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From Japanese Tradition: Is *Kura* a Model for a Sustainable Preservation Environment?

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INTRODUCTION

I have been monitoring and analyzing the environmental condition of the University of Kentucky Libraries for over three years as part of my job responsibilities. Through this monitoring experience, I became very interested in environmental controls and mechanical systems. More than a year ago, I had an opportunity to visit the new storage facility of the Archives of the Imperial Household Agency in Tokyo. When the AIHA built that storage building in 1989, they did not install a heating, ventilation and air conditioning (HVAC) system. The AIHA could have had any fancy environmental control systems they desired. I was curious about the AIHA's decision. I considered the Imperial Household Agency to be the last traditionalist agency remaining in the Stone Ages in Japan. Therefore, I suspected they were resisting new technology and sticking to a thousand-year-old tradition. After visiting their facility, I discovered my initial assumption was wrong, which led me to my research and today's talk about the storage facilities of the Imperial Household Agency (IHA). The IHA, a government organization, takes care of matters pertaining to the Imperial Household, assists in receiving foreign dignitaries, and performs ceremonial functions.¹

Originally established in the 8th century, the Archives of the Imperial Household Agency (AIHA) collects, preserves, and researches the Emperor's official and historical documents. Its collection, obtained from court nobles, lords, and prominent researchers, totals approximately 40,000 items.² The AIHA is open to the public. Users make appointments to use the requested items in the reading room.

The AIHA Building is located in the Imperial Palace at the center of Tokyo. The current Emperor lives at the Palace. The Palace was built on the grounds of Edo Castle in the 15th century, but most of the buildings were lost in fires and earthquakes. The current Archives building has three wings: the East Wing, built in 1989; the West Wing, constructed in 1992; and the Office Wing, which is situated between them. Each wing has an independent, mechanical, heating and cooling system, and is connected by bridges.

The East Wing is a four-story building with one basement, and houses rare paper-based materials. During research on the new East Wing's design, the AIHA staff is discovered that the HVAC system in other museums and archives often could not run

twenty-four hours a day due to the cost. Moreover, the HVAC systems rarely worked as planned. The AIHA was concerned about emergencies such as earthquakes: if the HVAC system stopped running because of a disaster, how could they avoid acute, short-term damage to the collections? Therefore, the AIHA decided to use an alternative to the HVAC system. This alternative was natural ventilation. The AIHA and SHIMIZU CORPORATION designed a low-energy building modeled after a traditional Japanese storage building called the Shosoin Treasure House. The Shosoin House is also managed by the IHA.

A TRADITIONAL STORAGE BUILDING: THE SHOSOIN TREASURE HOUSE

The Shosoin Treasure House was built in the 8th century during the Nara period (as a part of the prominent Todai Temple) in Nara prefecture. This 8th-century building has been well preserved to this day. The Shosoin treasure house is a repository of the treasures established by the widow of Emperor Shomu as a memorial to the Emperor in 756.³ The Empress gathered Imperial treasures and personal belongings of the Emperor and dedicated them to the Vairocana Buddha.

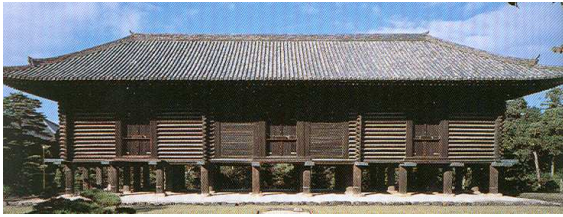
The Shosoin Collection

Most of the Empress' treasures, approximately 9,000 items, were preserved in this treasure house for 1,200 years, until they were transferred to the new air-conditioned storage in the 1960s because of potential fire hazards. The collection includes a great variety of objects and materials, such as manuscripts, furniture, musical instruments, stationery, armor, jewelry, herbal medicine, and textiles. Most of these treasures are in excellent condition. Their condition is partially due to the superior quality of the materials and craftsmanship used in their construction, and partially to the very limited access to the collection, which was granted only with permission of the Emperor. Only the Emperor could order the door of the treasure house opened. However, the storage environment itself is the key reason that the treasures are so well-preserved.

The Shosoin Building

The whole structure is built of *hinoki*, or Japanese cypress (Fig. 1). In Japan, 70% of the land is mountainous. Therefore, wood has traditionally been the primary building material in this timber-rich country. The treasure house was constructed of triangular timbers laid horizontally and of thick wooden planks, and it stands on massive pillars.⁴ There are no windows. The dimensions of the building are 108 feet long by 30 feet wide by 46 feet tall. The high, open stilts that support the floor prevent pests from entering, and provide good air circulation. Japan has heavy yearly rainfall, so the ground tends to be wet, and the air humid. Ground humidity and rising damp are major concerns of architects and caretakers. The distance from the base of the support pillars to the floor of the room is 9 feet. The inside of the building is divided into three sections: the northern, middle, and southern rooms. Each room has an upper floor, lower floor, and attic. The height of the first floor is 6 feet, the second floor 12 feet, and the attic 19 feet. The large, gable roof is made of tile, and the high ceiling and attic provide natural insulation. The long eaves, projecting 13 feet from the wall, shade the room from the sun. Individual treasures are stored in footed, wooden boxes made of *sugi*, or Japanese cedar, that are raised off the ground by four legs. The size of the boxes is approximately 40 inches long by 28 inches wide by 20 inches tall, with a board thickness of 0.79 inches (Fig. 2).

Fig. 1 Shosoin Treasure House



©Imperial Household Agency

Fig. 2 Japanese Cedar Storage Box



©Imperial Household Agency

The Environment at Shosoin

Masakazu Naruse at the IHA monitored the temperature and relative humidity (RH) of the Shosoin Treasure House using a type of data logger on the first and second floor, and inside of a cedar box placed on the second floor. The following analysis is based on his publication.⁵

Figure 3 explains the temperatures on both the 2nd floor and the outdoor regions surrounding the building from September 1999 to September 2000.⁶ The temperatures on the first floor and inside the second-floor box are not shown here because their data was almost identical to that from the second floor. The indoor temperature is closely related to the outdoor temperature and shows seasonal drift, but the fluctuation of the indoor temperature is smaller than the outdoor temperature fluctuation. (According to Naruse, on the second floor, the average temperature was 60.8°F, with the highest at 87.3°F, and the lowest at 32.9°F. The outdoor average temperature was 59.7°F, with the highest at 97°F, and the lowest at 26.4 °F.) While the temperature graph displays the moderate insulation capacity of the building, the humidity graph presents the more dramatic effect of the building's and box's construction.

Figure 4 shows the relative humidity of the outdoors, the second floor and inside of the cedar box.⁷ The indoor RH has a much smaller fluctuation than the outdoor RH, while the RH inside the box has an even smaller fluctuation. (Naruse reported that on the second floor, the average RH was 68%, the highest 96%, and the lowest 45%. Inside the cedar box, the average RH was 67%, the highest 77%, and the lowest 57%. Outdoor average RH was 72%, the highest 100%, and the lowest 16%.)

The stable RH resulted from the superior moisture-control ability of the Japanese cedar boxes and cypress building. The research concluded that the stable RH level, with only mild seasonal changes in temperature, was the major factor contributing to the preservation of the treasures. In

particular, these condition offered a significant advantage for the preservation of humidity-susceptible artifacts, such as wooden and lacquer objects.

Fig. 3 Temperature- Outdoor and Inside of Shosoin Treasure House (Sep.1999 - Sep.2000)

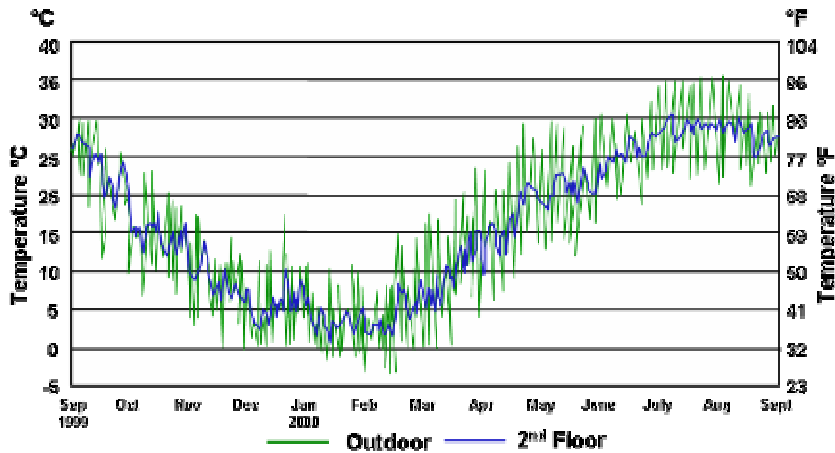
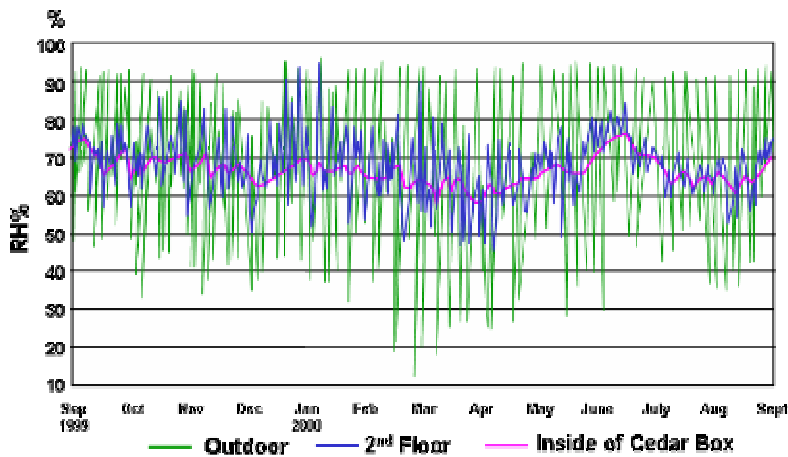


Fig.4 Relative Humidity - Outdoor, Inside of Treasure House, Inside of box (Sep.1999 - Sep.2000)



THE ARCHIVES OF THE IMPERIAL HOUSE AGENCY BUILDING

Knowing the limitations and advantages of low-energy storage houses, the AIHA staff convinced the administration and its architects to incorporate this low-energy building design into the new East Wing. The following components play an essential role in the energy-efficient concept of the AIHA building.

Key components in the energy-efficient East Wing:

- ✓ Favorable local conditions (climate factors, site conditions, orientation)
- ✓ Superior heat insulation
- ✓ Greater humidity control capacity
- ✓ Natural ventilation
- ✓ Air and particle pollution control

- ✓ Stable microclimate
- ✓ Human control

Favorable Local Conditions (Climate Factors, Site Conditions, Orientation)

What is the climate like in Tokyo? Most parts of Japan, including Tokyo, are in the temperate zone of the middle latitudes, with clear changes in seasons. Tokyo's winters are cold with occasional snow. By contrast, its summers are considerably warmer, with temperatures rising to over 90°F. June and July comprise the rainy season, but throughout the year, the humidity remains high. Tokyo has a heavy yearly rainfall. (The average yearly rainfall from 2001 to 2005 in the metropolitan region of Tokyo was 61.97 inches.)⁸ This year-round, high humidity makes Japan a fungal kingdom. Extreme seasonal temperatures, year-round high humidity, and a particularly hot and humid rainy season are therefore the climate factors to be considered in the design of the AIHA building.

The construction site was carefully chosen. The building was built on top of a hill because of its dry condition. The East Wing is oriented on a north-south axis to minimize the southern exposure and solar heat gain.

Superior Heat Insulation and Capacity

The East Wing's gable roof is made of copper. Mineral fiber was blown under the floor of the attic for insulation. However, the roofing material, which is copper, and the shorter attic height and eaves make it difficult to keep the top floor cool during the warm season. (Conservation scientist Toshiko Kenjo, at the National Research Institute for Cultural Properties, reported that when the temperature on the first, second, and third floors was 73°F, the fourth floor was 82°F⁹.) Roof windows are placed for ventilation.

The external wall surface is made of porcelain tile. The thermal insulation of 2 inches of glass wool board and dead-air space are between the interior and exterior walls.

Fig 5 East Wing Exterior



Greater Humidity Control Capacity

Controlling high humidity and resultant mold problems was critical in designing this building for the humid climate of Japan. The entire interior is made of wood, because of its superior humidity control. Japanese cedar is used for the walls and the ceiling, and Japanese oak for the floor (Fig.6). Japanese cedar and Japanese cypress are lighter-weight woods having a small specific gravity. Specific gravity is a ratio comparison of the weight of a material to water. It is obtained by dividing the weight of the material by the weight of an equal volume of water. The differences in the specific gravity of woods are accounted for by differences in the size of the wood cells and the thickness of the cell walls. Specific gravity is a general index for insulating efficiency, and also for humidity control capacity.¹⁰

In addition to the enduring proof of Shosoin that these woods act as humidity control materials, scientific research also confirms the superior humidity control capability of wood, particularly Japanese cedar, cypress, and other lighter-weight woods. Conservation scientists Kenzo Toishi and Toshiko Kenjo, at the National Research Institute for Cultural Properties, experimented with the changes in the moisture content of several wood species under different temperatures and RHs.¹¹ They found that the moisture control capacity had a close connection with the weight (specific gravity) of the wood.¹² At a given temperature, the lighter woods, including Japanese cedar and cypress, have the greatest moisture capacity: the lighter woods absorbed a greater amount of moisture from a humid atmosphere, and likewise they discharged a greater amount of moisture to the drier air. Responding to the rapid temperature change, the lighter woods also demonstrated a greater speed in both moisture absorption and release. For instance, Japanese cypress and *kiri* (paulownia), the lightest Japanese woods, took 10-15 minutes to reach equilibrium with the surrounding air by both moisture absorption and discharge. While heavier woods, such as oak and pine, discharged moisture in 10-30 minutes, their speed of absorption was much slower, taking 55-240 minutes.

Fig. 6 East Wing Interior



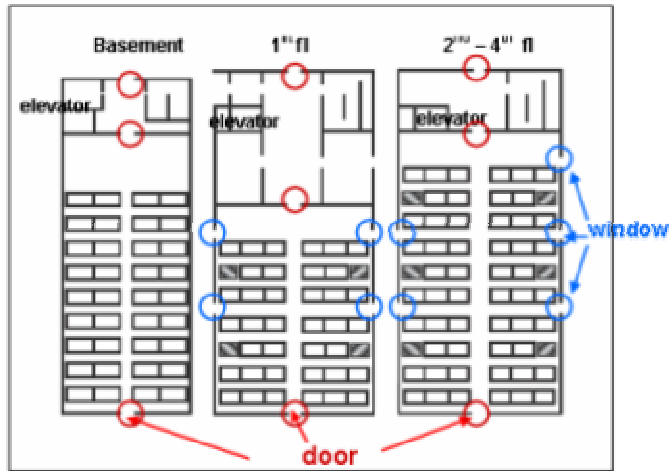
For better air circulation and a drier environment, the south and north sides of the basement are exposed to outside air.

Natural ventilation

Each room has four to five windows and two doors. The windows and doors are placed opposite each other to promote cross ventilation throughout the building (Fig.7). To promote good air circulation, the shelves are arranged in a way to avoid blocking the air flow from the windows

and doors. The bottom shelves are raised above the floor and each item is spaced on the shelf to facilitate the movement of air around it.

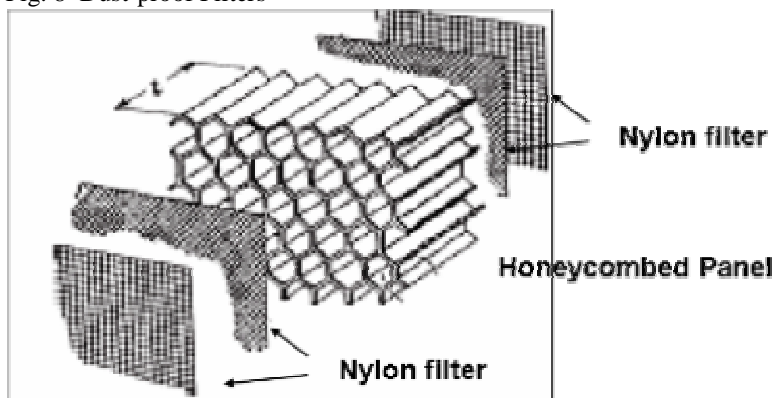
Fig. 7 East Wing Floor Plan¹³



Air and Particle Pollution Control

Dust-proof filters are installed in the windows and doors as insect screens normally would be. (Fig.8). In addition, shoes are prohibited inside to achieve a cleaner environment.

Fig. 8 Dust-proof Filters¹⁴



© Toshiko Kenjo

Stable Microenvironment

Every artifact is housed in wooden boxes to create a stable microenvironment. As we saw in Shosoin, Japan has a tradition of preserving artifacts in wooden boxes. Japanese cedar and *kiri* (paulownia), both lighter-weight woods, are the most commonly used materials, and are found in the AIHA (Fig.9). The majority of AIHA's boxes are made of *kiri*, which displays the greatest moisture control capability of any Japanese wood.¹⁵ Because its porous structure encloses a lot of small, dead air pockets, wood in general is a fairly good insulating material. Since the more dead air per unit volume the better the insulating value, lighter woods are better heat insulators than heavy woods.¹⁶ As mentioned before, *kiri* also displays the greatest capability to control humidity change. In addition to being stored in wooden boxes, some items are also wrapped

with Japanese paper for additional protection from the rapid changes in temperature and RH. In order to avoid creating stuffy air conditions inside the box, the AIHA's staff do not completely fill the boxes.

Fig.9 Kiri (paulownia) Boxes

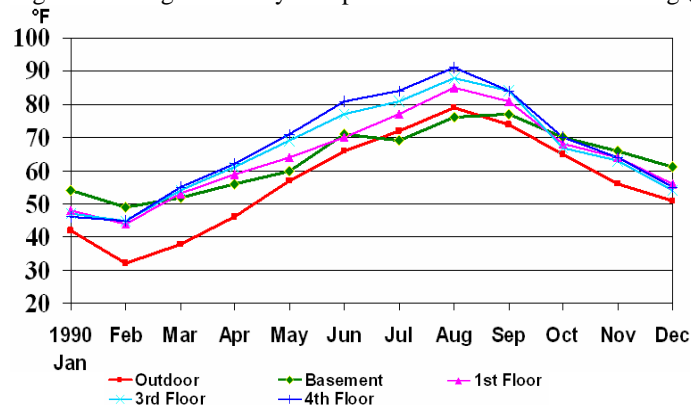


Temperature and Relative Humidity at AIHA

Toshiko Kenjo, at the National Research Institute for Cultural Properties, has monitored the temperature and RH in the AIHA building using data loggers, and published the results. The following figures are from her data.¹⁷

Figure 10 shows the average monthly temperatures in the basement, first, third, and fourth floors, and outdoors from January to December in 1990. (The data were recorded every two hours.) While the lowest outdoor temperature was 32°F, the lowest indoor temperature was 44°F, showing the building's good thermal capability in winter. However, summer temperatures were more problematic. During the hottest months of July and August, every floor but the basement recorded a higher temperature than the outdoors. The highest outdoor temperature was 79°F. The fourth floor measured the highest at 91°F with the next highest at 88°F on the third floor, while the basement was at 77 °F, showing a need for improvement in insulation during the summer.

Fig.10 Average Monthly Temperature Outdoor and East Wing (Jan.1990 -Dec.1990)



During this same period, the lowest outdoor RH was 39%, and the highest was 90%. The basement had the driest RH which ranged from 45% to 68%. The third and fourth floors

measured a higher RH, ranging from 58% to 73%, but the fluctuation range was much smaller than that of the outdoors, showing the building’s capability for humidity control.

Major, rapid fluctuations in temperature and RH cause damage and lead to dimensional changes and deterioration of the artifacts. Thus, the daily range of temperature and RH, which is the difference between the maximum and minimum temperatures and RH for one day, was examined for the period from January to December of 1990. The results are summarized in Table 1 and 2. The average yearly daily range was derived from the average monthly daily range.

Table 1 displays the daily temperature range. Each floor had small daily fluctuations, varying from 0.27°F to 0.56°F. When comparing the indoor daily range to that of the outdoors, the daily range variance of temperature on all floors was less than 10% of the outdoor daily range. For instance, the percentage of the basement change was only 2.88% of the outdoor change. (See “Ratio of the indoor AYDRR to the outdoor AYDTR.”)

Likewise, in Table 2, each floor had small daily RH ranges varying from 1.11% to 2.38%. The daily range variance of RH on all floors was less than 10% of the outdoor daily range. This analysis displays the building’s capacity to buffer acute changes and influences from the outdoor environment.

Table 1

	Average Monthly Daily Temperature Range (°F)				
	Basement	1 st Floor	3 rd Floor	4 th Floor	Outdoor
January	0.36	0.72	0	0.54	11.52
February	0.54	0.72	0.9	0.72	5.22
March	0.54	0.72	0.54	0.18	9.54
April	0.72	0.36	0.18	0.54	10.98
May	0	1.26	0.36	0.54	13.68
June	0	2.34	1.62	0.72	11.52
July	0	0.36	0.18	0.36	8.28
August	0	0.36	0.18	0.9	9.72
September	0.18	0.36	0.54	0.9	7.92
October	0.54	0.72	0.18	0.36	8.82
November	0	0.54	0.54	0.72	8.64
December	0.36	0	0.18	0.18	6.66
Average Yearly Daily Temperature Range (AYDTR)	0.27	0.7	0.45	0.56	9.38
Ratio (%) of the indoor AYDTR to the outdoor AYDTR*	2.88*	7.49	4.80	5.95	100

* 2.88 = 0.27 /9.38 x 100

Table 2

	Average Monthly Daily Relative Humidity (%)
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	Basement	1 st Floor	3 rd Floor	4 th Floor	Outdoor
January 1990	0.3	0.7	1.3	1.2	28.9
February	2	4	3.5	0.5	14.5
March	2.5	3	2.5	3	11.5
April	5.5	14	1.5	5	40.5
May	0.2	0.5	1.1	1.6	37.1
June	0.2	1.2	1	0.7	29.2
July	0	0.5	0.9	0.5	29.3
August	0.8	1	1.7	1.7	20.4
September	0.2	1.1	1.1	1	28.2
October	0.6	1.6	2.3	2.2	19.7
November	0.8	0.7	0.2	0.1	18.8
December	0.2	0.2	0.7	0.8	22.7
Average Yearly Daily RH Range (AYDRHR)	1.11	2.38	1.48	1.53	25.1
Ratio (%) of the indoor AYDRHR to the outdoor AYDRHR**	4.42	9.48	5.90	6.10	100

** 4.42 = 1.11 / 25.1 x 100

Based on these measurements, Kenjo reported that from June to October, the temperature and RH in the East Wing reached a level where xerophilic fungi (dry-loving mold) could grow. She recommended opening the windows and doors for natural ventilation, usually in the morning between 10 and 11 o'clock, when the outdoors is slightly cooler and drier than the indoors. Introducing fresh air to the room also creates air movement, which is important to avoid stuffiness and the resultant mold problems. Currently, the AIHA staff periodically checks the outside temperature and RH to assist in deciding if and when they should let in outside air. While this natural ventilation can reduce the potential risk of mold, it introduces rapid changes in temperature and humidity to the room. These fluctuations are damaging and should be minimized. Kenjo's experiment also found that the *kiri* (paulownia) boxes used at the AIHA greatly reduced the fluctuations in temperature and RH caused by natural ventilation.

One of the main concerns in using wooden materials for archival storage is indoor air pollution from acidic compounds in those woods. The quantities of acidic compounds (mainly carboxylic acids) vary depending on the variety of trees, regions, age, timber section, drying methods, and other factors. According to the National Research Institute for Cultural Properties, for instance, Japanese cypress contains less acidic compounds than foreign cypress that originated in subtropical regions; the center section of lumber is less acidic; and the timber treated by air seasoning gives off less acidic gas compounds than timber treated by artificial (kiln) seasoning.¹⁸ Traditionally, the lumber used for treasure boxes and storage buildings was prepared by a long period of natural air seasoning (over one year). However, lumber made by artificial seasoning and then imported from subtropical regions is increasingly used for these storage units. Such lumber retains large quantities of acidic compounds, including resin (which stains the artifacts and causes acidic deterioration), and off-gases acidic chemicals. At the AIHA, all the interior woods are Japanese species, but not all of the interior timbers were treated by air drying or had a

long (one year) air-drying period. Chemicals such as wood preservatives were not used on the interior wood. Likewise, no chemicals were applied to the wooden storage boxes.

Kenjo and the AIHA staff started monitoring the indoor air pollution immediately after the completion of the East Wing's construction, before any of the collections were moved in, and found resin contamination from the interior wood. Actions to remove the pollution were taken, including vigorous natural ventilation, the use of industrial dehumidifiers, and placing paper boards on the walls and floors. As a result, one year later, when the collections began to be brought in, no resin residue was observed inside the East Wing. (The East Wing had a scheduled waiting period of over one year after the completion of construction. During this waiting period, as mentioned above, environmental conditions were monitored and necessary improvements were made.)

Human Control

In addition to the low-tech environmental control system of checking the outside temperature and opening/closing the windows, the AIHA's labor-intensive practices are highlighted in the centuries-old traditional custom of *bakryō*. Once a year, in October, when the temperatures and RHs of indoors and outdoors become very close, the AIHA staff take every item out of the boxes to air them out, and to inspect for and prevent mold. The items are not taken out of the building, but are spread on large tables and carts inside the building.

CONCLUSION

The AIHA has achieved its primary goals in the East Wing's environment, including stabilizing the temperature and RH, and controlling the humidity and resultant mold outbreak. One of the key reasons for the AIHA's success is the use of local products and technology. For instance, traditional building materials such as wood proved to be one of the best methods of controlling humidity. The techniques of a multilayer enclosure system demonstrated its effectiveness in buffering rapid changes in temperature and RH. Another reason for this success is the employment of labor-intensive alternatives, such as opening/closing the windows, and annual airing-out practices. As Mr. Nakamura, who is responsible for collections care at the AIHA, said, this manual interaction with collections teaches the AIHA staff about their collections, the storage environment, and their responsibilities for collections care. These educational moments are the key to success in raising awareness about preservation and providing an optimum, long-term preservation environment.

ACKNOWLEDGEMENTS

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- ⁶ This chart was recreated from the temperature graph made by Naruse Masakazu in the publication (Naruse, 2001). For accurate data and interpretation, see the cited publication.
- ⁷ This chart was recreated from the relative humidity graph made by Naruse Masakazu in the publication (Naruse, 2001). For accurate data and interpretation, see the cited publication.
- ⁸ This number was taken from the data of Japan Meteorological Agency (<http://www.jma.go.jp/jma/indexe.html>)
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- ¹² According to Toishi and Kenjo, the specific gravity of *kiri* (paulownia) is 0.3, of *sugi* (Japanese cedar) is 0.49, and of *hinok* (Japanese cypress) is 0.59.
- ¹³ The drawing was recreated from the picture created by Kenjo. (Kenjo, 2002).
- ¹⁴ Kenjo 2002.
- ¹⁵ Toishi and Kenjo 1970.
- ¹⁶ Albert G.H.Dietz, *Materials of Construction: Wood, Plastics, Fabrics*. New York, D.Van Nostrand Company, Inc., 1949.
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