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Paper test rooms: design considerations

Scope

The purpose of this TIP is to generally describe the primary factors impacting a TAPPI conditioned lab and provide a conceptual list of items to consider when building the conditioned space. TAPPI T 402 “Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets and Related Products” (1) requires atmospheric conditions of $23 \pm 1^\circ\text{C}$ temperature and $50 \pm 2\%$ relative humidity (RH) uniformly throughout the testing room. To attain these requirements, a room should be built with basic functional features. The information presented is intended to guide and to educate and therefore can be modified to meet the specific conditions required.

This is not an engineering treatise on how to construct a test room. Such information can be obtained in many engineering design books (see References). Various technical organizations have related standards that are of value (see References).

Safety precautions

Adequate protection to personnel and building must be considered in the design. Conformance to all local building codes, including lighting and sprinkler protection is foundational to any safe room design.

Conformance to the National Electrical Code provides proper electrical safeguards.

There must be an emergency exit.

The mechanical equipment must be guarded to prevent personnel injury.

Fireproof materials must be used for maximum safety.

Insure that the intake to the system is so located that no contaminated air can be drawn into it.

Adequate provisions should be made in the design of the air cooling coils to allow them to be cleaned and sanitized effectively. Room air is primarily recirculated, so the air conditioning system should be periodically inspected and cleaned in a manner to inhibit the growth of microorganisms that have the potential for causing respiratory problems.

Test room design

Maintaining specified atmospheric conditions in the preconditioning and instrumental test areas is essential. The test room should be designed, constructed and provided with instrumental control to maintain the specified environmental conditions. The performance of the equipment should be determined by using calibrated instruments for temperature and relative humidity (RH). Small changes in temperature can create significant changes in room RH, and both must be well controlled and monitored. The classic treatise on construction of a suitable facility was that of Clark (2). This paper may not be readily available, but it has been reproduced in detail in the book, “Pulp Technology and Treatment for Paper” (3) which can be found in most industry libraries. Description of several

adaptations of Clark's concept are found in reference (4). Many of the detailed ideas in this TIP, while not specifically cited, are from these references.

Creating an adequate facility to conform to the TAPPI conditions requires much more than just an adaptation of comfort air conditioning. Even those units designed for protection of electronic data processing equipment do not usually meet the needs. Areas of inadequate response are lack of sensitivity of the humidity sensor, inadequate supply of humidification, lack of proper control elements, and insufficient capacity of the system (especially in dry, cold winter air.)

If the room is too large, control is more difficult, air distribution may be erratic unless properly designed and, of course, the facility will be more expensive. If, on the other hand, the room is too small, surges can be expected and the conditions are influenced by the apparatus and human activity in the room particularly each time the door is opened. It is recommended that no room be smaller than 200 ft² in area.

In general, it is most efficient to design the air circulation system for the room such that the air is circulated, but only part of the air in the room is replaced by bringing in outside air, thus minimizing the load on the conditioning equipment. Air conditioning experts should be consulted to determine the amount of fresh air which should be supplied.

Given the challenges posed by thermal conductivity through windows and exterior walls, the most straightforward approach to building out a conditioned space involves building a "box within a box", thus isolating the conditioned lab thermally and through moisture barriers from the surrounding building envelope.

Construction

The materials of construction recommended are common to the building trade. Others may be used if they perform the same function. When materials are selected, these factors should be considered: density; resilience; resistance to settling; permanence; ease of handling; dimensional uniformity and stability; and ease of fabrication, applying, and finishing. The ultimate objective is to maintain a constant interior surface temperature as close as possible to the recommended temperature. Any deviation will make it more difficult to obtain the standard atmospheric conditions. If at all possible, exterior walls should be avoided. If exterior walls are required as part of the construction process, extra thermal and moisture insulation will be needed.

Where a room is built against an exterior wall, considerations must be made to seal all electrical conduits to avoid cold air flow and condensation. Consideration of circulating air space between the exterior wall and insulation should be done to avoid possibility of moist areas allowing mold growth.

Framing

The supporting structure can be metal, concrete, concrete blocks, or wood. It must be strong enough to carry the exterior and interior overlay and thick enough for the required insulation.

Exterior covering

Most exterior building materials are satisfactory. For outdoor service, weatherproof material must be used.

Interior liner

Preferred building materials for the walls and ceiling are plasterboard, wood paneling, and metal sheeting. The floors can be concrete or wood with a floor covering. All surfaces should be finished and sealed with a protective and serviceable coating. They should not become moisture or heat sinks; all exposed wall, floor, and ceiling surfaces of the finished room should be coated and/or made of materials that do not react with water. Where seismic considerations are relevant, polyurethane foam insulated steel or aluminum laminated panels will withstand greater vibration and flexing than concrete block, drywall, or laminated particle board.

Insulation

Adequate insulation should be applied to all walls, ceiling and floor to prevent thermal loss or gain. Surfaces exposed to extremes in temperature should have more protection. Ideally, insulation will have an "R-Value" of 30 or more. The closer the exterior temperature is to the interior room temperature, the easier control will be. If the room is situated inside a building where the temperature is normally comfortable for its occupants, there is less need

to provide thick insulation for the walls of the room, but it is still recommended. Wall, ceiling and floor temperature between 21°C and 25°C is recommended. Where the exterior conditions are greatly different from the desired 50% RH, the insulation should be protected from the highest humidity by a moisture-vapor barrier. For obvious reasons, then, the inclusion of an outside wall or roof in the structure of the Paper Test Room should be avoided if at all possible.

Windows and doors

Exterior walls should not have windows. Any windows to the building interior windows should be double-paned. If entry to the room is not frequent, especially if the outside conditions are not greatly different from the interior, an air lock may not be necessary; but if there is considerable traffic into and out of the room and external conditions vary considerably from the interior, an air-lock door is desirable. This underscores the desirability of providing windows to the room, especially where the room is the mill test station. Visitors should be encouraged to look through the windows rather than enter the rooms.

A slightly positive internal air pressure is advisable.

Floors

Concrete floors in contact with the ground can provide an opportunity for moisture penetration depending on the moisture in the surrounding environment, the thickness of the concrete, and the surface used to cover the concrete. It may be necessary to apply a moisture barrier between the concrete and any tile or flooring surface. One can measure the water vapor transmission rate of the floor before finishing the room to determine if the moisture flux through the floor is significant relative to the conditioning capacity of the room.

Equipment

Where practical, it may be wise to have redundant environmental control systems to avoid room downtime during service and repair operations and to avoid overtaxing equipment.

Refrigeration

The refrigeration unit must be reliable and have low maintenance for long continuous operation.

Continuous control elements should be used for temperature and humidity control, not discreet stepwise actuators. PID control should be utilized. Cascaded PID may be necessary. Generally, self-tuning PIDs will be needed. Anticipatory control with input from exterior sensors may minimize the need for seasonal set point changes.

The unit must be able to maintain the specified atmospheric conditions under ambient heat loads, which include structural, external air temperature, relative humidity effect, equipment, room lighting, and occupants. The use of a secondary cooling medium such as chilled water is highly desirable, provided it is available throughout the year. Alternatively recommended is a direct expansion system, incorporating temperature control through the continuous mixing of the liquid and hot-gas phase of refrigerant entering the evaporator. Such a design eliminates on-off cycling, improving reliability, and can improve response time by the controller (thermostat, etc.).

It is recommended that the American National Standards Institute (ANSI) Code be followed unless company policy requires that another code be used.

Air Handling

The air volume within the conditioning equipment should be relatively large. The advantage is closer control of temperature and humidity. If a small volume air delivery system is used, auxiliary air moving equipment must be installed in the test room. The air-moving equipment must have filters that remove dirt, paper fiber lint, and other particulates.

Heating

Electric heaters are the preferred means for supplying heat because of ease of control. Steam heat exchangers can also be used, assuming they can respond sufficiently quickly to changes in demand.