehumidification Or dilution*
New basic	25 kW	-	0.16 kg/h*	77.4 MWh	-	1,400 kg*

* = assumed dehumidification by dilution, caused by low oxygen system

Figure 1 shows that the calculated EMC is in between 7.8 and 9.2 mass-%. Yearly differences are hardly noticed, but extreme seasons can cause EMC to rise or fall a bit. Important to note: near the working area EMC is a bit lower. Collections in smaller containers will mostly experience 0.4 mass-% difference when being placed elsewhere.

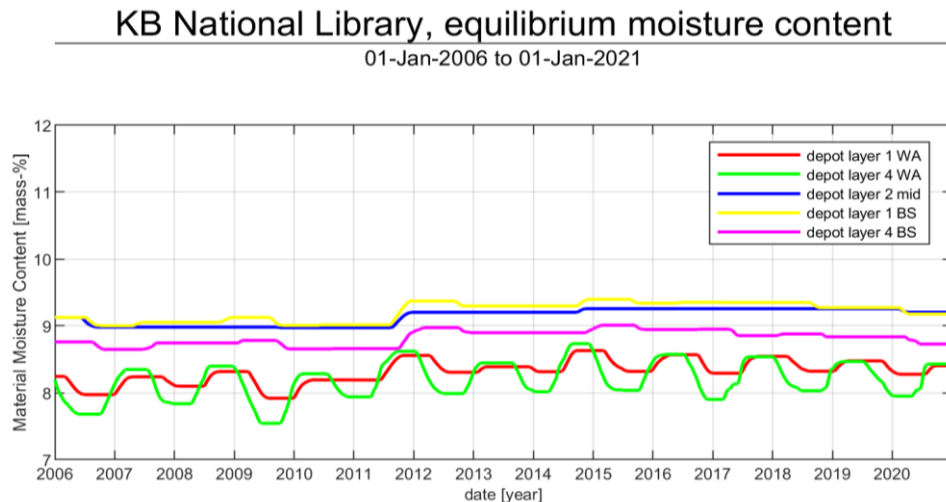


Figure 1: Calculated EMC for 5 positions in the repository

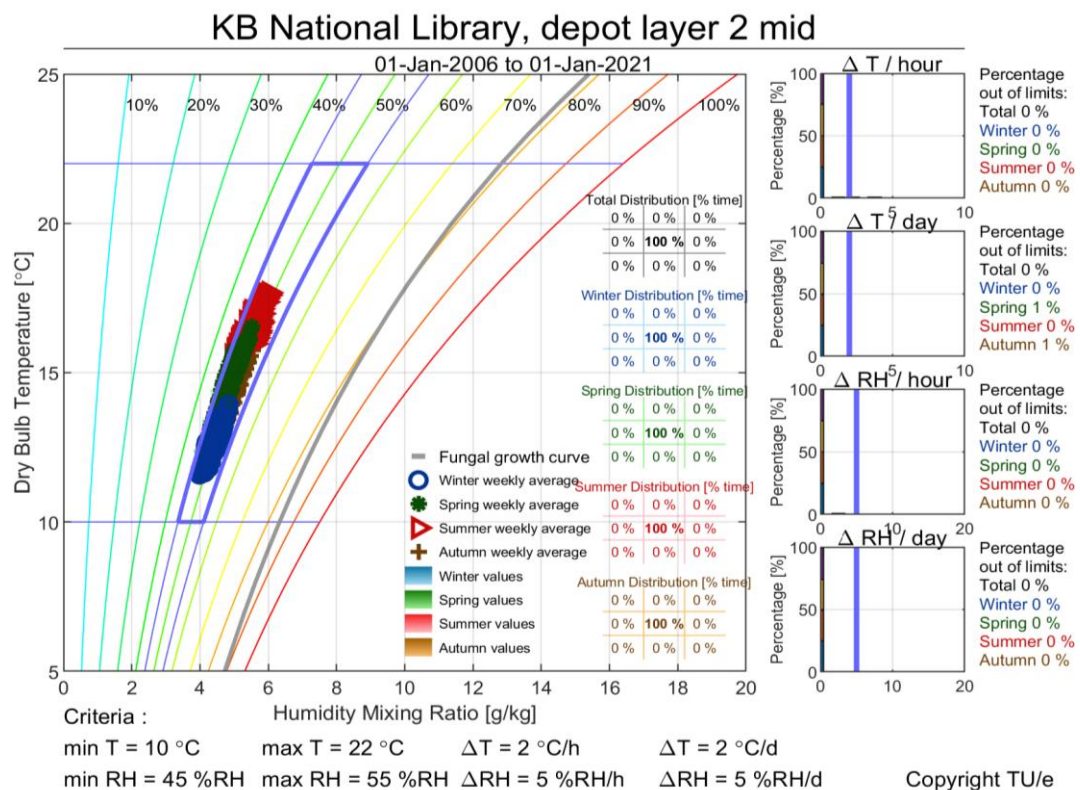


Figure 2: Climate Evaluation Chart for the center position in the repository; the blue segments indicate the stipulated requirements

Figure 2 shows that the center position of the repository has a temperature in between 12 and 18 °C, while RH is in between 45 and 52 %RH. This is very stable. Note: the bandwidth plotted of 45 to 55 %RH is more stringent than desired by the KB.

4 Different position of collection 'special sizes'

There are currently 2 options for the 'special sizes' collection:

- on a grilled floor on top of the shelves in the repository part and/or
- on the 3rd floor of the front building.

Both are simulated. It is assumed that when the 'special sizes' are stored in the front building, all walls, floor and ceilings are being insulated with 8.0 m²K/W and that the created space is open towards the repository (with a grille for safety).

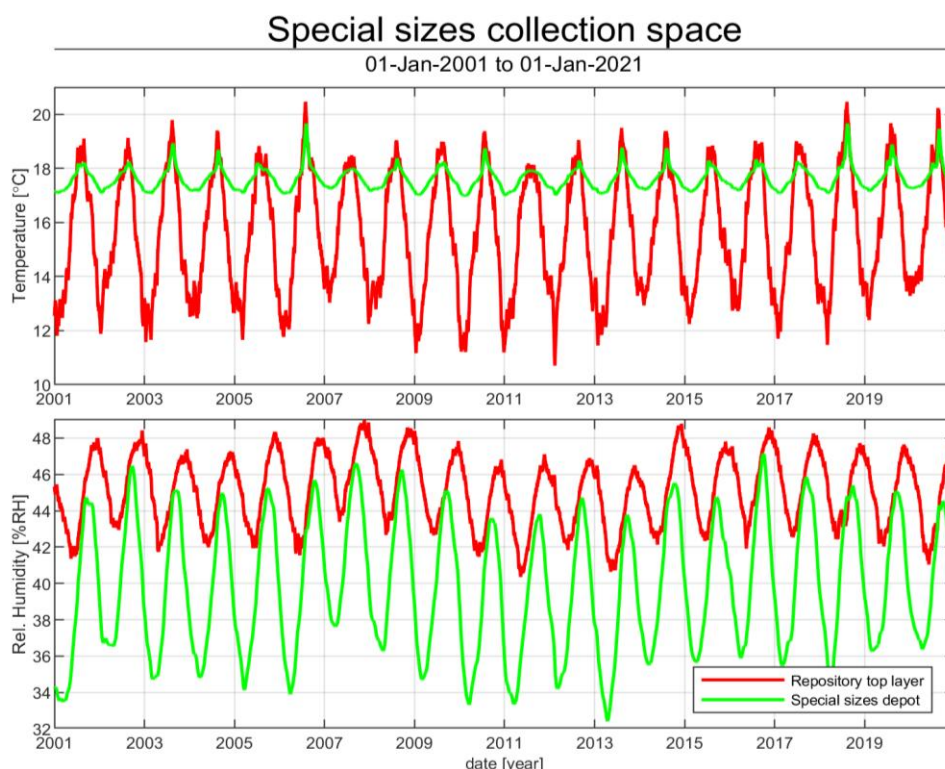


Figure 3: Temperature (top) and relative humidity (bottom) at 2 locations for special sizes

Figure 3 shows that the top layer of the repository will have a winter temperature around 11 to 13 °C, while for the depot in the front building this will be around 17 °C. Because of this temperature difference (while having a similar humidity mixing ratio), RH will drop to lower values for this depot with a minimum of 32.5 %RH. Also the yearly fluctuation is about 10 to 12 %RH, which is quite high. That is not beneficial for safekeeping the collections.

In order to improve the behavior of the depot within the front building, 6 different measures were simulated and assessed:

1. Higher air flow (forced) in between repository and 'special sizes' depot;
2. Placing the 'special sizes' depot at the 2nd instead of 3rd floor;
3. Increased insulation in between 'special sizes' depot and front offices;
4. Letting the air return to the low-oxygen system go through the depot;

5. As 4, but return air is routed towards the 'special sizes' depot, while maintaining the same exhaust and inlet in the repository as planned;
6. 'Special sizes' depot completely separated as individual climate zone.

Figure 4 presents an overview of the calculated indoor climate in the 'special sizes' zone. Variants 4.1, 4.2, 4.3 and 4.6 still show higher temperatures (in winter down to about 16 °C); only 4.4 and 4.5 have a winter drop in temperature that resembles the repository (both show a minimum of 12.3 °C). Only 4.6 has a controlled RH in between 45 and 55 %RH by using a separate system (which is against the passive principle); the other variants show a resulting RH of the repository absolute humidity in combination with a different temperature profile. Only variants 4.4 and 4.5 obtain an RH that meets the requirements.

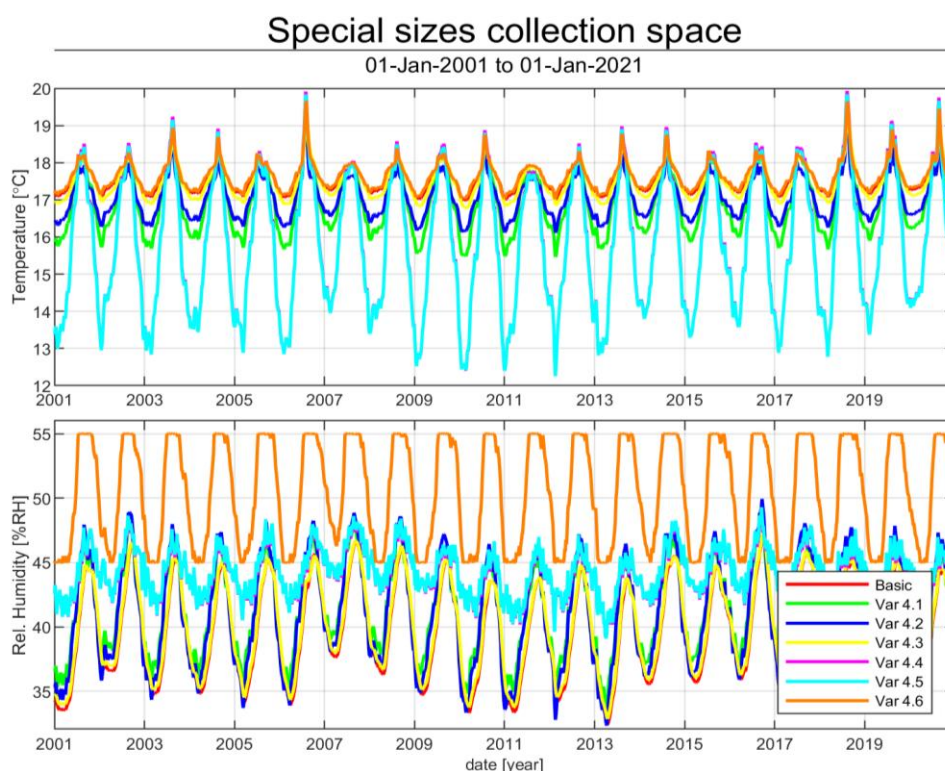


Figure 4: temperature (top) and relative humidity (bottom) for 5 different simulations

The only method for the 'special sizes' collection area to resemble the indoor climate in the repository is to have a return air grille in this area and under-pressurize this area to allow for enough air flow. NB: this air flow is about 1.000 m³/hour (half of the total return air!).

Table 7 confirms this: only model 4.4 and 4.5 (green) have a similar average temperature and relative humidity compared to the repository (orange).

The difference between 4.4 and 4.5 is that in variant 4.4 the 'special sizes' depot must have an open connection to the repository and therefore must be placed adjacent to it, with openings in the wall. Variant 4.5 is more flexible: the return air ducts are led to the depot space; the position of the ducts in the repository can remain the same (at floor level near the front part), while the depot itself does not need a direct connection to the repository; it can be placed where it suits best.

Table 7: Results of design phase model, for 6 variants. The yellow area marks the repository conditions (at top level), the green area shows the best fit to these conditions

	Temperature [°C]						Relative Humidity [%RH]					
	Min	Max	Av	S-	S+	Short	Min	Max	Av	S-	S+	Short
Above repository	10.7	20.5	15.6	3.8	3.5	0.87	40.4	49.0	45.1	3.9	3.4	0.59
Front depot Basic	17.0	19.7	17.6	0.6	1.0	0.28	32.4	47.1	39.9	6.6	6.1	0.89
Front depot Var 4.1	15.5	19.8	17.0	1.4	1.6	0.39	33.6	49.0	41.4	6.4	5.9	1.32
Front depot Var 4.2	16.1	19.5	17.1	0.9	1.2	0.34	32.3	49.9	41.2	7.4	6.9	1.44
Front depot Var 4.3	16.8	19.4	17.5	0.7	1.1	0.22	32.8	47.2	40.2	6.4	5.9	0.88
Front depot Var 4.4	12.3	19.9	15.9	3.1	2.9	0.65	39.1	49.1	44.3	3.9	3.3	1.19
Front depot Var 4.5	12.3	19.8	15.8	3.0	2.9	0.65	39.1	49.3	44.4	3.9	3.4	1.20
Front depot Var 4.6	17.0	19.7	17.7	0.6	1.0	0.27	45.0	55.0	50.5	5.5	4.5	1.49

It can be concluded that variant 4.5 would be the most appropriate option. The 'special sizes' depot needs to be an insulated (around 8 m²K/W) part in the front office building with 1.000 m³/hour of return air out of the repository, which is extracted out of the 'special sizes' depot and directly fed into the low-oxygen climate system. To avoid leakages, an air lock needs to be used and the construction needs to be airtight (no office air entering).

5 Answering the research questions

How does the building behave after some design changes?

Very similar to the realistic optimized model; differences are in the order of 0.1 °C and/or 0.8 %RH.

Where can the 'special sizes' collection best be stored?

Looking at indoor climate alone, the collection can best be placed on top of the crated collections in the same repository area.

Storing the special sizes in the front building can only be done by taking precautions.

Are additional measures needed to make the collection area in the front building suitable?

Yes; the effects of extra insulation and extra internal air flow are too limited to provide for a climate that is nearly identical to that of the repository. The only option to cater for a similar climate is to direct half of the return air (recirculation for the low oxygen system, in total 2.000 m³/hour) to the 'special sizes' collection area. This can be done by placing both areas adjacent to each other or by rerouting the return air by using additional ducts (which makes placement of the 'special sizes' depot more optimal).