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Unprecedented rains in Mumbai on 26/7/2005 caused severe floods and damage to goods in homes, offices, factories and warehouses. This is a typical scene on a road in Mumbai.

Restorative Drying

The art and science of drying articles in order to restore them to their original condition or as close to it as possible.

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Jagdeep Singh is a mechanical engineer with an MBA from FMS Delhi. He has also specialised in corrosion engineering from NACE, USA. With his extensive experiencing in marketing of IAQ and energy recovery products, he has been instrumental in introduction of water damage restoration services in India resulting in large savings for the nation and insurance companies.

Carrier's office in Kalina, Mumbai was flooded. All computers and office furniture including records were ruined. Work came to a total standstill. So was the HVAC plant room in the basement of Sahara's new hotel in Santacruz, Mumbai. The main transformer had to be shut down and the chiller packages with pumps were inoperative. Wipro's office in Bangalore on the ground floor was similarly flooded and heavy damage took place. These are real examples that occured during the 2005 southwest monsoon season in Mumbai and the north-east monsoon season in Bangalore. Many more offices and warehouses suffered the same fate in these cities as well as in Ahmedabad and Chennai.

Besides floods, cyclones and hurricanes, potential for water damage exists due to broken water pipes, fire control, defective fixtures, faulty construction and seepages as well as many other contaminating sources including overflowed toilets, sewer backups or river floods. The water damage can occur at any place like offices, hotels, hospitals, factories and schools.

Psychrometrics, interestingly, has come to the rescue, providing technologies which act like saviours to the affected people. One such technology is known as restorative drying. Before we get into the details of how this drying technique works let's understand the different types of water damage that occur.

Water Damage

Water damage is that which causes future use or value of any property to become impaired by water. Hence it is important to preserve, protect and secure the property, equipment, material and structures from further damage.

Water Damage Stages

Water damage is classified in the following manner

1. Water migration
2. Primary structural damage
3. Secondary humidity damage
4. Secondary damage from fungi
5. Sick building syndrome

Water migration

Water migrates horizontally from the source in all directions and spreads laterally into adjoining materials. Saturation increases in material as gravity pulls the moisture deeper. Finally water wicks up vertically.

Primary structural damage

Saturated wood and other hygroscopic materials begin swelling. Increase in moisture content result in cupping, buckling, deformation and delaminating. When metals come under direct contact with water, severe corrosion starts and depending on the water quality this corrosion then results in pitting leading to permanent damage.

Secondary structural damage

As water begins to evaporate, indoor air humidity increases beyond 80%, and hygroscopic material takes on water vapor affecting books, pictures, paintings and musical instruments. Gradually doors, drawers, woodcarvings, electronic items and other equipments, acoustical tiles and even dry walls take on humidity and begin to swell, deform, buckle and delaminate. High humidity causes condensation on cooler surfaces like ceiling and walls. Metal corrosion occurs because of high humidity.

Secondary damage from fungi

In time fungi and bacteria germinate and multiply in organic materials. First affecting files, books and upholstery. In time, organic insulations and inorganic insulations are affected.

Sick building syndrome

In the end the damage is so great that restorative dying too becomes difficult. If such damage to contents and structure occurs the indoor air quality degrades rapidly and the structure becomes sick and uninhabitable.

Restorative Drying

The pioneer technology of restorative drying removes abnormal water from structures/material/equipment to "restore" materials to their original normal condition (equilibrium moisture condition). It prevents permanent loss by controlling moisture damage, microorganism and soil contamination, odors, and loss of indoor air quality. The purpose of restorative drying is to decontaminate and dry materials efficiently. Except for easily movable items like furniture and contents, the aim is usually to dry equipment or material on-site rather than remove them. In some cases, restorative drying can even save saturated books and documents, hardwood floors, and soaked walls and ceilings.

Water damage restoration is an emergency business. The primary purpose is to preserve, protect and secure the property, equipment, material and structures from further damage.

Figure 1 : Flood extractor

Extraction

Extraction is the first step in drying down any structure. It has a huge impact on how quickly we arrive at the finish line. Extraction removes water 1,200 times faster than dehumidification. Extraction tools like flood extractor and extractor are designed to agitate which improves cleaning. Delamination (split into layers) can happen quickly if the operator is not careful, especially while trying to achieve a deep, thorough extraction. Once the extraction is complete, drying equipment is installed to complete the remainder of the job. The extraction process removes the majority of the water but cannot completely dry the water soaked material.

Figure 2 : Extractor

Balanced Drying

Rapid drying is essential to prevent damage to structure and contents while reducing the chance for microbial contamination. You want to dry materials quickly yet cost effectively. But the need and cost for rapid drying using dehumidifier rentals must be balanced with the replacement cost and potential for permanent damage. These are not always simple decisions because of the great number of variables.

When you arrive to dry a flooded structure, variables not within your control may include the building construction, outside weather conditions, existing HVAC systems, the amount of water needing to be removed, the type and degree of saturation, the location of the damage, and the permeance of affected materials. However, the indoor humidity and the degree of air movement are within your control. When you set up a balanced drying system, you make the decisions on how to establish these controls.

Figure 3 : Blowers

Appropriate Air Velocity and Volume

Air velocity over and through wet materials increases the rate of evaporation. All other drying elements being equal, the greater the air velocity and volume, the faster the rate of drying. Where and how many air movers you install is dependent on a number of criteria. However, it is not unusual to install at least one air mover for every room, and in larger rooms to install one unit for every two hundred square feet. Keep in mind that as more air movers are installed, the amount of moisture in the air increases rapidly, requiring additional dehumidification.

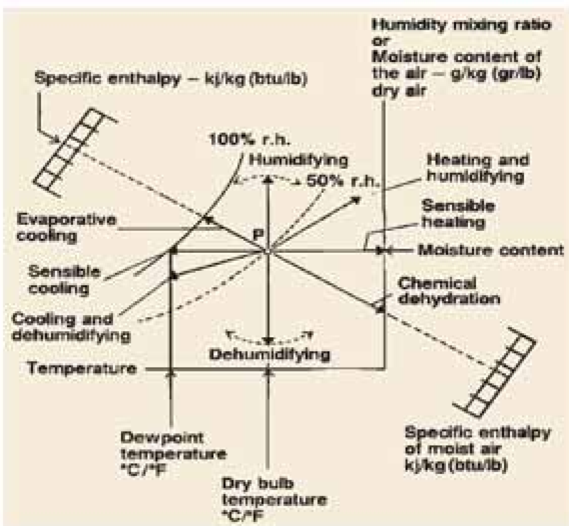

Figure 4 : Psychrometric chart

Appropriate Drying Temperatures

In theory, the greater the temperature the faster the rate of evaporation, and therefore the drying rate. However, high temperatures are not practical on most restoration jobs. High temperatures usually increase fungal germination and growth. Most affected structures are occupied and excessive indoor temperatures mean greater amounts of water vapor released into the air, more dehumidification is needed and the potential for secondary damage can be a problem. In any case, most heating systems cannot provide indoor temperatures above 85°F. Due to these reasons, the indoor temperature on most jobs should be about 21- 22°C (70-72°F) in the initial stages. In some cases the temperature can be raised after the initial stage of high humidity is complete.

Figure 5 : Restoration inspection tools

Appropriate Indoor Humidity

Given practical limitations, establishing appropriate airflow and temperature are fairly simple. However, dehumidification is more complex. On the one hand, the drier the ambient air, the faster materials dry. The rate of evaporation is directly proportional to the humidity difference between the surface of wet materials and the adjoining air. The ideal humidity for most jobs might be as low as 25% RH. At the very least, you need to use at least enough dehumidification to ensure that the humidity is decreasing within the structure, and your humidity goal is being achieved.

Table 1 : Judgment issues: Replacement Vs Restorative Drying.

Lean Towards Drying	Lean Towards Replacement
Drying cost less than 60% of new	Drying cost more than 60% of new
Drying is faster than replacement	Replacement is faster than drying
Drying should be successful	Drying may not be successful
The insurance company prefers drying	The insured prefers replacement
No mold on or within surfaces	Mold growing on or within surfaces
Water came from sanitary source	Water from an unsanitary source
Drying is more customer convenient	Replacement is more customer convenient

Establishing Humidity Goals

Remember to establish a humidity goal early on the job. Setting this goal is partly science and partly art. Every situation includes a number of influences, including cost effectiveness, potential health issues, the impact of time, customer convenience, your own capability, available electric power, the availability of drying equipment, and so on.

A condition of 40-50% RH at 21°C (70°F) is a good condition for drying porous materials like wet carpet, wet cushion, and surface moisture. Relative humidity may be reduced even lower when it is costeffective to dry dense or structural materials that otherwise would have to be replaced. For more dense materials, especially those with a greater chance of incurring permanent damage over time, or those with greater replacement cost, a lower humidity target of 25 %- 40 % RH may be cost justified. A number of factors determine how many dehumidifiers to place on a job site, and how long to leave them in operation.

Judging Dehumidifier Needs

There are three basic methods used to determine how much dehumidifying capacity to install during the initial service call. These are called air mover based, BTU based and air exchange methods. A fourth method, based on keeping track of relative humidity, is used after the system has been installed and operating for at least several hours.

Potential Variables in Determining Use of Dehumidifiers

- Cost of restorative drying versus replacement with new
- Indoor and outdoor temperature and humidity conditions
- Degree of saturation and porosity of affected materials
- Capacity of the building's heating and air conditioning system
- The time available or the drying time objective in days or weeks
- The potential for mold damage to affected materials over time.
- The potential for indoor air quality degradation over time.
- Customer convenience and /or loss of business revenue.

Air Mover-Based Method

It is natural to want a rule of thumb to decide how much dehumidifier capacity you need when setting up a drying system. One very simple method is to initially place dehumidifiers based on number of air movers taking the relative humidity into account. If humidity is over 50%, place additional dehumidifiers. As situation becomes drier you can remove units according to the hygrometer readings.

Table 2 : Air change rates of dehumidifiers.

Potential Rate of Evaporation	Air Change Rate	Changes Per Hour
Highly saturated environment that includes saturated, highly porous materials like carpet, carpet cushion and surface moisture	Every 20 minutes	3 changes per hour
Saturated environment includes wet, semi-porous material like dry wall, wood flooring, glued down carpet and surface moisture	3 changes per hour	2 changes per hour
Environment with mostly low porosity materials like vinyl and tile flooring or plywood with some surface moisture	6 changes per hour	1 change per hour

BTU -Based Method

Dehumidifier performance or power is rated in a number of ways. BTU's can be used as a basis for initial dehumidifier installation. Install 2500 BTU of dehumidifier capacity for each air mover in operation.

Air - Exchange Method

A third method is based on how many times you process all the air inside the structure. You need at least two numbers to calculate air exchange - the cubic feet per minute (CFM) rating of your dehumidifiers, and the total cubic feet of the structure. Different materials accept and release moisture at different rates depending on a number of factors, the most important being the materials porosity. Porous materials take in and release moisture faster than non-porous materials. The rate of evaporation, and therefore the initial demand for humidity reduction, is greater as the porosity increases. The greater the material's porosity the greater the rate of evaporation, and therefore a greater need for dehumidification.

Relative Humidity Method

After air movers and dehumidifiers have been operating for some time, the simplest and most effective means of judging the amount of dehumidification needed is to monitor relative humidity and temperature with a good electronic thermal-hygrometer. You should establish the trend toward that goal.

25%- 40% RH at 21°C (70°F) – is a safe but very effective humidity, for drying very porous materials like carpet, and even for drying dense structural materials including framing, drywall, and flooring. If dehumidification is progressing well it may be possible to remove some dehumidifiers from the environment. Only desiccant dehumidifiers can achieve this lower end of the humidity condition.

Considering the Variables

The goal is to maintain balanced drying system as close as possible to 40% RH, or even lower when dehumidification is costeffective to dry structural materials that would otherwise have to be replaced.

Outdoor Temperature and Humidity

Consider both the outdoor temperature and humidity levels when setting up a drying situation. If exterior humidity is very low and you can use an " open drying system" (described below), dehumidification may not be required.

Using Existing Systems

In some cases, you can use existing heaters and air conditioners to control and balance the temperature in the flooded area, especially when exterior conditions are at the extreme.

Building Construction

The type of building and its construction influence how long it takes to dry. A building may have a high infiltration rate; that is, significant volumes of air enter the building even when it is closed up.

Permeance and Type of Materials

When drying porous materials, which give up their held moisture readily, dehumidification may proceed fairly rapidly. When drying saturated materials with a lower permeance factor, like hardwoods, moisture held in the materials may take longer to extract by dehumidification.

Need for More Rapid Drying

Some situations require the professional to dry a structure as rapidly as possible. In a situation of this type, install the maximum number of air movers and dehumidifiers available to provide the fastest drying possible.

Comparing Dehumidifiers

All dehumidifiers are not equal. Several different sizes exist, with differing capacities. A large dehumidification unit, although more expensive per day, can replace many smaller units while costing the same or even less.

Monitoring the Job

During the restoration process, conditions continually change. Therefore, cost -efficient drying requires frequent monitoring.

Daily Humidity Record

A "daily humidity record" will help you to keep track and stay in control of job conditions. If used regularly it will more than pay for the cost of maintaining it, by helping explain restoration procedures and cost to insurance agents, specifically the charges for dehumidifiers.

Daily Humidity Graph

As you record measurements on the daily humidity record , also graph and plot the specific humidity on a "daily humidity graph". It is much easier to see relationship in a graphic form than in written characters.

Open and Closed Drying Systems

Closed Drying System

In a " closed drying system " using dehumidification, the indoor environment is sealed as tightly possible against the effects of outdoor temperature and humidity conditions. Windows and doors remain closed. High-velocity air movers, dehumidifiers, and HVAC systems are used to increase the rate evaporation and to reduce the humidity.

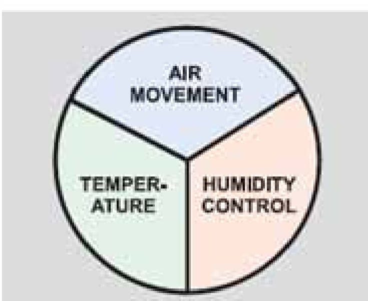

Figure 6 : All parts of the drying pie are equally important to rapid drying and a balanced drying system

Most jobs require a closed drying system. Generally, use a closed system when outside humidity is over 40% . With a closed drying system, the restoration technician has greater control over the variables involved in drying.

Open Drying Systems

Intentionally using outdoor air to reduce the indoor humidity is known as an “open drying system”. This is sometimes done when outdoor humidity is under 40% RH, outdoor temperature is approximately 16°C (60°F) or more, and the rate of evaporation is relatively high, from surface water or from porous materials like carpet . Doors and windows are left open to reduce humidity, and the structure is ventilated instead of dehumidified.

An open drying system is best applied in areas where the weather is consistently warm and dry. When using this system, the outdoor condition is the best humidity target you can achieve. Ventilating a structure with humid outdoor air can actually prolong the drying process. Also, as the rate of evaporation slows, you may need to convert to a closed drying system, especially in cases of structural saturation.

How A Dehumidifier Works

The **Desiccant Based Dehumidifier** removes moisture from the air by chemical attraction rather than condensation. Humid air is directed across a desiccant material that acts as a drying agent. The moisture is collected on or in the desiccant rather than as a liquid. A second hot air stream that heats the desiccant and releases the moisture, dries the moist desiccant. Then the desiccant is reused to dry more air. In a continuous process, the air is dried by the desiccant at the same time that more desiccant is being dried in preparation for reuse, so that dry air is available at all times.

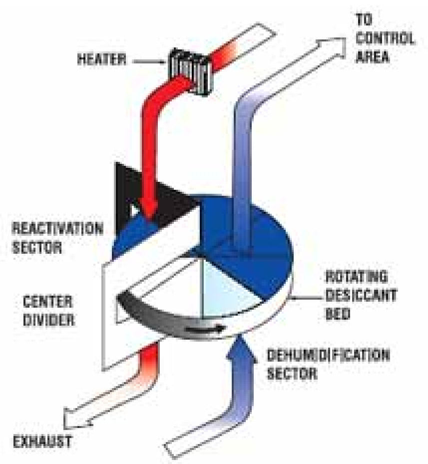

Figure 7 : A desiccant based dehumidifier

Rotating Honeycomb Dehumidifiers. In its latest configuration, solid desiccant is impregnated into a rotating wheel that contains structured air contact media in the form of a honeycomb. Air passes through the open flutes in the media and releases the moisture to desiccant contained in the media walls. The moist media then rotates into the reacti-vation air stream. It is separated from the process air by a partition. The heated desiccant releases its moisture and is ready to reuse on the process airside of the partition.

Dehumidifiers are used to remove water from the moisture-laden air. This system provides for a greater degree of control over the drying process. Indoor RH and material moisture content can be reduced faster.

Dehumidifiers can speed up the drying process reducing the length of time that drying equipment is required and thereby reducing additional expense. Other advantages of a closed drying system are the reduced possibility of mold growth, the reduction of secondary damage to structural materials and contents due to high humdity, all of which results in reduced reconstruction cost.

Desiccant based dehumidifiers are the most suitable for restoration needs in two ways. First is that they have very good dehumidification and moisture removal capacity at all conditions i.e. at all weather conditions. This is extremely important for the final phase of drying where moisture extraction is only possible by a very low RH percentage

The second advantage is the fact that the dehumidification in a desiccant based system occurs along the constant wet bulb line, which means that along with dehumidification the temperature of the air also increases aiding in removal of the moisture.

Figure 8 : Rotating Honeycomb dehumidifier

Some Examples of Drying Work Carried Out

Example 1 - Drying Of Books & Office Records.

A very unique and tedious effort, of salvaging more than 5000 books comprising of research work and scientific thesis after the recent (26-7- 2005) flash floods that hit Mumbai. Restoration of this priceless collection started with extraction, dehumidification and mold remediation and the job was effectively accomplished in about 8 days.

The books had been submerged in water and had remained in water for more than 24 hours. They were covered with mud and silt. The books were washed to remove mud. Mold and fungus had already started to appear on some books. Other books were glued to each other.

Five dehumidifiers were installed to provide 1200 cfm of dehumidified air. A vapour barrier of 30x15x8 feet was created around the area where the books and records were kept. To control mold growth the books were sprayed with special solutions and solvents. The books were brought to their original state. We managed to restore the library in about 8 days time working 24 × 7.

Example 2: Drying of Electronic Equipment Susceptible to Corrosion And Impairment

CNC machines are electronic controlled and used for various purposes. In this example two CNC machines used for making labels were totally wet as they had been submerged in 3-4 ft of water. Corrosion had begun to occur inside the panels after the water had receded. The machines were facing the danger of partial impairment of the electronic components.

Two dehumidifiers were installed supplying 500 cfm of dehumidified air. A vapour barrier of 30x15x8 feet was created around the machines. The machines were dried up completely and became functional.

Example 3: Drying and Restoration of Home Appliances

Drying and restoration of home appliances like TVs, Fridges, DVDs and Microwaves from a flooded warehouse. The goods were worth Rs. 6-8 crores. The warehouse had been completely submerged in water. The water had receded after four days. The corrugated boxes in which the appliances were kept were totally damaged. The appliances were wet and soaked with water and were covered with mud and silt. Our services were engaged by the insurance company. The goods were facing the danger of partial impairment of the electronic components.

The appliances were opened and mud and silt was washed with water. We installed three dehumidifiers of 5000 cfm. Two vapour barrier rooms were created. In one room of 30×70×6 feet, 70-80 appliances were kept. In another room of 20×8×12 feet, around 10 racks were kept on which small appliance were placed. The appliances were dried completely and became functional.

Conclusion

Restorative drying is a combination of art, science and experience and helps to restore water damaged goods to their original condition. Insurance companies can gain immensely from such facilities as it helps to recover most of the cost of the water-damaged goods. Offices can recover their paper records and factories their wet machines and finished goods. The possibilities of application are very diverse.

References

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