Thermocultures of Memory

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Memory institutions depend on heating-cooling infrastructures for the long-term preservation and mediation of cultural heritage. The energy-intensive thermal regulation of object and data storage environments is guided by the need to ward off decay and to safeguard computer hardware and operations. Despite the tremendous dependence of memory institutions on thermal regulation, temperature has been regarded as merely metaphorical in media studies (Sterne & Mulvin, 2014; Starosielski, 2014). Digital studies in cultural heritage (Cameron and Kenderdine, 2007) have also bypassed the topic of temperature and humidity as it affects the representation of cultural memory. In fact, there hardly exists any literature on the evolution of thermal cultures of memory institutions even though they might be considered as thermally-dependent media institutions. This article explores how thermal infrastructures are entangled with the preservation of cultural heritage in order to show how the latter is linked to the expanding use of energy and the embodied energy of natural resources. Understanding the energetic and material impacts of thermal infrastructures and practices in museums and archives demands us to ask ourselves: What are the origins of temperature control and humidity in memory institutions? How did the superimposition of the thermal cultures of the factory affect the practices of the museum? In addressing these questions, my goal is not only to direct attention to the materialities of thermal practices but also to provoke an ecological approach for the future of the memory institution. Could a re-evaluation of thermal infrastructures and practices shape an ecological institution?

Introduction

Under the shiny multi-touch tables of the Cooper Hewitt Smithsonian Design Museum in New York lie extensive energy-consuming thermal infrastructures. Behind the walls and under the ceilings run large-scale HVAC (Heating, Ventilation, Air-conditioning) systems configured to support preservation-level climatic control and visitor comfort. Embedded, entangled and riding within this infrastructure are other artifacts you will come upon: cabling for media exhibits, lighting systems, fire-safety sensors and electrical points. Zoom out of Manhattan and you will reach the museum's conservation and storage facility in New Jersey located in a remote low-cost warehouse. It is equipped with energy-intensive climate controls to provide the desired stable interior climate for the optimal conservation of design objects. Artifacts stored here constitute a high proportion of the Cooper Hewitt's design collections. The HVAC infrastructure constructed per object and the resulting energy use is a substantial percentage of the museum building itself. Zoom out further, and you will come across another prodigious concrete warehouse, a data center in Virginia that holds thousands of dedicated computer servers under strict regulations of temperature control with multiple redundancies of power sources. Their contents comprise the digital collections and administrative data of the Design Museum. The data center requires huge amounts of dedicated electrical power to maintain the optimum thermal conditions.

At most memory institutions such as the Design Museum, the regulation of temperature and humidity sustains exhibitions, artifact and digital collections. Besides providing the necessary thermal comfort of visitors and museum workers, thermal regulation is a condition for memory retrieval especially of digital assets, which is dependent on the calibration of temperature and relative humidity (RH) of data servers. In short, thermal regulation practices have a trio of purposes at memory institutions: first, to preserve vulnerable cultural objects; second, to safeguard digital assets and finally, to provide thermal comfort for visitors and workers. Not surprisingly, thermal practices have high energetic costs, which results in a significant carbon footprint of memory institutions. As Starosielski remarks, the 'stabilization of media in archives and [other memory institutions] keeps them from degrading, becoming waste, [yet] the shift to energy-intensive cooling mechanisms substitutes the waste of media objects for the waste produced by fossil fuels' (Starosielski, 2017: 303).

Thermal practices, or the practices of regulation of temperature and humidity, did not originate with the museum. They first appeared in factories and cinemas, building typologies that were isolated from the outside environment. Air-conditioning (AC) systems were initially developed for the standardization of materials and to maintain their purity, and they were then exported and adapted to memory institutions. Just as standardized temperatures and humidity levels were developed for manufacturing, they were also later customized for the preservation of cultural objects. Thermal cultures of the factory were transposed by engineers onto the museum just like any other facility in need of thermal management as 'solutions'. As Starosielski observes, there is something 'cultural' about such a transposition:

> The thermal manipulation of media's production and storage environments [was] guided by cultural investments: in the expansion of the lifetime of the media object, in its crystallization in a particular form that mirrors the moment of production, and in its ability to represent a given historical moment. (Starosielski, 2017: 303)

The factory and the museum share a certain cultural investment on thermal practices, albeit for diametrically opposite reasons. While in factories AC was used primarily as a deterrent for material degradation and to reduce waste for increased profitability, in museums such a deterrent had a non-profit orientation, namely, mass preservation. Temperature and humidity might be the common links between mass production and mass preservation. The factory as the 'object producing machine' mirrors the museum that has become, according to Rubio, an 'objectification machine' (2014: 620).

While much has been written in the fields of Architecture and Engineering regarding climate control design and construction, and while there exists a plethora of research in Conservation Studies focused on temperature and relative humidity (RH) conditions for artifact collections and historic buildings, not a lot can be found regarding thermal cultures in Museum Studies, which has focused on collections, storage, and exhibitions, leaving the thermal conditions of such objects to the conservator and the archivist. In both Museum memory studies (Bennett, 1995; 2003; Henning, 2006; Kavanagh, 2000; Pearce, 2013) and Digital Memory studies (Ernst, 2013) there is hardly any mention of humidity or heat as related to archives. Across the humanities temperature appears mostly as an image of force, which contrasts with temperature figured as a medium (Ernst, 2014: 2535). My goal is to go beyond metaphorical depictions of media and memory, to the actual thermal conditions for cultural memory.

This article traces one set of thermal practices, those that began in the factory for the maintenance of raw materials and for the comfort of workers and were then transferred to museums and archives for the preservation of cultural heritage. I seek to examine how thermal regulation and engineering was exported from the industry to museums and galleries, the resulting thermal practices of these institutions and finally, the energy costs and carbon footprints of cultural preservation. In the first section, I trace a brief history of thermal conditioning in memory institutions, namely, air-conditioning borrowed from the factory. I show that the infrastructure that aided the comfort of workers and preservation of raw materials was transferred to the museum for the preservation of cultural artifacts and comfort of visitors. In the second section, with the aid of case study conducted at the Cooper Hewitt Smithsonian Design Museum in New York, I examine the various parts of a contemporary museum where climate control is deployed. I discuss the thermal practices involved and the energy consumed. In the final section, I discuss contemporary efforts in the museum sector to re-evaluate and re-design thermal practices, and eventually reduce the energy costs of climate control.

By showing how temperature and humidity are tangible concerns and materialities governing memory institutions, I argue that a thermal perspective expands our understanding of a wider web of ecologies of cultural heritage. It takes us beyond metaphorics, to the climate, the ground, and the energies circulating in the environment (Parikka, 2015). By looking at the origins of thermal practices, their superimposition on museum and archival practices we can also start to pay attention to the particularity of long term preservation needs whether they may be objects or digital memory. The study of thermocultures of memory institutions offers an alternative to the existing narratives found in architecture, engineering and historic preservation. It commands us to research and design for —'collections of processes rather than for collections of "objects"' (Rubio, 2014: 620). It offers a common ground for temperature, humidity, material culture and mediation to be discussed in relation to one another, instead of as separate domains. It also provokes a discussion of the impacts of energy use and ecological roles of memory institutions.

Thermocultures: From Factory to the Museum

Since the early decades of the twentieth century artificial climates were the stuff of science fiction novels (Cooper, 2002). The domed city with controlled temperature, humidity and air quality has been a repeating vision since the early twentieth century. From the films *Logan's Run* and *The Truman Show* to Buckminster Fuller's geodesic dome, the concept of a glass-enclosed utopia has thrived in the public imagination. In literature, one may find several such competing visions as in William Gibson's *Neuromancer*, Samuel R. Delaney's *The Fall of the Towers* and China Mieville's *Perdido Street Station*. What they represent, besides the post-apocalyptic and exploitative nature, is a thermoculture brought on by engineering quests to have a complete artificial environment—a mechanical reproduction indoors of the best weather outside (Cooper, 2002). It is also an internal environment, not visible to the external public, as in the cinema in the 1920s where the first iterations of air-conditioning was applied.[1] Both the engineered factory and the museum share this phenomenon of a controlled internalized environment.

Fig.1. R. Buckminster Fuller stands in front of a depiction of his domed city design at its first public showing at a community meeting in East St. Louis, Illinois. Image by Steve Yelvington (CC BY-SA 4.0) Source: Wikimedia Commons

In this section, I examine the brief history of thermal cultures from factories to memory institutions such as the museum. As mentioned earlier, the architecture of the museum closely followed that of the factory, as its open space and volumes required a similar degree of climate control infrastructure. The museum as a space was, like the factory, climatically different, insulated and invisible to the public outside. Thus, air conditioning that sustained manufacturing conditions, was perfectly suited for museum buildings. Thermal comfort for machines, materials and workers, although different and unique, were extended to cultural objects and visitors. Thermal standards that aided the preservation of raw materials and their purity became codified for the preservation of cultural artifacts. Steyerl (2009) compares the museum as the new factory, where something continues to be produced behind the walls. Spectators become workers, toiling between thermally-regulated exhibition rooms, doing work. The climatic objectives of the factory, the cinema thus carries over to the museum: that of keeping workers, viewers, products and objects under an artificial thermal utopia.

Much of the architectural aesthetics of museums is still borrowed from the factory: closed windows, blind walls, thick ducts and pipes that snake across the ceiling. Early modern museums with their high ceilings and infinite free spaces were similar to the column-free spaces of the factory. Perhaps one can blame modernist architecture for the fascination with factory-like long spans. Especially for museums built in the International Style long-span halls containing an enormous volume of air had to be regulated. This architecture with its industrial volumes required more heating/cooling, and the air-conditioning that assisted manufacturing conditions thus seemed perfectly suited for museum buildings.

Early air-conditioning systems offered factories greater control over atmospheric conditions. As Cooper points out, ‘the combination of ventilation and humidification in a single apparatus permitted the replacement of open windows with a mechanical system. Manufacturers could now keep factory windows closed’ (2002: 22). This was thought to be beneficial for working conditions for the proper running of work without interference from outside, and the closed-window strategy soon became an ideal for factories as the most favorable conditions of manufacturing.

Although not mechanically controlled, Joseph Paxton’s Crystal Palace of 1851 was one of the first such industrially-inspired glass and steel buildings that fostered a micro-climate within Hyde Park, London. Yet the science of thermal preservation of cultural objects had not reached a maturity at this time, and was not incorporated into the structure, which was guided then only by the utopian thinking of modern architecture. Museum administrators often did not have the expertise and knowledge to participate in the design of climate control systems. Sometimes, even institutions were not completely convinced about the thermal control of their indoor environments. Planning for preservation was totally lacking in the past and is today tacked on as an ancillary (Thomson, 1986). According to Legnér, ‘limited communication between curators and engineers [are] obstacles standing in the way of a more profound understanding of the museum environment’ (2011: 134).

As it became apparent, in the museum, the installation of large HVAC systems to maintain ideal thermal conditions required the least transparent surfaces and allowed the museum to enclose itself behind walls. This enclosure was also attributed to the increased wall spaces for hanging bigger pieces of art, and for focused observation in exhibitions. Examples can be seen in the architectures of the Guggenheim Museum, the Museum of Modern Art, and other museums where exterior glazing is rendered minimal and the buildings are introverted. On the other hand, Mies van der Rohe's fully-glazed Neue Nationalgalerie (undergoing renovation since 2015), encloses almost 22 thousand cubic meters of air volume that needs to be treated by mechanical means. Whatever openings to the world outside are insulated, and layered to prevent the external environment from creeping in. In exchange for visitor comfort and safeguarding of cultural heritage, the museum thus seals itself from the outside, just like the utopian domed cities.

Not much has been written about the history of thermal control in museums, but it is possible to gather accounts from conservation history and engineering. In the 1910s and 1920s an increasing concern for the effects of temperature and humidity on collections forced museums in Europe and North America to install climate control systems (Bewer, 2010). According to Legnér (2011), thermal regulation commenced at Yale University's art gallery, where a steam heating system was installed in 1874 with the intention of reducing the deterioration rate of the panel paintings. By 1908, the Museum of Fine arts in Boston had installed humidity controlling and air filtering systems. The Cleveland Museum in 1915 put in place a 'plenum air system' that cleaned air going into the galleries with a water spray. And in 1930 the National Gallery in London investigated the possibilities for an air-conditioning system.[2] Legnér mentions it was only in 1932 that the National Museum in Sweden obtained mechanically humidified air.

Yet, by this time, almost all attention on indoor climate was focused on keeping temperature stable, whereas relative humidity was not considered important (Cooper, 2002). [3] By heating museum spaces and providing window ventilation, temperature was thought to contain the deterioration of artifacts and still maintain thermal comfort. For centuries, moisture control meant diverting rainwater away from the building and providing heat by fireplaces. Since there were hardly any controls on humidity, most early museums in Europe and North America would have had summer interior humidity between 60 to 90% RH. In winter, RH in heated zones would fall to 30, 20, or even 10%, causing huge fluctuations that resulted in damage to collections (Brown & Rose, 1996).

Figure 2. Factories were among the first to adopt modern air conditioning. Image & Source: Willis Carrier (fair use)

It was at this time thermal practices originally intended for metals and minerals were extended to museums and cultural artifacts. Temperature regulated for the comfort of workers became the temperature for museum visitors. Thermal practices that maintained the 'purity' of metals turned into benchmarks for cultural preservation for over a century. Mechanical infrastructure was borrowed from the factory and superimposed on museum buildings. Engineers re-purposed equipment that maintained the purity of materials and manufacturing processes towards artifact collections. Being based on recommendations and assumed values, these engineered mechanical systems were unorthodox, expensive to build and maintain. Thus, their reliability was compromised. While in the case of factories engineers recognized the need to design both for the architecture and the specific activities, building and process, such an awareness did not carry over to the design for museums (Cooper, 2002: 29).

Over the decades, the numbers had become standards, as guidelines for engineers (Michalski, 1993; 2015). Museums assumed that these values were scientific, based on a significant minimum in deterioration. According to Brown and Rose, "empirical observation of the reaction of cultural artifacts to variations in relative humidity (RH) over the last eighty or so years has become progressively codified into recommendations for "optimum" humidity levels for the preservation of these artifacts . These figures have arisen not from detailed research but are codifications of pre- World War II custom and practice, modified by the practicality of interior environmental control in specific climates" (Brown & Rose, 1996)[4] Thus, "the notion of an optimal museum environment evolved in the twentieth century to "the more stable, the better": [it was] not the collection, nor the building requirements, but the capabilities of the HVAC systems [that] determined the level of indoor climate conditioning" (Kramer et al., 2016). Today, a variety of standards for optimum relative humidity for historic buildings and their artifacts are based on custom and practice rather than well-designed research.

Finally when machines reappeared in the form of computing hardware and server rooms in museums, thermal control began to span the entire gamut of regulations governing the original factory. The thermal infrastructure of the factory thus presented itself as the ideal model for the thermal infrastructure of the museum. By such transposition, the aesthetics (engineering) of thermal control prevalent in industrial contexts were also carried over to memory institutions. From factory to the museum to the data center, thermal infrastructure gradually developed into an enormous composition of materials, metals and resources and not only that, its very operation affected a high energy footprint. Today, thermal conditions and associated practices are responsible for a great amount of climate control infrastructures and in turn energy consumption in memory institutions.

Thermocultures of a Design Museum

In this section, I investigate the thermal conditions and infrastructure of the renovated Cooper Hewitt Smithsonian Design museum, especially as related to its exhibition, storage and data center. I also examine how HVAC manifests in a museum in its various parts, and how these varied thermal infrastructures are responsible for extensive energy footprints. Although this particular museum is not a converted factory, and is instead a retrofitted mansion, its HVAC is composed of industrial systems. Underneath the historic facade, a complex infrastructure maintains the thermal conditions of the galleries and exhibition halls. Under stringent climatic control is also the museum's collections storage housed in a retro-fitted warehouse. The museum's data center in Virginia forms a remote support facility that is also supported by sizeable

HVAC systems. Usually, these energy-intensive mechanical infrastructures, among other electrical distribution, sanitation, building skin envelopes and security networks, are the highest energy consuming components of the museum (Mendler & Odell, 2005). As the museum's collections including digital assets grow and its media infrastructure expands it begins to rely overly on thermal practices to safeguard computer hardware and processes. In fact, thermal infrastructure needed for digital media becomes a priority, much more than the thermal preservation of cultural artifacts.

Retrofitting an old building, a historically protected structure, is no easy feat. The Carnegie Mansion was originally remodeled in 1976 to convert its residential layout to a public gallery for displaying design objects. The recent renovation has gone a step further in incorporating advanced media infrastructures within its walls and floors, new vertical transportation systems and concealed HVAC systems under the roof. Underneath the skin of the museum run large-scale HVAC ducts that are designed for preservation-level climatic control not only for artifacts but also for a great number of media exhibits. Cabling, lighting, fire sensors and electrical junctions, all are embedded within this infrastructure. Others such as sprinkler systems, water supply and sewage systems form another complex layer inside the museum walls. All of these are required for the efficient functioning of the museum's storage, exhibition and media distribution systems.

Most of this infrastructure and operations are concealed behind walls and basements, buried deep inside the museum hidden from view or only accessible by authorized personnel. The lighting systems are based on sensors and timers, linked to the security cameras and other alarm devices. Cables, ducts and wires housed in metal trays are secured and hidden from view in an interstitial floor above the foyer level. The materialities and embodied energy of this infrastructure is hard to comprehend and calculate. But for an old heritage building such as the Carnegie Mansion, it is inevitable to utilize mechanical systems rather than alter historical architectural features. This invisible infrastructure of mechanical climate control is an essential support system for the design artifacts on display at the museum. The energy reports of Cooper Hewitt Smithsonian Design Museum show an annual consumption of 7,73 kiloWatt-hour per square foot (sqft). For 17 000 sqft, this amounts to 131 410 kWh or 131,41 MWh (megawatt-hour) (Bhowmik, 2016).

During the renovation, new HVAC systems were integrated, in addition to new gallery areas, adjusted for the incorporation of a considerable quantity of new media devices, including a plethora of multi-touch tables, touch screens, computers, sensors and so forth. Gallery ceilings were disassembled so that electrical, plumbing, and security could be installed as part of the primary thermal infrastructure that services both the Mansion and the administration building (Miller & Fox Townhouses), followed closely by the lighting systems, security, cabling, indoor transportation systems and wireless network systems. The HVAC itself consists of a series of interlinked material apparatuses such as dampers, pre-filters, preheating coils, supply fans, cooling coils, reheating coils, humidifiers, return fans, air handling units and room sensors. These are overlaid on top of the thermal infrastructures or ride closely throughout the building. Here, controlling the HVAC for Relative Humidity (RH) as tightly as possible is considered the best possible course. Guidelines with a strict allowable bandwidth for RH are based on the mechanical limitations of HVAC systems rather than on the museum's collection needs. Thus, optimizing the indoor climate of the museum primarily by mechanical systems is favored over design and architectural features. These tight boundaries for temperature and RH often result in the assembly of vast and energy-guzzling equipment (Janssen & Christensen, 2013).

The second crucial supporting structure of the Design Museum is its conservation and storage facility in Newark, New Jersey that functions as a physical repository for the Design Museum's artifact collections. The building itself is a converted warehouse, a white concrete building occupying an entire city block, with windowless and climatically sealed floors. All street level windows and entrances are blocked off save for the main entrance that has a double security door. Its thermal infrastructure is another concealed thermal component that provides the required stable interior climate for optimal conservation of objects leading to increased energy consumption. The variety of artifacts here usually constitute a high percentage of a museum's collections since at any given time exhibition facilities can only support a fraction of the total artifacts. These range from furniture, ceramics, sculptures, paintings, handlooms, textiles, posters, and technical media. Here, a few thousand design artifacts are placed in separate climate controlled chambers. Each room is filled with mobile compact storage units as well as tall metal storage racks placed in rows along passageways. Artifacts are either wrapped in protective packaging or vacuum-packed in these racks. Early Herman Miller chairs dot the collection without occupants, and design artifacts lie around wrapped in cellophane. Each individual storage rack is identified by its number and code sticker and placement on a floor plan layout. The view is reminiscent of factories and storage warehouses.

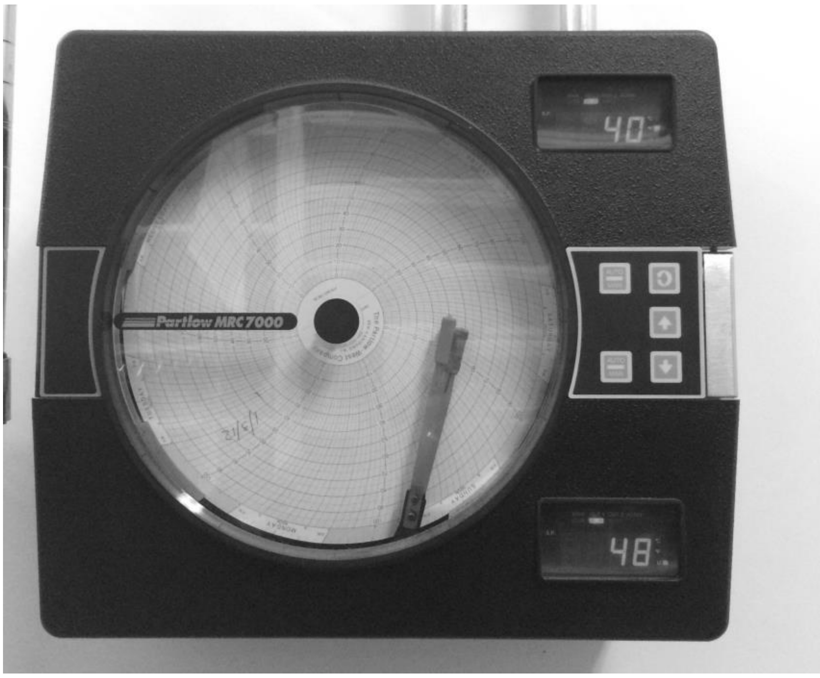

Fig. 3. The Circular Chart Recorder at the Crozier Storage and Conservation Facility of the Cooper Hewitt Smithsonian Design Museum records temperature and humidity measurements on a round chart over a timed interval. Image by Samir Bhowmik.

A prodigious network of air ventilation ducts, pipes, cables, cameras and exposed sprinkler-heads run on the ceiling. In a smaller chamber, inside multiple sealed glass compartments are older design artifacts from the early twentieth century. More than 200 000 objects are stored in these storage chambers. A high energy use footprint including the energy costs of transportation of artifacts back and forth has been the prime outcomes of this isolated and invisible infrastructure. The wall-mounted Circular Chart Recorder is usually set between 40 and 48 RH. The recorder is microprocessor-based and capable of measuring, displaying, recording, and controlling up to two process variables from a variety of inputs. These process variables include temperature, pressure, level, and flow. All climatic data can be monitored and recorded. The levels maintained here are quite stringent, much more regulated than prevailing International Standards such as ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers), EU's Committee for Standardization and UK

British Standards Institution (BSI). As a consequence the energy bills range in the thousand kWh mark.

Finally, the digital assets of the Design Museum are situated in the so-called 'Cloud'. In fact, the 'Cloud' in its physical manifestation is a concrete-steel warehouse: a Data Center housing thousands of dedicated computer servers under precise air conditioning, multiple energy back-ups and redundancies. In general, Data Centers are invisible infrastructural and technological black boxes. They contain entire arrays of computer systems, storage components, air conditioning, fire suppression devices, security controls and redundant telecommunications connections. Cabling trays, standard racks to mount equipment, raised floor systems, and many other material components form the infrastructure of a Data Center. Not only these have high embodied energy, in their entirety are energy-consuming. They also require substantial dedicated electrical power.

The Design Museum's host, the Smithsonian Data Center in Virginia contains over a thousand servers. The contents in its servers comprise digital heritage collections, scientific, and administrative data of the Smithsonian Museums including that of the Cooper Hewitt. Within the Data Center, two Dell Poweredge servers handle the collections database of the Cooper Hewitt's collections database. The servers contain over 273 404 object records and 90 012 image records. The Collections database in the data center is the backbone of Cooper Hewitt's daily museological operations. The servers assigned to Cooper Hewitt consume over 20 kWh/per month. A quick calculation shows that the carbon emissions is equivalent to 178 pounds of coal burned. The data center's energy reading in May 2014 was 1723 kWh (average of 20 676 kWh annually) equivalent to 1.2 metric tons of carbon dioxide emissions, 134 gallons of oil consumed, or 1276 pounds of coal burned. Its UPS (Uninterruptible Power Supply) meter reading was 278 KW, or about 0.192 metric tons. Together they clock carbon emissions of over 16.5 tons of CO2 annually. 13.6 acres of forests could only offset that. [5]

This case demonstrates how infrastructures needed today to support a museum's thermal conditions and practices have proliferated in materiality and energy use. The above analysis also shows the multiple levels and environments of thermal control in a memory institution. Combined with the already codified benchmarks which were the results of custom and practice, we enter a complex level of thermal practices and infrastructure. It is clearly evident that a media technologyintensive museum needs complex and sophisticated climate control infrastructures serving an array of physical and digital objects, humans and non-human media, much more than what the factory of the twentieth century needed. This complexity is also the cause of substantial energy consumption and carbon footprints. Beyond designer chairs and twentieth century textiles, the museum now also has to have thermal infrastructures in place for a growing proportion of digital media, computing hardware and digital storage systems. The climatically controlled spaces of the museum thus extend to the data center. As a consequence, a thermocultural study of the museum would now have to also consider the temperature and humidity regulation of a new cultural artifact: the computer server.

The Future of Thermocultures

How can we build a critical approach to the thermal practices of memory institutions? How would this extend our understanding of the impacts of cultural heritage preservation on the environment? Could we switch from designing generic climate systems to ones specifically aimed at cultural heritage objects? Can we manipulate relative humidity and temperature settings to reduce energy costs? Finally, would this allow us to reduce energy consumptions and carbon footprints?

In previous sections I have provided some evidence that temperature and humidity are energetic concerns and materialities. I have also shown these concerns were addressed earlier on in the architectural field and HVAC systems engineering that was then superimposed on museums. By seeking the origins of thermal practices, their adoption by museums and subsequent overlaying of thermal infrastructure, I hope to have provided a background for other research to build upon. With the example of the Design Museum, I have described how the thermal practices of the contemporary museum are spread over multiple domains and environments following multiple standards and benchmarks. I have also illustrated how these practices have high energy footprints. Perhaps, we can now start paying attention to the particularity of thermal practices whether they may be for design objects or for digital memory. Finally, there is need for awareness on these themes by further research and experiments; a priority to make thermal cultures of memory institutions as a field incorporating museum, energy, infrastructure and media studies.

To corroborate my argument, let us look at a recent study by Museums Victoria, Australia which found that temperature and RH international guidelines represent the major energy and money consumption in the museum, library and gallery organizations (CSPA, 2011). The study showed that museums were hardly involved in the planning of climate control infrastructure. There was a concern about the reality of climate change and rising energy costs. Significantly, thermal cultures of the museum: the maintenance of specific temperature, relative humidity (RH) and light levels were all questioned. The study suggests research into the possibilities for the relaxation of parameters for museums and galleries. To this end, EGOR (Environment Guidelines: Opportunities and Risks) set up by the UK NMDC (National Museum Director Conference) and AICCM (Australian Institute for the Conservation of Cultural Heritage) are investigating the implications with a set of multi-disciplinary researchers and practitioners in museums. Accordingly, several questions have been raised: those that of acceptable loss? Whether it is realistic to expect museum objects to stay under optimum temperature and RH considering the costs of energy use? Which alternative policies should be developed for cultural heritage? No doubt, altering such attitudes towards conservation by manipulating thermal practices will reshape the access, representation and mediation of cultural heritage in the future. With it will come a balancing act between energy use, climate change and how we value cultural memory.

I think there is a growing need to actively study these thermal infrastructures 'designed' for memory institutions since 'heat exchanges are not confined to communications systems, but move across and through infrastructure, ecologies, and bodies' (Starosielski, 2014: 2506). Thermal conditions have been rigorously investigated and modeled, but with only spatial, material and volumetric eye to detail, as in architectural and engineering approaches. Yet, buildings are dynamic spaces since collections are moved around, visitor counts evolve, artifacts are switched around and increasing amounts of digital media added. This dynamic quality of a museum is not included in initial energy models. Rough estimates, and early schematic programming drive the design of climate control systems in most cases and tweaked to some extent after commissioning and occupancy. The main occupants: workers who manage cultural objects and digital media are hardly engaged in the design of HVAC systems. But given that post-construction they are the main occupants and users, they should be involved in all stages of climate design, such as increased interaction in a multi-disciplinary design team that would include museum managers, curators, engineers and architects. The process of temperature and humidity manipulation cannot simply be left to technicians and engineers. Perhaps thus we could move from designing generalized climate control systems to ones aimed at cultural heritage management. By doing so, we might be able to regulate and customize relative humidity and temperature settings to particular contexts. Experimenting with new thermal protocols, guided by assessments from an environmental perspective, and even further study of degradation would entail a variety of novel interventions. The study of thermocultures of memory would thus provide a common platform for temperature and humidity, cultural heritage and mediation. It also would stimulate a discussion of the energy infrastructure, environmental impacts and ecological responsibilities. Finally, this may allow us to introduce a new regime of thermocultures for memory institutions and perhaps help to reduce energy consumption and carbon footprints.

Fig. 4. The study of thermocultures serves as a foundation for experimental art works such as the author's *Memory Machines* performative tour project that explored the thermal infrastructures of the Helsinki Central Library in 2019. Image by Juuso Noronkoski

In scholarship and research, museum and media studies could benefit from a study of thermocultures and look beyond metaphorical depictions of heat in media and memory. This would offer an alternative narrative to the ones originating from the fields of architecture, engineering and historic preservation. For long, museum studies have examined the humanities-focused topics of collecting, exhibiting, pedagogy and politics. The control of temperature and humidity was left to the conservationists and engineers, even though thermal conditions as we know today are intrinsic to the making and flourishing of arts, culture and civilization. Today, the museum has also become a place where human bodies, cultural objects and digital machines are simultaneously competing for thermal comfort and preservation. Additionally, these conditions are also competing in the diverse spatial and volumetric parts of the institution. As such the museum has transformed into a fertile ground for studying not only heritage, but also contemporary media culture, its dependencies, affordances, and practices as induced by temperature and humidity. The thermal infrastructure of the museum has itself become a cultural artifact, a giant archive worth studying.

Notes

1. The Cinema received the first complete air-conditioning system as introduced by Willis Carrier at Rivoli Theater in Times Square. The first design of a mechanical unit, which sent air through water-cooled coils, was not aimed at human comfort, however; it was designed to control humidity in the printing plant where he worked. See: http://www.williscarrier.com/m/1923-1929.php.

2. The building engineer J. Maclntyre proposed a value of 55% RH - 60 %RH, based on London's climate and the feasibility of the system. See Michalski (1993).

3. 'Humidity is most often associated with an increased probability of mold growth and other forms of bio-deterioration. Levels at 60% RH should be considered the threshold for damage. Since many collections are also hygroscopic, the humidity levels will also affect dimensional stability. Some types of wood board can vary up to one inch in length over a foot between 10% and 90% RH. Variation in relative humidity can loosen furniture joints, cause paint to chip from canvas, and cockle paper. In addition, fluctuating relative humidity can lead to chemical reactions. Metals will corrode, many dyes will fade, and even glass and mineral collections can be damaged.' Source: http://www.cool.conservation-us.org/byorg/chicora/chicenv.html

4. These standards for optimum relative humidity are generally based on: Italian UNI 10829:1999, the European EN 15757:2010 and the ASHRAE guidelines 2011.

5. United States Environmental Protection Agency, available here: http://www.epa.gov/ energy/greenhouse-gas-equivalencies-calculator.

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