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A Collection Climate Control System for an Ethnographic Storage of a Museum in North of Brazil

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ABSTRACT

This article presents a climate control strategy for the preservation of collections, specially designed for and installed at the Amazonian ethnographic storage of the Museu Paraense Emílio Goeldi in Belém, Brazil. Technologically simple and low cost to install, the system is robust and economical when in operation. It aims to maintain the relative humidity below 60% to prevent the collection from fungal and bacterial attacks while allowing the temperature to vary with the outside climate. The system has maintained the designed preservation environment for the last five years with minimum energy consumption and low maintenance costs. The strategy has also proven its robustness to maintain the conservation environment even during extended power outages common in the region.

INTRODUCTION

The greatest threat to museum collections in hot and humid regions is biodeterioration, especially fungal and bacterial attacks. (Agrawal 1993; Aranyank 1993) Since tropical climates are characterized by high temperature and relative humidity which promote activities of fungi and bacteria throughout the year, maintaining the collections in a dry environment (less than 70% RH to arrest biological activity) is essential for their preservation. (Brundrett 1990) Other degradation mechanisms, such as mechanical damage and chemical aging (Michalski 1993), are considered to be less important when developing environmental improvement strategies for collection preservation in these regions.

An increasing number of cultural institutions have been installing typical air-conditioning systems, which are designed for controlling the temperature for primarily human comfort, rather than as a means of providing preservation environments for their collections. The use of a typical air-conditioning system, however, can present problems for cultural institutions. Both the capital and the operational and maintenance costs are significant. It may require the installation of thermal insulation, vapor barriers and ductwork that can result in damage to the superstructure and/or interior of the building. And often the installation of an air-conditioning system may not guarantee the desired collection environment.

There are serious needs for developing climate control strategies that produce suitable preservation environments that are economical, robust, technologically simple, and require minimal structural modification. Climate control strategies based on the use of ventilation, conservation heating, and dehumidification or any combination of those, which are alternatives to a typical or traditional air-condition based approach, have been successfully tested in cultural institutions in temperate and humid climates. (Kerschner 1992; Padfield and Jersen 1990; Staniforth et al. 1994; Maekawa and Toledo 2001, 2002; Valentín et al. 1998) These alternative strategies will provide necessary beneficial alternatives to collection managers and conservators in tropical and sub-tropical climates, if they can be successfully tested in the region.

The Museu Paraense Emílio Goeldi (MPEG), located in a northern Brazilian city of Belém and the oldest scientific institution still active in the Amazon region and the second oldest natural history museum in Brazil, has collections of both historical and scientific significance regarding the knowledge of flora and fauna, the physical environment, and social

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groups that currently dwell or have dwelled in the northern regions of Brazil. The Amazonian ethnographic collection consists of about 15,000 objects from different ethnic groups: objects used in agriculture, fishing and hunting, food processing, ceremonies and celebrations. Classified according to region and tribe, they are mostly basketry, instruments, and ornaments, that are made from plant fibers, woods, seeds and bird feathers.

The climate of Belém is characterized as hot and humid, with annual average air temperature values of 78.4°F (25.8°C) in 1931-1960 and 78.8°F (26°C) in 1961-1990, relative humidity values of 86% in 1931-1960 and 86.5% in 1961-1990. The relative humidity can reach 100% during the rainy season, but the maximum air temperature never gets higher than 90.5°F (32.5°C) in the dry season, the minimum value being 72.5°F (22.5°C) in the rainy season (www.inmet.gov.br). The rainy season is from December to May, and the dry season is from June to November. The annual rain accumulation was 109.25 in. (2775 mm) in 1931-1960 and 113.78 in. (2890 mm) in 1961-1990. Because of the high daily evaporation, it is worth noting that it rains on a daily basis in Belém, at the end of the day, with monthly values falling between 1.97 and 5.9 in. (50 and 150 mm) in the dry period. Solar radiation attains its maximum in July and August (about 270 h of sun incidence), and its minimum in February and March (about 100 h). Evaporation is also high in the dry period (about 3.15 in. (80 mm) in July and August).

The majority of MPEG's storage environments are maintained by dual sets of several room (window-mount) air-conditioning units which are utilized in day and night shifts for extended maintenance-free operation of continuous climate control. However, these units are designed to produce low temperatures for human comfort, and these are not to maintain a stable preservation environment for collections. Furthermore, we can often see a large growth of black mold on the building's outside walls due to dew condensation resulting from a combination of poorly insulated walls and low inertia temperatures. Prior to the climate improvement project, the Amazonian ethnographic collection occupied two storage rooms at the Rocinha campus, the MPEG's headquarters near the city center of Belém. These rooms were over-packed, poorly furnished, and climatically unstable due to intermittent operation of room air conditioners, resulting in daily climate ranges of 81.5 to 90.5°F (27.5 to 32.5°C) and 45 to 70% RH as shown in Figure 1. There were also drawers full of naphthalene for protection against insects.

Another issue is that air-conditioning units consume large amounts of power. Table 1 shows the monthly energy consumption at the MPEG in 2002 produced from its monthly electricity bills. Including the daytime use of room air-conditioning units in individual office spaces, the museum spends about 70% of its budget on electricity. Since energy consumption of a particular storage facility cannot be isolated from the museum's energy bill, we estimated the energy cost of the old Amazonian ethnographic storage based on equipment installed in the facility as shown in Table 2. With the nationwide energy crisis in 2001, the Brazilian government mandated its facilities to reduce energy consumption by 30% by 2007. Therefore, the museum has been anxious to reduce its energy use.

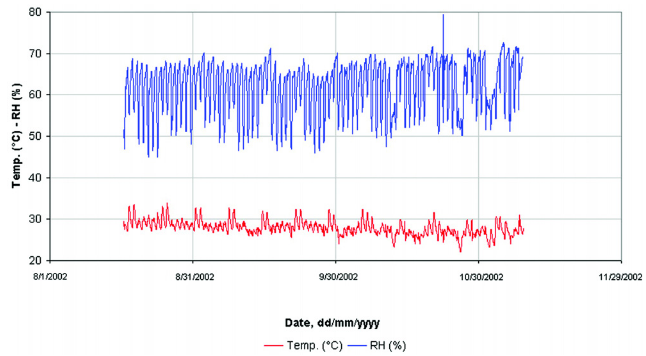

Figure 1 *Temperature and relative humidity in the old Amazonian ethnographic storage at the MPEG in 2002.*

Table 1. Daily and Monthly Energy Consumption at the MPEG in 2002

Month	Daily Consumption (kWh)	Monthly Consumption (kWh)	Total Cost (R$)
January	5,675	175,940	36,628.20
February	6,184	173,162	39,697.27
March	4,831	149,746	39,789.05
April	5,685	170,551	43,926.38
May	6,156	190,850	46,952.25
June	6,246	187,392	50,123.66
July	6,110	189,436	48,703.51
August	6,037	187,166	58,214.48
September	6,602	198,088	55,814.51
October	5,092	157,857	45,652.57
November	5,855	175,677	42,762.91
December	5,064	157,007	37,929.16
Total	69,537	2,112,872	546,193.95

Source: Electricity bills. R$ is Brazilian Currency, R$1 = 0.475 U.S. as of May 8, 2009

In addition, frequent and extended power outages are very common in the region and are another reason for fungal and insect outbreak, despite heavy and broad use of insecticides and fungicides. The museum was therefore searching for an innovative climate control approach that would be low-cost for both installation and operation, technologically robust, and capable of maintaining a stable conservation environment, even in a period of an extended power outage.

Table 2. Estimated Monthly Energy Consumption in the Old Ethnographic Storage

No. of Units	Equipment, Btu Rating	Watts	Hours	Days	Consumption (kWh)
1	Air cond. 30,000	3900	12	22	1029.60
1	Air cond. 30,000	3900	12	22	1029.60
1	Air cond. 30,000	3900	12	22	1029.60
1	Air cond. 14,000	2070	12	22	546.48
1	Air cond. 14,000	2070	12	22	546.48
22	Fluorescent light 40W	880	08	22	154.88
				Total	4336.64

NEW STORAGE FACILITY

In 2003, the MPEG gained a new storage space for the Amazonian ethnographic collection at its research campus at the edge of the city. It is located in a typical single-story contemporary urban building and consists of three rooms used for: (1) reception, quarantine and conservation treatments; (2) inventory and study of collections; and (3) the storage itself. The storage area measures 49 ft-3 in. × 59 ft (15 m × 18 m (270 m^2)), has a cement slab floor, a concrete slab ceiling of 9 ft-10 in. (3 m) high, and the walls are made of fired hollow bricks finished with cement plaster and white water-based paint. The roof is of corrugated metal sheets in two chutes, with a central air gap for passive ventilation of the attic space, with long eaves and a suitable surrounding drainage system.

Conceptual Design for Climate Control

The proposed climate control system for the new storage area consisted of sets of supply and exhaust ventilators and several portable mechanical dehumidifiers, and was to operate based on the output of relative humidity sensors located both inside and outside the buildings. The system was to operate only when the relative humidity rose higher than 70%—the threshold for microbial activities. The ventilators were to operate when the outside relative humidity was lower than the value to remove moisture, and the dehumidifiers were to activate when the outside relative humidity was higher than 70%. Therefore, the ventilators could not be used. It was decided to use mechanical dehumidifiers instead of heaters to reduce the rise of already high temperature and conserve energy. The approach would provide relative humidity control to protect the collection from the threat of fungi and bacteria while allowing the temperature to vary, since chemical aging and mechanical damages were not considered to be threatening.

Engineering Design of Climate Control System

The conceptual design of the climate system was forwarded to a local architect and HVAC company for detail design, equipment selection, and installation under the authors' supervision. Figure 2 shows locations of various HVAC equipment for the storage. The system consisted of two large [953 cfm (1620 m^3/h) each] centrifugal-type supply fans, four [424 cfm (723 m^3/h) each] axial-type exhaust fans, six oscillating fans, four portable mechanical dehumidifiers [177 cfm (300 m^3/h), 1331 Btu/h (390 W) each] and two humidistats. The supply air ventilators were placed outside the building, bringing filtered outside air through two centrally located ducts mounted under the ceiling, and distributing air through five diffusers on each side. Each supply fan had an insect net and double banks of G3-type particle filters. The venting air, after flowing through the shelves and drawers, was collected near the floor through two ducts with five return openings each, and along two walls which were parallel to the supply air ducts, and ducted to the exhaust fans located in wall cavities. Gravitational-type shutters were installed on their exhausts to prevent the infiltration of the outside air and insects. Four portable dehumidifiers connected to permanent drains were located near four corners of the storage room. Three oscillating fans mounted near the ceiling on sidewalls operated with the dehumidifiers for mixing the room air. Another three oscillating fans, independently operable, were installed on center columns to provide comfort for staff members and researchers. Two humidistats, with one relative humidity sensor inside the storage and the other outside the building, controlled the operation of ventilators, fans, and dehumidifiers. The climate system operated only when the interior relative humidity exceeded 70%, and deactivated once the relative humidity was reduced to equal or less than 60%. The ventilators (supply and exhaust ventilators) were operated simultaneously when the outside relative humidity was equal or less than 70%. If the outside relative humidity rose higher than 70%, wall fans and mechanical dehumidifiers were activated simultaneously, while ventilators were turned off. Costs of the detailed design, the equipment, and labor for the installation were approximately R$4.33/$ft^3$ (R$153/$m^3$) in 2003, less than one-fifth of a typical climate control system which controlled both temperature and relative humidity.

Building Envelope Modifications

For the installation of the climate control system, some architectural modifications were made on the building envelope of the new storage space to improve its air tightness. The modifications included the elimination of a large steel door directly leading to the outside and wall openings for air-conditioners. Some of the wall openings were converted to windows. The ceiling was insulated with 4 in. (0.10 m) thick fiberglass panels to minimize the heat transmission from the attic. An area surrounding the storage was paved for improved drainage around the building. Two fireproof metal doors were installed: one at the entrance to access the storage, and the other to access the conservation lab. A vestibule area was created just outside glass entrance doors into the storage surrounded by the two metal doors and a brick internal wall. This area provided a transition space between the storage and

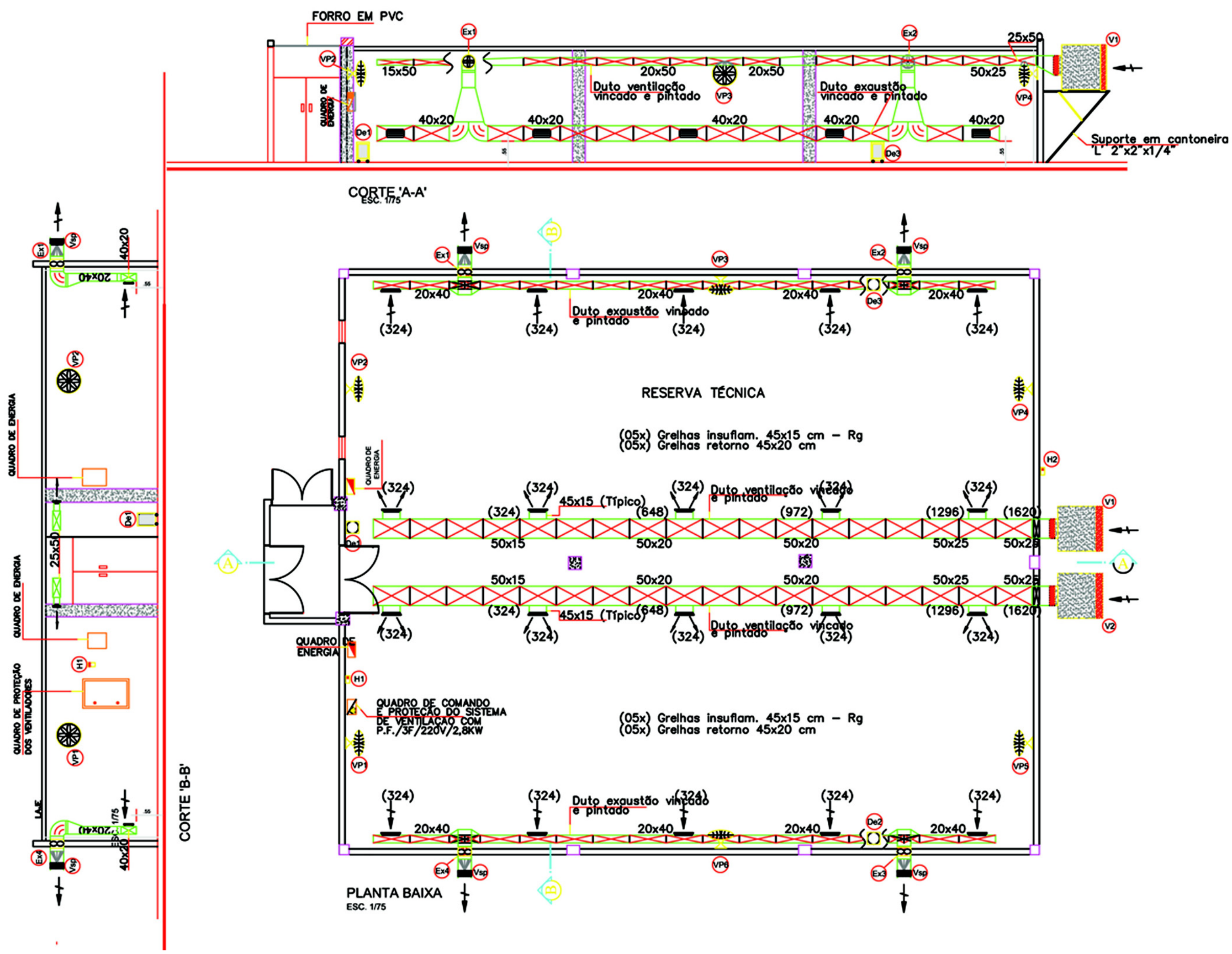

Figure 2 *Proposed climate control system design for the new Amazonian ethnographic storage at the MPEG.*

non-storage areas of the building for the control of infiltration of the humid outside air, dusts, and insects.

After the envelope modifications and prior to the start up of the climate control system, the climate of the new storage was monitored for several months. Both the temperature and relative humidity reached stable levels at 86.0 to 87.8°F (30 to 31°C) and 80 to 82%, respectively.

Furniture

Compact shelving systems and chests made of steel with a baked enamel finish were positioned in the storage to provide the maximum use of the space while the ventilating air could circulate through as well as around them. Side panels of the compact shelving system were fabricated with perforated steel sheets to allow air circulation through them even at closed positions (Figure 3). Drawers of the two chests also had large gaps between them to promote good air circulation, even in the closed position (Figure 4).

RESULTS

The climate in the storage room and the operation of the climate control system has been monitored since its installation in 2003. The system has operated successfully, maintaining the storage at the set relative humidity value of 60 to 70% RH. (See Figure 5.) The resulting temperature ranged 87.8 to 91.4°F (32 to 33°C). (See Figure 6.) With the temperature of the uncontrolled storage at 86.0 to 87.8°F (30 to 31°C), we expected the temperatures of the storage to be 82.4 to 89.6ºF (28 to 32°C) with the utilization of ventilators and mechanical dehumidifiers. The higher temperature may be a result of inefficient dehumidifiers. Although the temperature, 86.0 to 91.4°F (30 to 33°C), was as high as that of a sunny afternoon outside, with the utilization of the installed oscillating fans staff members have

Figure 3 *Side panels of a compact shelving system are made of perforated plate in order to allow air flow though the panel even in closed positions.*

Figure 4 *Drawers have gaps between drawers in order to allow air flow even in closed conditions.*

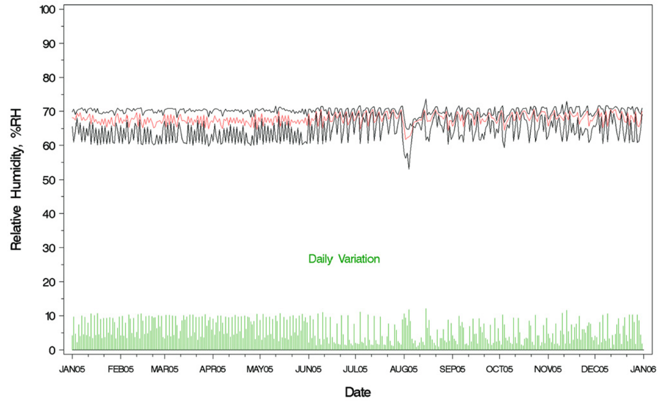

Figure 5 *Daily maximums, averages, and variation of relative humidity in the new storage in 2005.*

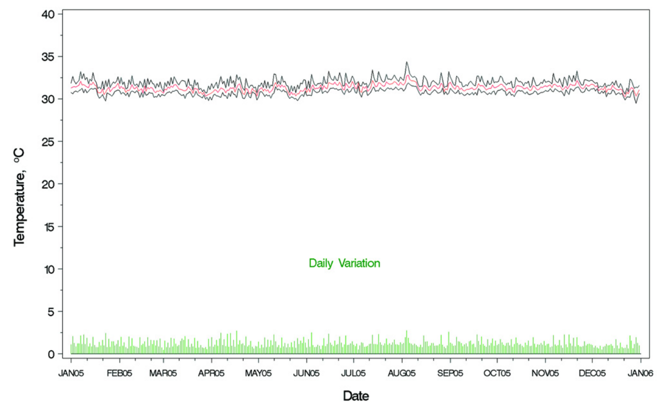

Figure 6 *Daily maximums, averages, and variation of air temperature in new storage in 2005.*

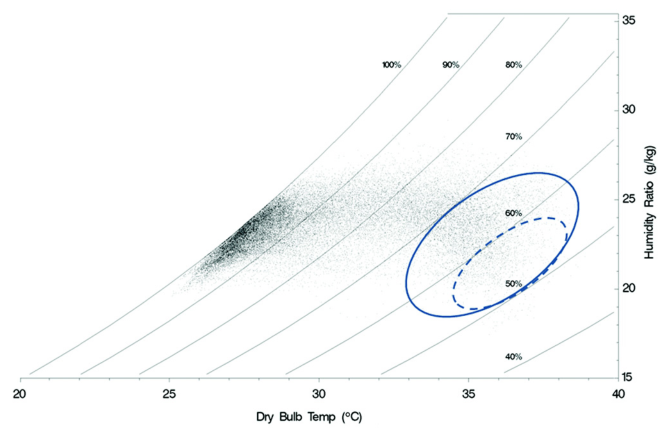

Figure 7 *The outside temperature and relative humidity (15 minute data) of 2005 plotted on a pshychrometric chart. The solid circle represents climate conditions for ventilation if the storage is ventilated to maintain less than 70% RH. The dotted circle represents climate conditions if the storage is ventilated to maintain less than 60% RH.*

been able to work for an extended period of time in the storage. Since the system easily maintained the relative humidity range, we were interested in reducing the set relative humidity to a lower range. However, a decision was made not to lower the set point due to a concern over possible higher temperature values resulting from the system's operation, such as higher outside temperatures for ventilation (Figure 7) and additional heat released by compressors of mechanical dehumidifiers (Figure 8).

While the climate control system was operational, insect activities were monitored using sticky insect traps distributed throughout the storage. Although less than a 70% RH environment had been maintained we did not observe any fungal activities. We did, however, document an elevated population

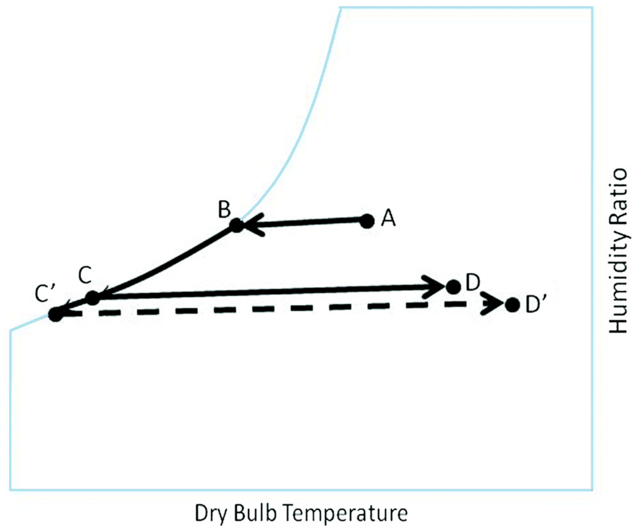

Figure 8 *Schematics of psychrometric processes of typical mechanical dehumidifiers describing more heat generated for more dehumidification due to the system's inefficiency.*

of psocoptera (booklice, barklice, and barkflies) at the end of 2006. This problem multiplied when the area had several power failure events one after another, and a fungal outbreak occurred. Some of this extended for more than two days. The set point of the system was then reduced to 50 to 60% RH in order to control the problems. The reduced relative humidity set point immediately controlled both the psocoptera problem and fungal infestation while the temperature remained at 86.0 to 91.4°F (30 to 33°C). This lower set point resulted in longer continuous operation of mechanical dehumidifiers, allowing them to run more efficiently with no additional heat generation.

The noise level has been less than 52 to 54 dB with ventilators or 60 to 61 dB with mechanical dehumidifiers and fans operating. These values were considered to be acceptable, since the space is storage and the staff occupies it only for a limited amount of time. Table 3 shows the resulting measurement of airborne particles conducted in August 2005. The dust level in the storage has been significantly lower than the outside as well as offices and the open corridor in the same building for all particle sizes.

Through a collection assessment that was conducted one year after the operation of the climate control system, both the curator and conservator of the collection confirmed that they found no new damage to any of the objects in the new storage environment. Meantime, some staff members noticed that the collections have obtained increased volume and color saturation. In particular, those made of feathers and vegetable fibers seem to have achieved rehydrated conditions in the new environment with air moisture content similar to the native environment.

Table 3. Number of Airborne Particles

Particle Size, μm	Storage	Outside	Corridor
<0.3	549,331	1,122,695	1,200,616
<0.5	29,961	59,532	80,375
<1.0	4,771	5,459	8,853
<5.0	68	159	408

Table 4. Energy Use of the New Storage During the First 6 Months of 2005

Month	Energy Use (kWh)	Month	Energy Use (kWh)
January	451	May	490
February	559	June	Missing
March	546	July	225
April	585		

Table 4 shows the monthly energy used in the storage during the first 6 months of 2005. The ventilators or dehumidifiers have on the average operated only about four hours daily, mostly during daytime, and the energy use has been approximately one-tenth of that of the old storage. Per unit area, the storage currently expends one-fifth of the average energy use of the rest of the research campus. During the first two years of the continuous operation of the system, the only maintenance needed, other than annual calibration of the humidity sensors and filters replacement, was the replacement of a failed solenoid switch for powering one of the ventilators. This failed component was easily identified and had minimum impact on the climate of the storage. Several events of the extended power failure were recorded during the five-year operation; however, they had minimum impact on the climate in the storage which maintained the designed relative humidity. These events have also proved that the system's operation is robust.

CONCLUSION

A conservation-focused climate control strategy was implemented for the new Amazonian ethnographic storage of MPEG in Belém, a tropical climate region in northern Brazil. The building envelope was tightened to significantly reduce the infiltration of dusty and humid outside air, and the ceiling was thermally insulated to reduce the transfer of heat from the attic. A compact shelving, drawer, and cabinet system with perforated panels and large gaps was installed to allow the maximum air flow through them. A mechanical system was designed to limit relative the humidity to less than 70% (later reduced to 60%) using centrally controlled ventilators and portable dehumidifiers while allowing the temperature to drift with the outside climate. Centrally located ventilators supply filtered outside dry air and peripherally located exhaust ventilators produced a center-to-periphery flow; while they maintained a positive pressure in the storage to limit the infiltration of unfiltered outside air. The climate control strategy has been maintaining the intended conservation climate of 50 to 60% relative humidity at 86.0 to 91.4°F (30 to 33°C) temperature with the minimum dust in the storage. The strategy has also proven its robustness to maintain the conservation environment even during extended power outages common in the region. The capital cost of the project was one third of typical air-condition based systems, and the operational cost has been one-tenth of the same system.

The climate control project proved its effectiveness in maintaining safe conditions for the MPEG ethnographic collection with significant saving of equipment, maintenance, and energy costs. The conservation-focused climate strategy can be a beneficial alternative to the traditional air-condition approach for cultural institutions in hot and humid climate regions, especially, with limited resources.

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