Chapter 1 – Principles of Water Damage Restoration

Page 90, 91, 92, 93

1. **Provide for the Safety & Health of Workers and Occupants -** "….Refer to Chapter 8, *Safety and Health*."
2. **Document & Inspect the Project**
   "……Refer to Chapter 9, *Administrative Procedures, Project Documentation and Risk Management."* (…) "Refer to Chapter 10, *Inspections, Preliminary Determination, and Pre-Restoration Evaluations."*
   a. **Initial Inspection**
   b. **Ongoing Inspection**
   c. **Final Inspection (Completion)**
3. **Mitigate Further Damage**
   a. **Control the Spread of Contaminates**
   b. **Control Moisture Intrusion**
   (Page 92) "Moisture problems should be identified, located, and corrected or controlled as soon as possible. Failure to correct or control moisture intrusion significantly degrades the ability of restorative drying techniques to return the structural materials and contents to an acceptable drying goal."
4. **Clean and Dry Affected Areas**
   (Page 92) "Restorers should clean and dry water-damaged buildings, systems, and contents. The cleaning process can help prevent the spread of soils and contaminants to unaffected areas and return the building and contents to an acceptable appearance. Cleaning can include bulk removal of unsalvageable materials, remediation of contamination, and detailed cleaning.
   a. **Cleaning**
      Initial/Bulk Cleaning – "The process of removing bulk debris, soil, or materials from the work area. This process can include but is not limited to: the removal of unsalvageable materials, removal of materials to gain access to expedite drying, or bulk contamination (e.g., sewage)."
      Detailed Cleaning – "The process of thoroughly removing soils and contaminants from the work area. This process can include but is not limited to: dry soil removal, abrasive cleaning, damp wiping, high-pressure washing, low-pressure flushing, or the application off appropriate cleaning agents or antimicrobials (biocides)."
      Final Cleaning – "The process of removing residual soils or materials from the work area to improve appearance and prepare for re-occupancy. Final cleaning can include but is not limited to: dry soil removal, damp wiping, or other appropriate activities.
5. **Drying** (…) Refer to Chapter 5, Psychrometry and Drying Technology.
   a. **Enhancing Evaporation**
   b. **Enhancing Moisture Diffusion**
   c. **Dehumidifying and Ventilating**
   d. **Controlling Temperature**
6. **Complete the Restoration and Repairs**

Chapter 2 – Microbiology of Water Damage

Page 94, 95, 96

1. **Microbial Ecology**
   a. **Normal Ecology**

Clean/Dry Environment: "Environmental bacteria and fungi are ubiquitous in the indoor environment. They are typically introduced as cells and spores from outdoors through opening between interior and exterior spaces, from carriage on clothing, and from tracked-in soil. Spores are the reproductive and resting stage for many molds and some bacteria. They enable the organisms to resist unfavorable environmental conditions for varying lengths of time (i.e., weeks, months or years). Once indoors, these biological agents interact with the inanimate environment by collecting or settling in or on a variety of surfaces or materials. Such collecting places, or "micro-environments" or "reservoirs," include carpet, upholstered furniture, wood, and various painted surfaces such as walls and ceiling, a variety of contents materials, and heating, ventilating, and air-conditioning (HVAC) systems."

"Both bacteria and fungi, along with their various components and by-products, constitute a major portion of indoor dusts. In a dry environment subject to routine cleaning (e.g., dust removal), such reservoirs are normally non-problematic. However, as water intrudes, or moisture condenses onto surfaces and materials, the microbial ecology begins to change with potentially detrimental effects.**"**

   b. **Shifting Ecology**

Damp/Wet Environment: "Bacteria and fungi grow in areas where moisture is available, and thus are commonly found in damp areas such as unvented bathroom, basement, under-sink cabinets where leaks and/or condensate is common, and in air conditioning system components. Continued chronic moisture conditions allow bacteria and fungi with higher moisture requirements to flourish. If conditions are such that moisture is limited, then these microorganisms can have a stable and non-problematic relationship with the inanimate components of the built environment."

"However, when moisture intrudes or accumulates more rapidly than the natural drying process, such as with chronic plumbing leaks or sudden flooding from rainwater or sewage backflow, the microbial ecology changes and favors rapid growth (amplification) of bacteria and fungi with high moisture requirements, (….) This amplification can damage valuable materials, and affect the quality of the indoor air, creating health risks for those who live or work there."

"In some water damage situations, such as with sewage contamination, the organisms present can include a variety of disease-causing human viruses and parasites in addition to the bacteria and fungi. "

   c. **Sewage**

Bacterial pathogens in sewage can include virulent strains of gram-negative organism such as Salmonella, Shigella, and Escherichia coli. Over 120 different viruses can be excreted inhuman feces and urine and can be found in municipal sewage, in addition to a wide variety of fungi and animal and human parasites. Sewage also constitutes a tremendous source of bacterial endoxins (cell wall components) that can induce a variety of adverse health effects. The potential adverse health consequences to occupants and restorers from sewage contamination and clean-up activities are discussed in Chapter 3, *Health Effects from Exposure to Microbial Contamination in Water-Damaged Buildings."*

2. **Water Activity**

   Microorganisms can grow in moisture films on a variety of surfaces and within porous materials. The amount of free water available to them for growth on a substrate, such as wallboard, carpet or ceiling tile, is described as water activity (aw). It can be compared to the equilibrium relative humidity (ERH) of a material. ERH refers to the relative humidity (RH) of the atmosphere in equilibrium with a material with a particular moisture content (ISIAQ, 1996). A measurement of 80% RH at the surface of a material would equate to a water activity (aw) of 0.8."

3. **Growth Requirements**

   Most bacteria have a minimum requirement of aw for growth that is >0.5 (95% ERH), while many molds have a lower minimum requirement of aw >0.88 (88% ERH). However, most molds that appear in the environment during the early stages of water damage require less moisture to grow. For those dry-tolerant (or xerophilic) molds, aw of 0.66-0.70 (66%-70% ERH) is sufficient to promote growth. Xerophilic molds include species of *penicillium and Aspergillus* that may produce potent allergens and toxic substances. A high percentage of *Penicillium or Aspergillus* species in an indoor dust or air sample is normally an indicator of a previously or currently damp condition due to water intrusion (such as floods and leaks) or an accumulation of condensation. Very wet or damp environments, particularly those with cellulose-based materials (such as wallpaper, drywall, books, cardboard, favor the growth of molds such as *Stachybotrys, Ulocladium and Chatomium*"

   "Also a variety of soil bacteria as well as some yeasts and molds, can grow in stagnant flood waters, as well as water reservoirs of heating, ventilating and air conditioning (HVAC) systems. Additionally, a variety of microorganisms can grow under low-to-moderately moist conditions, utilizing a variety of nutrient substrates that have collected in, on, or as a part of the composition of a variety of building, finishing, and furnishing materials such as wood, drywall, wallpaper, ceiling tile, insulation, carpet and upholstery, and wicker furniture. Porous contents materials such as book and papers are especially susceptible."

4. **Microbial Odors**

   "In addition to visible bacterial or fungal growth and detection of moisture in porous materials, an obvious indicator of microbial growth and contamination is a "musty," "moldy," or "mildew" odor. Bacteria and fungi produce a variety of volatile organic compounds (VOCs) during active growth on damp or wet building, finishing, and furnishing materials. These microbial volatile organic compounds (MVOC's), which are detected through the olfactory senses (smell), are generated by many molds, and also gram-negative and actinomycete bacteria as they rapidly metabolize and amplify."

Chapter 3 – Health Effects from Exposure to Microbial Contamination in Water-Damaged Buildings

Page 98, 99, 100, 101

1. **Introduction**
   "Microbial contamination associated with water damage in indoor environments is a public health problem. It presents a health risk to both occupants and restoration works, potentially resulting in a variety of illnesses of an inflammatory, allergic, infectious, and toxic nature. Floodwaters carry soil bacteria and fungi whose types, components, and by-products can induce respiratory inflammation and sensitivity, while sewage backflows additionally introduce a variety of infectious disease agents. Moisture accumulation (chronic leaks, condensation), leading to a state of unabated dampness, results in the growth and amplification of molds that can damage valuable materials and adversely affect human health."
2. **Dampness and Health**
   a. **Epidemiologic Studies**
   b. **Critical Assessment**
      "……The IOM '(Institute of Medicine)' stated that "Excessive indoor dampness is not by itself a cause of ill health, but it is a determinant of the presence or source strength of several potentially problematic exposures." It noted that damp environments favor bacterial and fungal growth and house dust mites, standing water supports cockroach and rodent infestations, and moisture may initiate chemical emissions from building materials and furnishings. In summary, on the basis of its review, the committee concluded that "…. excessive indoor dampness is a public health problem."
      In its summary findings, the IOM found sufficient evidence of an association between exposure to damp indoor environments and cough, wheeze, upper respiratory tract symptoms (nasal and throat), and asthma symptoms in sensitized persons. It also detailed limited yet suggestive evidence of an association between exposure to damp indoor environments and shortness of breath, the development of asthma, and lower respiratory illness in otherwise healthy children, all of which require additional research."
3. **Sewage and Health**
   "…..Unprotected workers who remediate sewage damage losses, as well as sewage treatment workers, and sewage sludge processors, are at risk for chronic respiratory disease, other systemic health effects, and a host of acute and chronic bacterial, fungal, viral, and parasitic diseases. Over 120 different viruses can be excreted in human feces and urine and find their way into sewage (Straub et al, 1993). These can include rotavirus, causing severe and sometimes life-threatening diarrhea in children; adneoviruses, causing respiratory and eye infections; and Norovirus, a significant cause of gastroenteritis. Parasitic agents include the highly infectious *Giardia* and *Cryptosporidium* that can result in chronic and severe intestinal diseases in both adults and children."

"Bacterial pathogens in sewage can include virulent strains of gram-negative organism such as Salmonella, Shigella, and Escherichia coli (Berry et al, 1994). In addition to the infectious disease risk, gram-negative bacteria contain endoxins that are released at the time of cell death and destruction. These cell fragments with endotoxins can be aerosolized during improper remediation activities, such as attempts to clean and dry sewage-saturated carpet in-place, as opposed to careful removal and disposal. Endotoxins can induce respiratory inflammation and airway restriction (chest tightness), and create the potential for allergic and infectious disease responses. There is also evidence that inhaled endoxins may adversely influence the central nervous system (Rylander,1994).

Attempts at salvaging sewage-contaminated carpet and other porous materials can also liberate extensive amount of allergens, as well as potentially infectious agents. This poses a risk for susceptible populations such as elderly, infants, convalescents, and those who are immunocompromised through disease or therapy."

4. **Secondary Fungal Contamination**

   "As discussed in Chapter 1, *Principles of Water Damage Restoration,* if water damage events are not mitigated timely, fungal contaminants will grow and amplify, quickly posing an allergic, toxic, and infectious disease health risk to both occupants and restoration personnel. An in-depth presentation of the health effects from indoor mold contamination is found in the current edition of the ANSI/IICRC S520 *Standard and Reference Guide for Professional Mold Remediation."*

   a. **Allergic/Inflammatory Effects**

      "…..Additionally, it is recognized that fungal contamination can trigger asthma, a chronic inflammatory disease of the respiratory system."

   b. **Toxic Effects**

   c. **Infectious Disease**

      "Individuals at an increased risk for opportunistic fungal infections include those immunocompromised due to HIV infection, neoplasm, hemotherapy, transplantation, steroid therapy, and underlying lung disease (Nash et al, 1997; The et al,1995). Children with neutropenia or prolonged corticosteroid or antibiotic therapy are especially susceptible to infection (Shenep and Flynn, 1997).

5. **Conclusion**

   "In light of both the recognized and potential health effects associated with microbial contamination in water-damaged indoor environments, restoration professional should take appropriate measures to protect building occupants, and maximally reduce exposure risks to their workers through training, immunization, and the use of administrative and engineering controls; personal protective equipment (PPE)."

Chapter 4 – Building and Material Science

Page 103 to 111

1) **Introduction**

   "…..Building envelopes are subject to the laws of thermodynamics, which imply that hot moves toward cold; wet moves toward dry; high pressure moves toward low pressure; and everything seeks equilibrium. These principles prevail and cause natural change in temperature, pressure, and moisture content, unless variables are present that enhance or hinder natural movement."

2) **The Building Envelope**

   "The building envelope separates the interior of a built environment from the outside environment. The building envelope includes exterior walls, foundation, floors, windows, doors, roofs, and ceilings. The building envelope has several purposes including keeping out wind, rain and ground water, and controlling the transfer of energy between the inside and the outside."

   a) **Building Penetrations and Flashing**
   b) **Wall, Floor and Ceiling Assemblies**

3) **Mechanical Systems**

   "….Some of these systems create positive pressure, while some create negative pressure, and some are neutral. Pressure differentials should be considered when investigation problematic systems."

   a) **21st Century Building Envelope Techniques**

      "Existing building design and construction practices present challenges to drying after water intrusion. For example, commonly used moisture retarders can prevent expeditious drying of building components. In a warm humid climate, moisture tends to move from outside to inside and can become trapped inside walls. In a cold climate, moisture tends to move from inside to outside and can also become trapped within walls. In a mixed climate, moisture enters interstitial spaces from either side, depending on season. An increase in insulation decreases the drying potential of buildings. …………..Installing semi permeable or non-permeable materials and assemblies on the interior, such as polyethylene vapor retarders under the gypsum wallboard, vinyl and other wall coverings, prevents drying to the interior. Using materials that are moisture sensitive, such as particleboard, paper-faced gypsum wallboard, and some laminate flooring, presents a challenge to drying. Some materials, such as oriented strand board (OSB) and concrete with chemical plasticizers do not absorb water easily; if they become wet they can be very difficult to dry."

4) **Air, moisture and heat flows in buildings**

   a) **Mechanisms of Airflow**

      "For a given volume of air entering a building, an equal volume of air must leave. Conversely, if air is being removed from a building, an equal volume must enter. This can be stated as: cubic feet per minute (CFM) in, equals CFM out."

      "As with fluids, moving air seeks the path of least resistance. In most cases air rises when heated and falls when cooled. Air flows from high pressure to low pressure (e.g., an inflated balloon has higher pressure on the inside relative to the outside. The obstruction of the balloon casing prevents the high pressure from moving toward the lower outside pressure). "

"All structures have planned openings (e.g., doors, windows, vents) and unplanned openings (cracks crevices, gaps, material shrinkage, utility penetrations). Planned opening may be designed to either add or remove air from a building. If designed properly these openings do not compete for air. In order for air to move into or out of an enclosed space, such as a building or portion of a building, there must be an opening and drying or pulling force. At times, these forces may be unexpected and potentially dangerous (e.g., a dryer vent may pull air so strongly on the built environment that it causes the airflow from a water heater gas vent to reverse).

"Caution should be used when blocking, sealing, or restricting airflow, or reversing the direction of airflow through a planned opening. Serious health and safety problems may result. If large amounts of air are drawn out a building, the probability of combustion appliances back drafting or expiring flame rollout is increased."

"........Driving forces, such as wind, heat/stack pressure, fans and duct systems, can affect the indoor environment and a building system."

- **Wind: "**The impact of driving wind on a building envelope creates pressure differentials. Wind can drive air and moisture into or out of a building."
- **Heat: "**As air is heated, it rises and pulls cool air from lower areas of a structure. This is know as the "*static effect*." The taller the building the stronger the force."
- **Fans: "**Some fans are designed for moving air within a building and other fans are used to move air out of a building, e.g., fans in attics, kitchens, bathrooms, clothes dryers, air exchange, and central vacuum systems. These devices often create unplanned pressure imbalance because they intentionally force air out of a building, while causing a pressure differential that results in infiltration of makeup air from unplanned openings."
- **Duct Systems: "**Duct systems usually are connected to fans that distribute air through heating and cooling systems. These ducts often leak and sometime run through unconditioned spaces. They may draw air from many unknown and controlled areas."

b) Mechanisms of Moisture Flow

Moisture moves into and through building in four wats. Understanding these four mechanisms is helpful in determining where and how moisture gets into a building, and it is necessary when devising an effective drying plan. The following are the four mechanisms of moisture movement:

i) **Liquid flow (bulk water):** Liquid flow causes the greatest amount of moisture to enter a building in the least amount of time. Rain, melting snow, ground water, overflowing appliances, or water intrusion from a broken water supply or drain line are some causes or sources of liquid flow.

ii) **Air transport:** Moving air carries moisture through either planned or unplanned opening in a structure.

iii) **Vapor Diffusion:** Water vapor pressure causes moisture to move through airspaces, whether in a room**,** a smaller interstitial space, or through voids within materials. In areas where water vapor pressure is different from one side of a structural component (e.g., a wall) to another, moisture diffuses through the component (e.g., a wall) to equalize the pressure.

iv) **Capillary Suction:** Porous materials are capable of absorbing water through capillarity. Concrete, wood, and gypsum are examples of materials that absorb water through capillarity.

c) **Porosity and Permeability**

"Permeability describes the potential ease with which fluids move through a material. Porosity describes the structure of material and its void spaces."

"The porosity of a material is determined by measuring the amount of void space (i.e., pores) inside a material and determining what percentage of the total volume of that material is made up of void space."

"The characteristics of internal pores of certain materials may cause the permeability to be significantly greater in one direction (i.e., hysteresis)."

"Porosity is important in terms of the volume of moisture that a material may sorb and hold, while permeance is more relevant to the ability to move moisture through or out of a material. Porosity is also important when contamination is present as the construction of the void space will impact restorability and influence decision to restore or discard materials. Porosity of organic materials can also influence conditions supporting microbial growth."

"We generally define materials as:

- **Porous:** Materials that sorb moisture quickly and if organic, can support microbial growth (e.g., carpet, gypsum board, fiber-fill insulation, CMU, textiles);
- **Semi-Porous:** Materials that sorb water slowly and if organic, can support microbial growth (e.g., unfinished wood, concrete, brick, OSB); and
- **Non-Porous:** Materials that do not sorb moisture (e.g., glass, plastic, sheet metal)."

"Materials are also generally described as being:

- **Permeable:** (i.e., perm rating greater than 10)(e.g., latex paint, gypsum board, clay, tile, fiber-fill insulation);
- **Semi-Permeable:** (i.e., perm rating greater than 1, and less than or equal to 10) (e.g., plywood, osb, brick, stucco, plaster); and
- **Non-permeable;** (i.e., perm rating equal to or less than 1) (e.g., vinyl floorcovering, foil-face insulation, polyethylene sheeting).

d) **Mechanisms of Heat Flow**

Heat flows from areas of warm temperature to areas of cool temperature in the absence of other factors. The greater the temperature difference between warmer and cooler areas (temperature gradient), the faster the heat flows. In winter, a heated building loses heat to colder outside air. Conversely, in the summer, an air-conditioned building gain heat from outdoor air. Building lose or gain heat in three ways: conduction, convection, and radiation heat transfer.

- **Conduction: "**Conduction is transmission of heat through a material; e.g., a metal cooking pan conducts heat from the stove's burner through the pan to the handle, making it hot to the touch. During the winter, warm air inside a building is separated from the cold air outside by the building envelope. Because heat moves from areas of high temperature to areas of low temperature, the inside surfaces of a wall warms as heat moves toward the colder air outside a building; e.g., as an inside wall surface heats up, adjacent materials also begins to warm. Over time, heat from inside a building will transfer through the wall to the outside."

"……Some materials transfer heat well. The more readily materials transmit heat, the more conductive they are. Glass, concrete, and metals are examples of good conductors. Other materials---called insulators----are very poor at transferring heat. They include wood, fiberglass, and foam sheathing."

- **Convection: "**Convection is the movement of heated gases or liquids. The movement can be either natural or forced. Natural convection occurs when the movement of gas or liquid is caused by differences in density. Warm air rises because it has a lower density than the surrounding cool air. Since cool air has a higher density than warm air, the cool air drops as the warm air rises. The movement of air along the surface of a wall increases heat transfer and causes convection loops adjacent to both interior and exterior surface."

  In forced convection, the movement of a gas or liquid is caused by outside forces. If the wind is blowing, the air movement across an outside wall is higher, increasing the rate of heat transfer. This rate of heat transfer depends on the temperature difference, the velocity of the gas or liquid, and what kind of gas or liquid is involved. For example, heat transfers more quickly through water than through air."
- **Radiation Heat Transfer: "**Radiation heat transfer is the invisible electromagnetic waves that pass from one object to another (from areas of higher temperature to areas of lower temperature.) For example, if someone stands by a window on a cold day, their body radiates heat to the cold surface of the window, making them feel cold. In summer, radiant energy from the sun enters a building through windows. The walls and contents of a room absorb energy, while at the same time, various objects in the room release radiant energy, causing the room to heat up."

5) The Effects of Moisture on Materials and Assembles

"…. How materials react to moisture includes many factors such as: their susceptibility to damage, permeability, absorption, and evaporation rates, and susceptibility to microbiological growth."

6) Impacts on the Building Envelope

a) Occupancy

"………..These conditions may also create the need for additional dehumidification or ventilation."

b) Climate

"Climatic and regional variable include rainfall, temperature, and humidity. Such variations may require that restorers use different equipment and techniques when drying similar wet structures during different times of year, or in different regions of the world."

Chapter 5 – Psychrometry and Drying Technology

Pages 115

7) **Introduction – "**In returning a building to an acceptable condition after a water intrusion, restorers should manage the environment within the building, keeping in mind what is happening with the moisture in the structural materials and contents. To accomplish this, restorers should understand how:"

- "to manage the psychrometric properties of the environment during the different stages of drying;
- Moisture impacts and moves through different materials;
- To promote surface evaporation from the materials; and
- The materials are assembled in the construction of the building."

8) **Psychrometry**

"Psychrometry is a sub-science of physics relating to the measurement or determination of the thermodynamic properties of air/water mixtures (e.g., humidity and temperature). Measuring and evaluating these properties enables restorers to better analyze and manage conditions during drying."

"It is important to understand that air is a mixture of gases, some in steady proportions and some that vary. The gases in steady concentrations are nitrogen (77.5%), oxygen (20.5%), argon, neon, helium, and others. This accounts for approximately 99% of the mixture. The rest of the makeup of air is in variable concentrations. These gases are water vapor (0.05% to 0.09%). Radon, carbon dioxide, and many others. Water vapor behaves as any other gas in air dispersing equally throughout a sample or volume of air. All gases follow the second law of thermodynamics. That is, areas of higher energy or concentration always disperse and move toward areas of lower energy or concentration."

a) **Critical Laws in Psychrometry**

"These important laws that relate to air and water vapor mixtures that can help restorers understand the restorative drying process are:"

i) **Second law of thermodynamics "**states that in an isolated system, concentrated energy disperses over time to lower energy areas. Energy dispersal also means that differences in temperature, gas pressure, and water vapor pressure attempt to even out until equilibrium is achieved. The second law implies that heat does not flow from a cold material to a hot material; it only flows from hot to cold."

- "This law helps the restorer understand why (1) moisture in an enclosed environment disperses to other areas of the environment, (2) moisture moves through materials from areas of high to low water vapor pressure and (3) heating a space causes heat energy to be introduced into building materials."

b) **Dalton's Law of Gases "**states that (1) within a mixture of gases, each gas occupies the same overall volume and (2) atmospheric pressure is the sum total of the partial pressures of the various gas components (e.g., nitrogen, oxygen, argon, moisture vapor, radon)."

- "Dalton's Law helps to explain the concept of relative humidity – the ratio of the partial pressure of the water in the air to its saturation vapor pressure at a given temperature and barometric pressure."

c) **The Ideal Gas Laws "**are a combination of several laws of which Robert Boyle's and Jacques Charles laws are more relevant."

- "Boyle's Law basically states that for a fixed mass of an ideal gas (water vapor being one) at a given temperature, pressure and volume are inversely proportional."
- "Charles' Law deals with the behavior of ideal gases at relatively low pressures and relatively high temperatures."

"The Ideal Gas Laws explain why (1) equipment being used at 5280' elevation (e.g., mile-high Denver, CO) will not deliver the same volume of air as it would at 0' elevation (i.e., sea level) and (2) how a vacuum freeze dry chamber causes solid ice to sublime, becoming gas without going through the liquid state."

9) Humidity

"Humidity is water vapor present in an air mass. There are four generally accepted expressions of humidity used in the water damage restoration industry:"

1. "Humidity ratio (HR) (alternatively, vapor content or mixing ratio) of a given moist air sample is defined as the ratio of the mass of water vapor to the mass of dry air in the sample. It is expressed in grains per pound (grams per kilogram) of dry air, sometimes shortened to gr/Ib of gpp (g/kg).

HR = $\text{Weight}_{\text{water vapor}}$ / ($\text{Weight}_{\text{moist air}}$ - $\text{Weight}_{\text{water vapor}}$) or $\text{Weight}_{\text{water vapor}}$/ $\text{Weight}_{\text{dry air}}$"

2. "Relative humidity (RH) is the amount of moisture contained in a sample of air as compared to the maximum amount the sample could contain at that temperature. This definition is accurate in concept; but strictly speaking, relative humidity is the ratio of the partial pressure of water vapor in a sample of air to the water vapor pressure at saturation of that air at a given temperature and atmospheric pressure. "

3. "Water Vapor Pressure (WVP) is the pressure exerted by the molecules of a vapor on surrounding surfaces, usually expressed in inces of mercury ("Hg) or millimeters of mercury (MM Hg). Atmospheric pressure is the total pressure exerted by all gas components in the air (e.g., nitrogen, oxygen, argon, carbon dioxide, water vapor.) VP is only one component of the total atmospheric pressure. Since water vapor is the primary vapor of interest in restoration industry, the term water vapor pressure (WVP) is often shortened to vapor pressure (VP). Unless noted when "vapor pressure (VP)" is used without qualification, it refers to water vapor pressure."

4. "Specific humidity (SH) is the ratio of the mass of water vapor to the total mass of a moist air sample. Often incorrectly used as a synonym for humidity ratio. Specific humidity is expressed as grains per pound of moist air.

SH = $\text{Weight}_{\text{water vapor}}$ / ($\text{Weight}_{\text{dry air}}$ + $\text{Weight}_{\text{water vapor}}$) or $\text{Weight}_{\text{water vapor}}$/ $\text{Weight}_{\text{moist air}}$"

10) Airflow

"Directed airflow is used in the restorative drying process to accomplish two objectives:

1. To circulate air throughout the workspace to ensure drier air continually displaces more humid air. Air needs to be circulated to all affected interstitial cavities, such as wall and ceiling voids, beneath cabinetry and underneath and within wood flooring systems. Airflow can be directed using carious equipment or techniques (e.g., temporary ducting, stairwells, airmovers, structural cavity drying systems.)

2. To direct air at material surfaces in order to displace the evaporating surface moisture within the boundary layer of air and transfer energy to the surface moisture and materials. The boundary layer is a thin layer of air at the surface of materials that due to surface friction does not move at the full speed of the surrounding airflow. The affect of this law of airflow retards water evaporation at the surface and heat transfer to the materials. Directing sufficient and continuous air at material surfaces minimizes this boundary layer, removes evaporated water, and aids in transferring thermal energy to the surface of materials."

Airflow needs to be properly managed. This means that "more is not always better." On some denser materials like concrete, plaster, or wood, excessive airflow on low evaporation materials (i.e., Class 4 materials) during the falling drying rate stage can overdry the wetted pores at the surface of the materials and potentially hinder the drying process."

a) **Properties of Airflow – "**Airflow is usually described in terms of velocity and volume.

The **Velocity of Airflow** describes the speed of airflow moving through equipment or across a surface. The velocity of air moving across a wet surface plays an important role in the drying process. It is typically measured in feet per minute (FPM), feet per second (FPS) or meters per second (MPS). The effect of velocity on drying is discussed later in this chapter.

The **Volume of Airflow** describes the amount of air delivered by and airmover, dehumidification system, air conditioner, or similar piece of equipment. The volume of airflow is typically measured in cubic feet per minute (CFM) or cubic meters per hour (CMH), and is useful in calculating circulation or exchange rates within an environment.

Manufacturers of drying equipment usually provide the rated volume of air the unit delivers as its outlet in standard cubic feet per minute (SCFM). (……..)

Static Pressure describes the potential pressure exerted by a flow of gas (i.e., air) as measured in the normal direction of its flow. (……..) Equipment manufacturers will usually provide pressure rating for their fans, which are useful when a long run flexible ducting is required to distribute air throughout a space. The fan must deliver air at a static pressure great enough to overcome the resistance of a duct system, interstitial constraints, or floating carpet."

11) Temperature

"Temperature indicates the intensity of sensible heat of the air and within materials. Thermal energy influences the ability for water vapor to be suspended in a sample of air and is critical in the physical phase changes between solid, liquid, and vapor. The process of evaporation is a product of adding energy. The more energy added to a liquid, the more rapidly evaporation occurs."

12) Other Related Terms

1. Specific volume: "the specific volume of air as indicated on a psychrometric chart refers to the volume (e.g., cubic feet) of air per mass (e.g., pound) of dry air. (…….)"

2. **Enthalpy: "**the enthalpy of the air is a measure of the total energy in the air." (……)

a. **Sensible energy "**is the energy in the air that can be sensed or measured with a dry-bulb thermometer. A change in sensible energy changes the temperature people feel."

b. Latent energy "(sometimes referred to as hidden energy) is the energy that is required to bring about a phase change in water. It is the energy associated with evaporating and suspending water vapor in air."

"The greater the energy in a sample of air, the more moisture can be evaporated and suspended as a gas in the sample of air. In short, the reason warmer air can suspend or contain more moisture is not due to the enlarged volume of the air, but because the amount of energy in the air is greater. Therefore, if moisture is available for evaporation, more will be evaporated and suspended as gas."

13) Managing Psychrometric Properties for Restorative Drying

"Humidity, airflow, and temperature influence the movement of moisture within a material as well as the evaporation rate from the surface of material. These properties greatly impact the overall drying time for a project. The restorer's task is to manage the environment to return the affected materials and structure to the moisture levels and environmental conditions prior to the water intrusion."

"Equilibrium as it relates to the restorative drying industry assumes that prior to the water intrusion, a structure and its materials were in equilibrium relative to their surrounding environment. Throughout the year and from day to day, the moisture content of materials changes in response to the fluctuations of humidity and temperature of the built environment. As long as these materials' moisture content remains below thresholds needed for microbial growth, the changing moisture content is of little concern as all building materials have some tolerance for fluctuating moisture content."

"When a water intrusion occurs, the materials respond to the surroundings by taking on moisture either through direct contact with water or indirectly through the high humidity environment. The moisture content of materials that are in direct contact with water can quickly exceed the threshold that promotes microbial growth or deterioration of the material. Executing a proper drying plan will reduce the amount of time necessary to return the materials to a moisture level below the threshold for microbial growth and acceptable moisture content (i.e., drying goal)."

"It is important to quickly control the moisture in the air (e.g., dehumidification, ventilation) and use sufficient airflow to dry the surfaces of materials to reduce water activity, thus lowering the potential for microbial growth. This also stabilizes the environment, rapidly reducing the potential for secondary humidity damage to materials. At this point, the focus in on eliminating the surface moisture."

"As the job progresses and the environment is stabilized, materials can appear dry on the surface but can still be wet internally. The moisture in the materials is moving toward the surface. It is important to control humidity, provide constant airflow, and manage energy (heat) applied to the materials to promote drying. At this point, the focus is on moving the moisture within the materials."

"As the job progresses, there can still be some affected areas of the materials that meet the drying goals and other areas that do not. It is important during this stage to re-direct air movement and ensure good transfer of energy (heat) to the remaining wet areas. The overall need for humidity control and airflow can be lower than at the beginning of the project, since there can be a significant reduction in the amount of moisture being evaporated during the latter stages. It is important for the restorer to monitor the moisture in materials carefully and manage the equipment to achieve the drying goals throughout the affected area. Refer to Chapter 13, *Structural Restoration*."

14) **Drying Technology**

"Drying technology is an established body of knowledge and practice that deals with the effects of moisture in materials, its movement within, and evaporation from the surfaces."

15) **How Moisture is Held in Materials**

"Many of the materials that are used in building construction are hygroscopic, meaning they draw moisture into them from the surrounding environment. All hygroscopic materials in the built environment will contain moisture and will generally be at equilibrium relative to their surrounding environment in the absence of a vapor barrier or retarder. The water is held in the material either through adsorption (water or vapor adhering to the exterior surface and interior surfaces of cell walls) or absorption (vapor penetrating into the cells or crystalline structure. With some materials (e.g., salts), absorption actually dissolves the compound, thus changing its chemical makeup. The term sorption can be used to indicate the process of taking up moisture without specifying either adsorption or absorption, while desorption describes a material giving up its moisture."

"In a controlled laboratory environment, porous and semi-porous building materials will reach a state of equilibrium according to the surrounding relative humidity (RH) and temperature. At equilibrium the net effect is that the material is neither gaining nor losing moister – usually referred to as equilibrium moisture content (EMC). Additional, the water vapor pressure of the moisture held in the pores of the material will be equal to the surrounding environment. In a normal building environment, a steady state of EMC is not possible since the relative humidity and temperature are always fluctuating."

"Moisture content (MC) is defined as the amount of water contained in a material, expressed as a percentage of the weight of the oven-dry (or bone-dry) material."

"Water can be held in hygroscopic materials as bound or free water:

1. **Bound water:** this is moisture held within the cellular or crystalline structure of the material. This moisture may be sorbed into the cells or can become physically or chemically bound to the surfaces of the cells. Some of this moisture is always present in the materials and does not need to be removed. In fact, much of bound water in concrete is a critical part of the hydration process and actually strengthens it. A certain amount of bound water in wood is also desirable, contributing to its dimensional stability and strength."

2. Free Water: "this is liquid moisture on the surface and held in the pores of the material. All of this is excess moisture that has been drawn into the materials through capillary action. As free water remains, the cell material will absorb the moisture, thus being bound water until the point of fiber saturation. In most cellulose-based products, (e.g., wood, paper) this fiber saturation point is between 25-30% MC. All free water needs to be removed during the restorative drying process. (Figure 3)"

"As it relates to specific materials they need to be dried to the point they will:

1. Not support microbial growth (e.g., mold, bacteria);

2. Regain their structural integrity; and

3. Be restored to their intended purpose."

Water Activity (aw) "is the vest indicator of the likelihood of a material to support microbial growth. It describes the amount of free water available for microbial growth on a substrate and is comparable to the ERH of a material, which is the relative humidity taken at the surface of a material. An aw of 0.80 is equivalent to an ERH of 80%. According to ACGIH's *Bioaerosols: Assessment and Control* book in section 10.3.3, "Practically speaking, if aw can be kept below ~0.75, microbial growth will be limited; below an aw of 0.65, virtually no microbial growth will occur on even the most susceptible materials". In other words, the restorer's task is to dry all materials to be at equilibrium with an environment below this threshold (i.e., 0.65 aw) although, a threshold of 0.60 aw would provide a greater level of assurance. If the surfaces of hygroscopic materials (e.g., gypsum board) can be dried and maintained below the above threshold, microbial growth can be quickly halted; even though the core of the material may still have elevated moisture content."

16) How Moisture Moves Through Materials

"When building materials become wet following a water intrusion, the drying effort needs to reverse the mechanisms by which the moisture entered. The free water is drawn out through capillary action, followed by excess bound water via diffusion."

- **Capillary action** "is the movement of a liquid through the slender tubes or pores of a material. It is a result of, (a) surface tension of the water and (b) the adhesion of the water with the pore walls. These attractive forces cause the water to rise to the point that it balances the force of gravity of the column of water. The narrower the pore, the higher the water rises. Since capillary action is the movement of liquid, it is a quicker means of moisture movement than diffusion. Water moves through a material easier when it does not have to overcome surface tension within the capillaries of the materials."
- **Moisture diffusion** "is the movement of water vapor molecules through the mass of the material. It is driven by moisture gradients within the material as well as vapor pressure differential from inside the material to one or both outer surfaces of the material. Diffusion occurs much slower than capillary action, but is a necessary part of the process by which excess bound water is removed."

"Drying is the combination of water and vapor movement through a material to the surface where it evaporates. While free water is moving to the outer surface and evaporating, the external condition of temperature, humidity removal, airflow, and material exposure drive the drying process."

17) How Materials are Dried

"During the drying of any material, two processes can occur simultaneously (see Figure 4):

Process 1: Surface evaporation: This occurs as energy (i.e., heat) transfers from the surrounding environment to the material. The rate of evaporation depends on the temperature of the moisture in the materials, the humidity of the air, the airflow at the surface and exposure of the wet surfaces to the environment. Surface evaporation is controlled by diffusion of vapor from the surface of the material to the surrounding atmosphere through a thin film of air in contact with the surface."

Process 2: Internal moisture movement: "This involves internal moisture moving (as liquid, vapor, or both) within the material toward the surface, in order to be removed at the surface. The movement of moisture internally within the material is a function of the physical properties (i.e., porosity, permeability composition) of the material, the vapor pressure differential across the material, and its internal moisture gradient."

18) Constant & Falling Drying Rate Stages

"During drying, most materials go through three distinct stages of drying; constant drying rate stage followed by two falling drying rate stages. Figure 5 depicts qualitatively a typical drying rate curve of a hygroscopic material."

"During the constant drying rate stage, liquid water is present at the surface and evaporates into the air over the material at a constant, unhindered rate. Warm dry, rapidly moving air will cause faster evaporation than cool, stagnant air. As the liquid evaporates, it is replenished with water from within the body of the material via capillary action. The constant drying rate can be quite short (e.g., minutes) or much longer (e.g., hours) depending on the degree of saturation, physical properties of the material (e.g., porosity, permeability, composition) and the factors influencing surface evaporation (see later section on Evaporation from Material Surfaces). As long as the liquid water is continually available at the surface the rate of drying remains constant."

"When liquid water is no longer available at the surface, the second stage of drying begins (i.e., falling drying rate). (……………) Howard Kanare, in his book Concrete Floors and Moisture, explains the drying of cured concrete, and specifically the falling drying rate stage in this manner. "Liquid water recedes from the exposed surface of the material into the pores. Within each pore, water clings to the sidewalls and forms a curved surface called the meniscus. At the surface, water evaporated from the meniscus in each pore of the material. At this point, water still fills the pore structure of the material; there are continuous paths for liquid water to flow from within to the partially filled pores at the surface where water can evaporate. The surface may appear to be "dry," but the material is just beginning to dry in a very thin layer. The rate of drying during this stage steadily decreases."

"The third stage of drying (i.e., falling drying rate) results when there are no longer sufficient liquid-filled pores to support capillarity and moisture must now move through the material toward surface as a vapor. This vapor diffusion is driven by differences in moisture content gradient within the material (following the second law of thermodynamics) and a differential in vapor pressure in the material and the surrounding air."

19) How Energy Impacts The Movement Of Moisture In Materials

"For water to change phase from liquid to gas, energy (i.e., heat) is required – called the heat of vaporization. When sufficient energy is applied to bound moisture within a material, the bond between moisture molecules and the material is broken, thereby increasing vaporization. The greater the water vapor pressure differential and the more energy that is transferred in the core of the material, the faster the moisture will move through and evaporate from the material. However, the diffusion through the material is not directly proportional to the amount of energy applied. There is a diminishing return as the amount of energy is increased."

Heat energy transfer occurs in three ways:

1. Conduction – transfer of energy through a solid.

2. Convection – transfer of energy through movement of a heated fluid, such as air.

3. Radiation – transfer of energy emitted from a heated surface to another surface; requiring no medium (e.g., air) to convey the energy.

20) Evaporation from Material Surfaces

"Evaporation is the process by which water changes from its liquid phase to its gaseous phase. The evaporation load is influenced by several factors:

- Concentration of the moisture in the air – impacts the capacity of the air to contain more moisture;
- Water vapor pressure differential between the surface of the wet material and the surrounding environment – impacts the direction and speed of moisture movement;
- Temperature of the wet material – impacts the available energy required for the phase change (i.e., vaporization) of the water;
- Air movement across the surface of the wet material minimized the boundary layer, removes evaporated water, and aids in transferring thermal energy to the surface of materials; or
- Access to wet materials – impacts the surface area available to the dry air (e.g., open walls, move furniture, remove vapor retarding materials.)"

"One of the most important factors influencing surface evaporation, especially during the constant drying rate stage, is airflow velocity. Generally, continuous rapid airflow is needed to enhance evaporation of the wet surfaces. A review of research in the wood industry has shown that airflow velocities across the material surfaces of 600 feet per minute (FPM) or greater is generally adequate during this stage. As drying of the materials progresses into the failing rate stage, the velocity of airflow has a diminishing return as the water available for evaporation at the surface reduces."

"During the falling drying rate stage, most researchers suggest that airflow velocities across the material surfaces of 150 feet per minute (FPM) or greater is adequate. This reduced velocity of airflow can be beneficial for low evaporation materials (e.g., plaster, wood, concrete, masonry) due to the much slower internal diffusion of moisture. Additionally, overdrying the surfaces are of hardwood and thick timbers can result in drying stresses and drying out of the wetted pore surfaces internally, resulting in reducing moisture mitigation even further."

Chapter 6 – Equipment, Instruments, and Tools

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1) **Introduction**
2) **Water Removal Equipment and Tools**
    a. **Pumps:** (……) Restorers use two types of pumps: submersible pumps and surface pumps.
    b. **Extraction Units:** (…….) There are two basic types of extraction units: truckmount and portable.
    c. **Extraction Tools**: They include, but are not limited to: light wands, weighted drag tools, stationary tools, hand-held tools (e.g., stair and upholstery tools) and self-propelled units.

    Light Want: A light want is a non-weighted tool used for water extraction and carpet cleaning.

    Hard Surface Wand: A hard surface wand is a tool specifically designed to extract standing water from hard surfaces (e.g., concrete, tile, vinyl, hardwood).

    Weighted Drag Tool: A weighted drag tool is generally used for extraction on carpeted surfaces.

    Stationary Tool: Stationary tools are rectangular panels with multiple holes or slots in the base of the unit. The restorer typically stands on the stationary unit, compressing the carpet and cushion and creating a vacuum seal beneath the unit.

    Self-Propelled Unit: Self-propelled units are powered by a motor that moves the unit across the carpet.
3) **Air Moving Equipment-** (……) The equipment can be used to direct airflow at or across wet materials, to accelerate evaporation, to provide ventilation, or to create an air pressure differential between two areas. Many airmovers can also be fitted with ducting to direct airflow to other areas or out of the structure. Air moving equipment has various airflow and static pressure capabilities. Generally, there are two types of airmovers: centrifugal and axial.

    Centrifugal Airmovers: (…..) High-pressure centrifugal airmovers typically produce static pressure levels above 2.5” water column (WC), and utilize motors of at least ¾ HP. They are primarily used to direct airflow into restricted areas that are resistant to ambient air movement and exchange (e.g., under carpet, under kitchen cabinets, into building cavities, or under flooring systems.)

    Low-pressure centrifugal airmovers typically produce static pressure levels below 2.5”WC and have motors rated from ¼ to ½ HP. They are primarily used to promote evaporation by creating airflow across the surface of materials. Examples can include carpet and hard surface floor coverings, walls and ceilings.
4) **Axial Airmovers:** (……..) They move air parallel to the axis of the fan. Generally, axial airmovers produce higher volume airflow and a lower static pressure than centrifugal airmovers.
    (…) Low-pressure axial airmovers are generally used to direct airflow at surfaces to accelerate evaporation. Some models are used with stands to direct airflow to different surfaces (e.g., ceilings, floors, walls).

5) **Structural Cavity Drying Equipment:** In addition to the systems designed to operate with high-pressure centrifugal and axial airmovers, specially designed units exist that create even higher-pressure airflow. These units are specifically designed to force air into or out of wall cavities or other interstitial spaces, or under flooring materials for efficient drying of otherwise inaccessible areas. This equipment is designed primarily for drying wet wall, ceiling, and other assemblies including complex flooring systems.
(……) Attachments can be affixed to these systems for filtering, directing, and manipulating air. Such manipulation could include utilizing ducting and wall vents to direct air beneath floor systems with sleepers or flutes, and into wall or ceiling cavities. Pressurization can be positive, negative or both (i.e., push-pull). Attachments can include a system of panels or mats temporarily adhered to the top of wood flooring to negatively pressurize interstitial spaces beneath floor. The usefulness of these panels can be influenced by the amount of actual pressure exerted on the flooring system. The greater the pressure and resulting airflow, the faster the moisture will be removed from beneath the flooring material. Positive-pressure systems carry many of the same risks as other airmovers in that they can spread contamination. When drawing moist air out of potentially contaminated cavities using negative pressure, an-line HEPA filter should be used to remove contamination before exhausting the air into the room.

6) **Air Treatment Equipment:** Air treatment equipment is designed to alter or remove airborne contaminants, classified as particulates or gases. Particulates are solids and can be organic (e.g., mold, pollen, bacteria and viruses), or inorganic (e.g., asbestos, mineral dusts, soot, and ash. Some gases can be the byproduct of biological activity, combustion, or material off gassing. Source removal of contaminants or odor-causing substances is always preferred. Where the cause of odors (i.e., contaminants) or the perception of odors cannot be eliminated by physical removal of the source, alternate methods can be considered (e.g., filtration, ozone, pairing agents, dilution).
Air Filtration Devices (AFDs): AFDs consist of a motorized fan, filter(s), and housing, designed to remove airborne contaminants from the incoming air stream. AFDs typically have a series of filters consisting of a pre-filter, secondary filter, and a primary HEPA filter. The pre-filter and secondary filters prevent premature loading of the HEPA filter by trapping larger particles.
Airborne gases can be removed through the use of sorption filters like activated carbon. The sorption media will be effective on specific gases. (……)
AFDs are sized based on the cubic feet of air per minute (cfm) they process. They can be installed to create negative, neutral, or positive pressure in an area. (……)
AFDs can be installed to create negative or positive pressure differentials. When used to create negative pressure differentials, they are referred to as negative air machines (NAMs). They also may be used as air scrubbers to recirculate and filter air within a space.
AFDs used in contaminated areas should be sealed at the air intake side upon turning off to avoid releasing contaminations. They should be cleaned and decontaminated before being removed from the affected area and used on a subsequent job. Filters should be replaced as necessary following manufacturer's guidelines to maintain performance efficiency. Restorers should ensure that contaminated equipment is clean and decontaminated, or contained prior to moving through unaffected areas, transported, or used on subsequent jobs. Refer to the latest

edition of ANSI/IICRC S520 *Standard and Reference Guide for Professional Mold Remediation, for further guidance on using AFDs in mold-contaminated areas.*

Additional Air Treatment Devices: Other air treatment devices exist that alter contaminants to make claims to improve air quality and control odors. These devices can include ozone and hydroxyl generators, electrostatic precipitators and ultraviolet lamps. At the time of this document's publication there is insufficient information available to support the use of these devices in water damage restoration projects. Some of this equipment can produce varying amounts of ozone, which can cause health concerns in an occupied environment.

7) **Dehumidification Equipment:** Dehumidification is the process of removing moisture from air. The two primary dehumidification technologies used in the drying industry are refrigerant and desiccant. Refrigerant dehumidification involves cooling the air below its dew point, causing moisture to condense. Desiccant dehumidification places air in contact with a desiccant material that removes moisture by direct sorption. In closed drying, systems dehumidification is essential for removing evaporated moisture from air to promote drying and minimize or prevent secondary damage. Dehumidifiers of sufficient performance and capacity are necessary to create an effective drying system.
   Refrigerant Dehumidifiers
   Low-Grain Refrigerant (LGR)
   Desiccant
8) **Heat-Drying Systems:** Heat-drying systems dry wet materials by circulating heated air throughout the affected area or by focusing thermal energy directly on the wet materials. The resulting moisture laden air is either dried by mechanical dehumidification or exhausted to the outdoor environment. Thermal energy accelerates evaporation and desorption of moisture from materials.
9) **Heat-Drying Equipment:** Supplemental heat can be used in the event the installed heating system is not operational or its use is not advisable. Heat may also be used to achieve desirable drying conditions and accelerate evaporation from building materials and contents.
   Direct-Fired Heaters: Direct-fired heaters incorporate a single air stream where both combustion and the process air are combined. They shall not be used unless adequate ventilation is available and monitoring is provided because the combustion by-products (i.e., carbon monoxide) remain in the air stream.
   Indirect-Fired Heaters: Indirect-fired heaters have a heat exchanger incorporated into their design that separates the combustion chamber from the process air stream. If indirect-fired heaters are placed within an occupied area, the combustion stream shall be ducted to the outside.
   Electric Heaters
   Hydronic Heaters
   Radiant Heat Devices: Radiant and infrared heat devices primarily heat objects instead of the air, and therefore can be used to focus heat on specific surfaces. Restorers are cautioned that some radiant heat devices are capable of raising temperature beyond the flash point of some materials.
   Desiccant Dehumidifier: Desiccant dehumidifiers are not primarily heaters, but a by-product of the moisture removal process is sensible heat, which results in a significant rise in the temperature of the process air stream.

10) Other Equipment

Air Exchangers: Air exchangers work by exchanging indoor and outdoor air through a cross-flow heat exchanger, which results in transfer of energy (heat) from one air stream to the other. Air exchange units, also called energy recovery ventilators (ERV), are typically used in colder climates where removal of moist air inside a space is desirable but where the loss of heat from interior air is not.

Portable Air Conditioners

11) Detection and Monitoring Instruments

Thermometers: Thermometers measure temperature (e.g., Fahrenheit, Celsius) of either air or materials. Three commonly used thermometers are air, surface, contact, and infrared.

Hygrometers: Hygrometers measure the relative humidity of an air sample.

Psychrometers: A psychrometer measure the difference in reading between two thermometers, one have a wet bulb and the other having a dry bulb, to determine the moisture content or relative humidity of air.

Manometers: A manometer is an analog or digital instrument that measures the static air pressure differential between two or more adjacent areas. This device can be used to monitor contained, contaminated spaces to reduce the potential risk of cross-contamination.

Gas Detectors: A gas detector is a device that measure the concentration of one or more gases in a space (e.g., carbon monoxide, oxygen.

Particle Counters: A particle counter is an instrument that detects and counts particles in the air and can differentiate particles based on size.

Moisture Sensors: Moisture meters are devices that display a value of moisture content or level based on electrical variances in materials. They measure moisture either on a relative scale and referred to as moisture level; of in actual percentage of moisture content. Two types of moisture meters are:

- **Non-invasive (non-penetrating) Meters:** Non-invasive meters use either electrical conductivity or radio frequency emissions to detect moisture. These meters allow restorers to test or scan areas without damaging the material. They can also be used to quickly identify areas needing further evaluation. The reading obtained are based on the presence of moisture in, on, or under materials, with limitation due to false positives (e.g., foil back insulation, metal ductwork, steel studs, lead paint, corner beads) and false negatives (e.g., air gasps, voids, material density, layering).
- **Invasive (penetrating) Meters:** Invasive meters measure moisture based on the electrical conductivity between two probes in the material being tested and displayed on an analog or digital readout. These instruments can be used to provide actual or relative measurements.

A wide variety of professional-grade moisture meters are available that are designed and calibrated for a specific material or combination of different materials. Some models feature different scales for wood, gypsum board, oriented strand board (OSB), plywood or other building materials.

12) Thermal Imaging Cameras: Thermal Imaging Cameras (infrared camera) are used to detect surface temperature differences and do not directly detect moisture or measure through materials. (……)

A thermal imaging camera produces a thermal image of a material that can provide rapid identification of potentially moist areas by indicating apparent temperature differences at the surface of materials. Areas identified with the camera as suspect for being wet should be verified by further testing with a moisture meter. Temperature differentials on material surfaces can be due to various influences including but not limited to:

- an evaporative cooling effect on the material's surface;
- missing or compacted insulation;
- thermal bridging; and
- air striking the surface of the material from the HVAC system.

13) **Psychrometric Charts and Calculators**
A psychrometric chart or calculator is an instrument that allows the restorer to use measured conditions such as temperature and relative humidity to calculate other psychrometric properties, such as dew point, water vapor pressure, humidity ratio, enthalpy, air volume, density, and wet bulb temperature.
14) **Data Logging Devices:** Data loggers and paper chart recorders are instruments that measure and record various data over time (e.g., atmospheric conditions, moisture levels, equipment operations). (…..) Typically, a data logger is installed at the beginning of the project, and provides a historical record of conditions throughout a project.
15) **Remote Monitoring Systems:** Remote monitoring systems combine data logging instruments with the added functionality of offsite access to the data.

Chapter 7 – Antimicrobial (biocide) Technology

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1) **Introduction-** In addition to having general knowledge of potential microorganisms present in a water damage restoration project, restorers should have an understanding of the proper use of agents that can help control the growth of these microorganisms and reduce potential risks associated with some of their metabolic by-products (e.g., endotoxins, mycotoxins).

    Microbiological growth is inevitable when moisture, nutrients, and moderate-to-warm temperatures are present. It is important to recognize that not all water intrusions warrant the use of antimicrobials (biocides). Thus, it is important for restorers to evaluate whether antimicrobial (biocide) application is appropriate.

    There are several steps in the restoration process that restorers should perform or facilitate, which can return the structure to a sanitary condition without using antimicrobials (biocides). These steps should include: stopping the source of moisture intrusion, removing un-restorable contaminated materials, followed remediation, drying, and final cleaning of affected materials, systems, and contents.

    When there is a Category 1 water intrusion that has not changed in Category (e.g., a delayed response or pre-existing damage), the use of antimicrobials (biocides) is generally not warranted. When a Category 1 water intrusion has changed in Category or when there is a Category 2 or 3 water intrusion, then the use of antimicrobials (biocides) may be warred. Alone with other cleaning products and processes, antimicrobials (biocides) can play an important role in limiting the spread of bio-contamination and disease.

    There are also factors that might preclude the use of an antimicrobial (biocide). Many antimicrobials (biocides) are deactivated by organic matter in water or on surfaces (e.g., chlorine-based formulations, alcohol, peroxide, quaternary ammonium compounds; therefore, pre-cleaning is an essential first step.

2) **Definition and Regulation:** Antimicrobials are substances used to destroy (biocides) or suppress growth) growth inhibitors/static agents) of microorganisms (i.e., bacteria, viruses, or fungi) on inanimate objects, surfaces, and materials.

    Terminology: Classes of antimicrobial products include sanitizers, disinfectants, sterilizers (sporicides), and growth inhibitors;

    - **Sanitizers:**
    - **Disinfectants:**
    - **Sterilizers (sporicides):**
    - **Growth inhibitors (bacteriostats, fungistats):** Products used to treat surfaces or be incorporated into materials to suppress or retard future vegetative bacterial and fungal growth under moist conditions.

    Other commonly used terms and their definitions include the following:

    - **Antimicrobial:** Substances that kill or control microorganisms (such as bacteria, fungi, viruses) or inhibit growth of microorganisms.

- **Bacteriostat:**
- **Biocide:** Any substance that kills living organism.
- **FIFRA:**
- **Fungicides:**
- **Pesticide:**

3) **Antimicrobial (Biocide) Chemistry**
4) **Remediation of Microbial Growth and Biocide Use**
   The IICRC recognizes the practices for management of microbial growth and of antimicrobial (biocide) use outline by the American Conference of Governmental Industrial Hygiene (ACGIH) *ioaerosols: Assessment and Control,* 1999, as a valuable resource for understanding biocide use and its limitations. Some useful quotes from that work follow:
   - **Section 15.4 Biocide Use.** "Remediators must carefully consider the necessity and advisability of applying biocides when cleaning microbially contaminated surfaces [see 16.2.3]. The goal of remediation programs should be removal of all microbial growth. This generally can be accomplished by physical removal of materials supporting active growth and thorough cleaning of non-porous materials. Therefore, application of a biocide would serve no purpose that could not be accomplished with a detergent or cleaning agent. Prevention of future microbial contamination should be accomplished by (a) avoiding the conditions that led to past contamination, (b) using materials that are not readily susceptible to biodeterioration, and (c) where necessary, applying compounds designed to suppress vegetative bacterial and fungal growth or using materials treats with such compounds."
   - **Section 16.**2 **Biocide Use and Application.**
   - **Section 16.2.3 Biocide Use and Application.**
   - **Section 16.2.4 Aqueous Biocides.** "Disinfectant-detergents and sanitizer-detergents clean and inactivate microbial contamination in one step. Studies have shown that cleaning with a detergent may be as effective as cleaning and treatment with a biocide."
5) **Risk Management**
6) **Application Methods:** Antimicrobials (biocides) shall be used according to label directions. (…….) Remediation procedures rely on thorough cleaning and source removal first, and then, if appropriate, the application of antimicrobials (biocides). Clean contaminated surfaces as thoroughly as practical before applying antimicrobials (biocides). With Category 2 on carpet, though cleaning is required before applying antimicrobials (biocides).

   A low-pressure sprayer is usually the recommended equipment for application. This produces large droplets, which reduce air suspension time (drift) and the potential for inhalation. High-pressure air streams can result in undesired dispersal of spores, microorganism, and other biological debris. Forming aerosols or wet fogging antimicrobial (biocides) has performance limitations and is not recommended, because of the increased risk of inhalation of antimicrobials (biocides).

Chapter 8 – Safety and Health

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1) Introduction

"The regulations referred to in this Standard and Reference Guide are based on U.S laws and regulations, but it is understood that other countries generally have comparable health and safety requirements. Restorers shall understand the laws and regulations related to health and safety for the particular country or locale in which they work."

Although there are few specific federal, state, provincial, and local laws and regulations directly related to water damage restoration and microbial remediation, there are safety and health regulations applicable to businesses that perform such work. Federal safety and health regulations in the United States that can impact the employees of a restoration business include, but are not limited to the following Occupational Safety and Health Act (OSHA) Standards found in Title 29 of the Code of Federal Regulations (CFR) parts 1910 and 1926:

- 29 CFR 1910 – General Industry Standards
- 29 CFR 1926 – Construction Industry Standards

Restoration firms shall comply with applicable sections of both the OSHA General Industry Standards and the Construction Industry Standards. Individual state and local governments can have additional safety and health requirements that are more restrictive than the Federal Occupational Safety and Health Act. Each state in the United States is required to use Federal OSHA as a minimum statutory requirement. Employers shall comply with these safety and health regulatory requirement. Specific items addressed by these regulations include, but are not limited to the following.

- Site Safety Survey
- Emergency Action and Fire Prevention Plans;
- Personal Protective Equipment;
- Asbestos;
- Lead-based paint;
- Heat Disorders and Health Effects;
- Bloodborne Pathogens;
- Confined Work Spaces;
- Hazard Communication;
- Lockout/Tagout Procedures and Electrical Safety Orders;
- Fall Protection;
- Noise Exposure; and
- Scaffolds.

Issues directly pertinent to the hazards of occupational exposure in buildings damaged by water are addressed more specifically in Chapter 3, *Health Effects from Exposure to Microbial Contamination in Water-Damaged Buildings.*

2) OSHA General Duty Clause

The OSHA "General Duty Clause" states that "Each employer:

- Shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees.
- Shall comply with occupational safety and health standards promulgated under this Act" See 29 USC 654, 5.

Protection of the safety and health of restorers and building occupants is a primary concern on restoration and remediation projects. It is the responsibility of employers to ensure that employees entering and working in water-damaged or contaminated work areas, or in designated areas where contaminated contents are cleaned or handled, have received the appropriate training, instruction, and personal protective equipment. In the absence of specific OSHA standard for water damage restoration, it is important to recognize the general principles of exposure prevention as they are conveyed through the "General Duty clause," as well as to understand the current information available about the potential hazards from occupation exposure in water-damaged structures, systems, and contents. Restoration workers can also encounter lead, asbestos, or other structures, systems, and contents. Industry standards have been adopted for recognized hazards by government agencies such as OSHA and the EPA, as well as ACGIH and industry trade associations.

a) OSHA Regulations

(……) A complete list of federal OSHA regulations can be obtained from http://www.osha.gov/law-regs.html. The OSHA regulations for the General Industry (29 CFR 1910) and Construction Industry (29 CFR 1926) require that no employee shall work in surrounding or under working conditions which are unsanitary, hazardous, or dangerous to his or her safety or health.

3) Emergency Action and Fire Prevention Plans

"Emergency action and fire prevention plans (OSHA 29 CFR 1926.35 and 1910.38) are required for all work places, including water damage restoration job sites."

4) Personal Protective Equipment (PPE)

29 CFR 1910.132 requires that employers provide their employees with the necessary PPE to reduce the risk of exposure to chemical, physical, or biology hazards. Biological hazards that can be encountered when performing water damage restoration work include, but are not limited to, allergenic, toxigenic and/or pathogenic microorganisms. Various types of PPE are available to help prevent exposure.

The following are potential routes of exposure:

- Inhalation (respiratory);
- Contact with mucous membranes (eyes, nose, mouth);
- Ingestion; and
- Dermal (contact with skin)

Employers shall provide dermal and respiratory protection for employees entering a containment area where microbial contamination is present and remediation is being performed. Appropriate PPE is used to protect workers from possible inhalation or skin contact with microorganisms and their by-products, as well as chemicals or other substances that may be applied or handled in the course of restoration or remediation work. The selection of PPE depends on the anticipated exposure, types of microbial contamination, activities to be completed, and potential hazards of chemicals that may be used in the restoration process. Restorers should consult an IEP or other specialized expert if there is a question regarding PPE selection. PPE can include, but is not limited to:

- Respirator;
- Eye protection;
- Disposable coveralls including hood and booties;
- Foot protection;
- Hand protection;
- Head protection; and
- Hearing protection.

Respirator Use and Written Respiratory Protection Plan

Employees shall wear respirators whenever engineering and work practice controls are not adequate to prevent atmospheric contamination at the job site.

Respirators

The types of recommended respiratory protection range from NIOSH-approved N-95 filtering face pieces, to full-face air-purifying respirators (APR) or powered air-purifying respirators (PAPR) equipped with P-100 (HEPA) filters and self-contained breathing apparatus (SCBA). P-100 filters should be used to protect against fungal spores and fragments, bacterial spores, dust and other particles. Organic vapor cartridges protect against Microbial Volatile Organic Compounds (MVOCs), some chemicals used when remediating sewage contamination, and other chemical compounds used in microbiological remediation projects.

When using APR's air is drawn into the respirator face piece by inhaling through filters or cartridges. When using PAPR's, air is mechanically delivered through the filters or cartridges into the face piece. Different types of cartridges are available to remove chemical contaminates by process of absorption or adsorption. Filters (e.g., P-100, R-100, N-100, N-95) are for removing particles.

5) Warning Signs

(……) Typical warning signs related to restoration work can include, but are not limited to:

- Do Not Enter – Sewage Damage Remediation in Progress;
- Caution: Slip, Trip, and Fall Hazards;
- Caution: Hard Hat Area;
- Work Area Under Negative Air-Pressure; and
- No Unauthorized Entry.
- Personal protective equipment required.

6) Mold

Buildings that have been wet for an extended period, or have been chronically wet, can develop mold contamination. If restorers encounter mold growth during the course of the restoration project, water damage restoration activities that my disturb the mold should shop until such time that the area of existing or suspected mold contamination is contained.

7) Asbestos

The asbestos safety regulations are found in OSHA Construction Standard 29 CFR 1926.1101 and General Industry Standard 1910.1001. These regulations shall be followed whenever a detectable amount of asbestos is encountered or is presumed to be present and might be disturbed.

8) **Lead**

The lead regulations are found in OSHA Standards 29 CFR 1926.62 and 1910.1025.

9) **Heat Disorders**

Work activities involving high air temperatures, radiant heat sources, high humidity, direct physical contact with hot objects, or strenuous physical activities have a high potential for inducing heat stress. Employees are at risk for heat induced stress, particularly when engaged in activities in areas such as attics and crawlspaces, or when wearing PPE.

(….) PAPRs can provide additional cooling for restorers in hot environments.

10) **Confined Space Entry**

OSHA regulations addressing confined spaces are found in 29 CFR 1910.146 and 29 CFR 1926.21. Further guidance may be obtained from American National Standard ANSI Z117.1-1989, *Safety Requirements for Confined Spaces.* The OSHA and ANSI standards provide safety requirement to be followed while entering, exiting, and working in confined spaces at normal atmospheric pressure. A "confined or enclosed space" means any space that:

- Is configured so that an employee can enter it;
- Has limited means of ingress or egress; and
- Is not designed for continuous occupancy.

If it is determined that the confined space is a Permit Required Confined Space, then the confined space shall have a posted permit.

11) **Hazard Communication**

The OSHA Hazard Communication Standard (29 CFR 1910.1200) requires that information concerning chemical hazards (physical or health hazards) be provided to employers by chemical manufacturers and communicated to employees by employers. This is accomplished by means of hazard communication programs, which include a written program, container labeling and other forms of warning, safety data sheets (SDS), and employee training prior to working with hazardous chemicals. Examples of chemicals used during water damage restoration and remediation are the adhesive spray used to make enclosures, detergents, and disinfects (biocides) for cleaning, sealers, and encapsulants.

Restorers working on multi-employer work sites shall:

- Inform other employers of hazardous substances;
- Inform other employers of means to protect their employees;
- Provide access to SDS; and
- Inform other employers of the labeling system used.

12) **Lockout/Tagout (Control of Hazardous Energy)**

13) **Safe work Practices in Contaminated Environments**

Restorers shall incorporate the following items into restoration and remediation work procedures:

- Tail-gate meetings to discuss the daily work activities, including a review of safety issues;
- Wear PPE appropriate to the hazards identified in the work area;
- Use protective disposable coveralls with attached or separate shoe covers;
- Don protective clothing prior to entering the containment or other designated work areas;
- Inspect PPE prior to use;

- Repair or replace damaged protective clothing;
- When an injury occurs, the injured worker and co-workers are to take the steps delineated in the company safety program;
- Workers are to be instructed as to job specific emergency plans including emergency exits;
- Workers are to informed about the location of the emergency shower and eye wash stations; and
- Report injuries to the supervisor as soon as possible.

14) Immunization and Health Affects Awareness

15) Vehicle Safety

16) Ergonomics

17) Lifting

18) Heat Producing Equipment Cautions

Chapter 9 – Administrative Procedures, Project Documentation and Risk Management

Pages 158

1) **Administrative Procedures**

Work Authorizations

Contracts: (……..) By documenting the understanding of the parties at the beginning of a project, written contracts reduce the possibility of dispute, disagreement or conflict during performance of the scope of work. It is recommended that contract documents be accurate and complete, free of ambiguity, and contain adequate disclaimers, reservations or recommendations when project uncertainties, limitations, complexities or complication exist, or are indicated.

Many contractual disputes develop when contract additions or modifications are made during performance of the work, but are not adequately documented. Verbal change orders may create future misunderstanding or disagreement resulting in legal disputes and litigation. Substantive of material deviations from the original, agreed-upon contract or scope of work should be documented in a written and detailed change order, which includes a description of the changes to the work, time for performance, price/fees, and method of payment. Further, it is recommended that the client's designated agent, and the restorer's representative accept the change order in writing.

Communication: Many times the source of a dispute between parties is the failure of the parties to communicate timely, clearly and adequately. The following communication strategies are helpful in preventing or reducing communication problems:

- Listen carefully and restate the request or inquiry to the other party;
- Be realistic in providing assessments and completion schedules;
- Communicate with appropriate parties at the commencement of a project work day to determine and very priorities and objectives;
- Meet with the client at the end of each project work day to communicate project progress;
- Maintain a professional demeanor and attitude with all communications;
- Be responsive and compassionate, since a water damage event is extremely disruptive to the client;
- Develop, implement and consistently follow and organized, systematic method of receiving, evaluating and acting upon information received during the course of a water damage restoration project; and
- Document communication when necessary or appropriate to verify the communication and satisfy documentation and recordkeeping recommendation set forth elsewhere in this document.

(…..) It is recommended that significant items that could potentially affect the job be discussed verbally and then reduced to writing and distributed to appropriate materially interested parties.

2) **Project Documentation and Recordkeeping**

Time Keeping Documentation

Equipment, Material and Supply Usage Documentation

Project Monitoring Logs: Retorers should maintain organized, written logs to monitor progress and demonstrate effectiveness of the drying process. (…….) Specific items recorded on a project log can include, but are not limited to:

- The name of the project;
- The dates and times of service;
- Ther person performing the service;
- The instrumentation used;
- The appropriate psychrometric readings (e.g., temperature, RH) in the:
    - Affected area;
    - Unaffected area;
    - Outdoors;
    - Inlet to and outlet from dehumidifiers or HVAC systems, if present
- Moisture level or content measurement of representative materials in the affected and unaffected areas;
- Drying goals and standards for the affected materials; and
- Location of the moisture level or content reading

Required Documentation

Recommended Documentation

Documentation of Limitations and Deviations: The client might request or decline water damage restoration services that prevent the restorer from complying with this Standard. When proceeding in such circumstances, there is a heightened risk of future conflict with the client and potential liability to the restorer. If the restorer decides to proceed with the project despite limitations on compliance with industry standards, the restorer should adequately document the situation and circumstances, which can include advising the client in writing of the potential consequences of such noncompliance and attempting to obtain a written waiver and release of liability from the client for those potential consequences. However, this might not prevent restorer liability because of the fact that the job was accepted with knowledge that it could not be completed successfully, or that the results might be questionable. When a restorer decides to deviate from the standard, he should document the circumstances that led to such a decision and have all the materially interested parties agree in writing to the deviation.

Recordkeeping and Record Retention

Emergencies

3) **Risk Management**

Risk Management Tools

Although not necessarily an exclusive list, at a minimum it is recommended that the restorer consider application of the risk management tools summarized below:

- (……..)
- Resist compromising applicable standards and protocols to satisfy the requests of the owner and insurance adjuster or other materially interested parties, but it

required to do so, consider taking precautions such as documenting the deviation request, notifying appropriate materially interested parties, disclaim, and obtain releases;

Client Insurance

In response to the explosion of mold insurance claims between 2001 and 2002, insurance companies in North America added new exclusions and low coverage limits for mold-related losses to virtually all personal line of insurance (e.g., homeowners and auto liability), commercial lines (e.g., general liability and property), and professional liability policies (e.g., consultants, insurance agents and architects). These exclusions and coverage limits left property owners and contractors with a significant gap in their insurance coverage.

(…….)

These developments in the insurance industry have created ramifications for the restorer and mold remediator. Accordingly, it is recommended that restorers and remediators be mindful of the following:

- Owner insurance policies covering structures subject to water damage or mold remediation are complex.

Restorer/Remediator Insurance

Assessor Insurance

Other Insurance

Caveat

Chapter 10 – Inspections, Preliminary Determination and Pre-Restoration Evaluations

Pages 172

1) **Introduction:** (……) Each project can present a unique set of circumstances that should be considered when establishing the order of the procedures discussed in this chapter.
2) **Qualifications:** Restorers are expected to be qualified by education, training, certification, and experience to appropriately execute key set of core skills.
3) **Documentation**
4) **Definitions**

Category of Water: The categories of water, as defined by this document, refer to the range of contamination in water, considering both its originating source and its quality after it contacts materials present on the job site. Time and temperature can affect or retard the amplification of contaminations, thereby affecting it category. Restorers should consider potential contamination, defined as the presence of undesired substances; the identity, location and quantity of which are not reflective of a normal indoor environment; and can produce adverse health effects, cause damage to structure and contents, or adversely affect the operation or function of building systems.

Category 1 (Ashley Note: See initial Report)

Category 2

Category 3

Regulated, Hazardous Materials and Mold

Class of Water Intrusion: Restorers should estimate the amount of humidity control needed to begin the drying process. A component of the humidity control requirement is the evaporation load (i.e., Class of water).

The term "Class of water" is a classification of the estimated evaporation load; is used when calculating the initial humidity control (e.g., dehumidification, ventilation). The classification is based on the approximate amount of wet surface area, and the permeance and porosity of affected materials remaining within the drying environment at the time drying is initiated. Information needed to determine Class should be gathered during the inspection process. The Classes are divided into four separate descriptions, Class 1,2,3, and 4.

Class 1- (least amount of water absorption and evaporation load): Water intrusion where wet, porous materials (e.g., carpet, gypsum board, fiber-fill insulation, concrete masonry unit(CMU), textiles) represent less than ~5% of the combined floor, wall and ceiling surface are in the space; and where materials described as low evaporation (e.g., plaster, wood, concrete, masonry) or low evaporation assemblies (e.g., multilayer wallboard, multilayer subfloors, gym floors, or other complex built-up assemblies) have absorbed minimal moisture.

Class 2- (significant amount of water absorption and evaporation load): Water intrusion where wet, porous materials (e.g., carpet, gypsum board, fiber-fill insulation, concrete masonry unit (CMU, textiles) represent ~5% to ~40% of the combined floor, wall and ceiling surface are in the space; and where materials described as low evaporation (e.g., plaster, wood, concrete, masonry) or low evaporation assemblies (e.g., multilayer wallboard, multilayer subfloors, gym floors, or other complex built-up assemblies) have absorbed minimal moisture.

Class 3- (greatest amount of water adsorption and evaporation load): Water intrusion where wet, porous materials (e.g., carpet, gypsum board, fiber-fill insulation, concrete masonry unit (CMU, textiles) represent more than ~40% of the combined floor, wall and ceiling surface are in the space; and where materials described as low evaporation (e.g., plaster, wood, concrete, masonry) or low evaporation assemblies (e.g., multilayer wallboard, multilayer subfloors, gym floors, or other complex built-up assemblies) have absorbed minimal moisture.

Class 4- (deeply held or bound water): Water intrusion that involves a significant amount of water adsorption into low evaporation materials (e.g., plaster, wood, concrete, masonry) or low evaporation assemblies (e.g., multilayer wallboard, multilayer subfloors, gym floors, or other complex built-up assemblies). Drying may require special methods, longer drying times, or substantial water vapor pressure differentials.

Other Factors to Consider When Estimating Drying Capacity

Other factors can impact the drying environment. Restorers should understand and consider these factors when estimating the drying capacity needed to prevent additional damages and begin the drying process. These factors include:

- Influence of heating, ventilating, and air conditioning (HVAC) systems;
- Build-out density of the affected area;
- Building construction complexity; and
- Influence of outdoor weather

See Chapter 13 *Structural Restoration*

5) **Initial Contact and Information Gathering**

This information can include, but not limited to:

- Structure type and use;
- Source, date, and time of water intrusion;
- Status of water source control;
- General size of affected areas (e.g., number of rooms, floors);
- Suspect or know contaminants;
- History of building usage;
- History of previous water damage;
- Types of materials affected (e.g., flooring, walls, framing);
- Age of structure;
- Changes in structure design; and
- Number of occupants.

6) **Initial Response, Inspection and Preliminary Determination**

Safety and Health Hazards

Identify Priorities and Concerns

Extent of Water Migration

Pre-existing Damage: Examples of pre-existing damage can include, but are not limited to: dry-rot, chronic water leaks, urine contamination, and visible mold growth. Indications of pre-existing damage can include, but are not limited to:

- Malodors;
- Visible evidence of staining and deterioration; and
- Evidence of damage unrelated to water (e.g., wear, use, lack of maintenance).

Secondary Damage: Throughout the drying process, restorers should inspect for water-related secondary damage issues. Secondary damage is defined as the wetting or impairment of the appearance or function of a material from prolonged indirect exposure to water or indirect exposure to contamination carried by or resulting from the current water intrusion, which is reversible or permanent. Restorers should inspect for excessive humidity and elevated moisture content in areas adjacent to the affected area.

Dry Standards and Drying Goals: Dry standards are a reasonable approximation of the moisture content or level of materials prior to a water intrusion. An acceptable method to establish a dry standard is to evaluate the moisture content or level of similar materials in unaffected areas. When unaffected materials are not present, the restorer may use a reference from similar structures, experience from similar drying projects, and knowledge of the geographical area. The dry standards are then used by the restorer to establish acceptable drying goals.

Drying goals are a target moisture content or level of materials established by the restorer that are based on the dry standards.

Drying goals may be at, or above the dry standard and should be documented as they relate to specific materials. The restorer should establish drying goals that would be expected to:

- Inhibit microbial growth; and
- Return materials to an acceptable moisture content or level.

According to ACGIH's *Bioaersols: Assessment and Control* book in section 10.3.3, "Practically speaking, if aw can be kept below `0.75, microbial growth will be limited; below an aw of 0.65, virtually no microbial growth will occur on even the most susceptible materials." In practical terms, the restorer's task is to dry all materials to be at equilibrium with an environment well below this threshold (i.e., 0.60aw). Refer to Chapter 5, *Psychrometry and Drying Technology.*

Water activity can be approximated with the use of a thermo-hygrometer and a small containment, such as 1' x 1' clear 6 mil plastic barrier. The thermo-hygrometer is placed in contact with material, then contained to the material surface with the plastic barrier until it is acclimated. A thermo-hygrometer can be consider acclimated when there is no significant change in relative humidity over a 15-minute period (i.e., ≤1%).

Returning material to an acceptable moisture content or level can be accomplished by setting a drying goal that returns materials to a close approximation of their dry standard. In the case of solid hardwood products, the drying goal should be within 4 percentage points of its normal moisture content of dry standard, but in all cases below the point that would support microbial growth. For all materials, it is recommended the drying goal be within 10% of the dry standard, and no support microbial amplification. To illustrate this, if the measured dry standard is 20 points, then the drying goal would be a maximum of 22 points.

Preliminary Determination: The "preliminary determination" is the determination of the Category of water. If the preliminary determination is that the water is Category 1, then the restorer can proceed without contamination controls (e.g., erecting containment barriers, initial cleaning, establishing pressure differentials) and work protection. With regard to Category 2 or 3 water intrusions, remediation should occur prior to restorative drying. Restorers shall use contamination control and appropriate worker protection. Where necessary, an indoor environmental professional (IEP) should be used to assess the levels of contamination.

Performing the initial moisture inspection

7) **Pre-Restoration Evaluation**
Evaluating Emergency Response Actions
Evaluating Building Materials and Assemblies
Evaluating Contents
Evaluating HVAC Systems
Evaluating Below-Grade, Substructure and Unfinished Spaces: (…..) Below-grade, substructure, and unfinished spaces can contain safety and health hazards. Safety issues for entrants to consider include, but are not limited to: electrical shock hazards, puncture wounds and bites from rodents, insects or small animals, oxygen-deprived atmospheres and airborne contaminations. If a hazardous condition is know or suspected, the restorer should appropriate respiratory protection. Refer to Chapter 8, *Safety and Health.*

8) **Project Work Plans**
9) **Ongoing Inspections and Monitoring:** Restorers should record and monitor relevant moisture measurements daily, preferably at the same time of day, until drying goals have been met and documented. The frequency of monitoring may be adjusted by the agreed scope of work, potential for secondary damage, job site accessibility, or by agreement between the materially interested parties. Such adjustments should be documented .
The information gathered during ongoing inspections and monitoring can lead the restorer to adjust the placement of drying equipment and modify drying capacity. Where progress is not acceptable ,the restorers should take corrective action. The ongoing inspection process can lead to the discovery of a complication. As complication arise, restorers should document the nature of the complication, the impact on the restoration process and scope, and communicate with materially interested parties. Refer to Chapter 11 *Limitation, Complication, Complexities and Conflicts.*

Chapter 11 – Limitations, Complexities, Complications, and Conflicts

Pages 184

1) **Introduction:**
Limitation means the act of limiting or the state of being limited, constrained, or restricted. For purposed of this document, a "limitation" is a restriction placed by others upon the restorer resulting in a limit on the scope of work, the work plan, or the outcomes that are expected.
Conflict means a state of disharmony between persons, ideas, or interests. For purposes of this document, a "conflict" is a limitation, complexity, or complication resulting in a disagreement between the parties involved about how the restoration project is to be performed.
2) **Limitations:** Limitations are restrictions places upon the restorer by another party that results in a limit on the scope of work, the work plan, or the outcomes that are expected, and can include but are not limited to one or more of the following:
   - The source of the water intrusion has not been corrected;
   - Funds are limited;
   - The appropriate use of containment is not allowed on contaminated water losses;
   - The restorer is told to extract Category 2 water but not remove and discard contaminated porous materials such as gypsum board or insulation; and
   - The restorer is told to return contaminated contents without retuning them to a sanitary condition.

   Only the owner or owner's agent, not the restorer or others, can impose limitations on the performance of a project. If an attempt to impose a limitation is initiated by any other materially interested party, the owner or owner's agent should be advised and provide approval before the limitation takes effect. Limitations that allow for services to be rendered in compliance with this standard should be clearly defined in writing. Limitations placed on any project that are inconsistent with this standard can result in conflict.
3) **Complexities**
4) **Complications**
5) **Conflicts:** Limitations, complexities, or complications that result in a disagreement between the parties involved about how the restoration project is performed are called conflicts. When limitations, complexities, or complications develop or are placed on the project by the owner or owner's agent, which prevent compliance with this standard, restorers can choose to negotiate an acceptable agreement, decline the project, stop work, or accept the project with appropriate releases and disclaimers. Conflict resolution should be documented.
6) **Related Issues**
Hazardous or Regulated Materials
Insurance: Restorers should be aware that the terms and conditions of their insurance coverage can create project limitations and complications. The extent of applicable insurance coverage, as further prescribed by the insurance exclusions in the policy, can exclude certain work activities from the insurance coverage (e.g., regulated, hazardous materials, mold). If the applicable insurance does not cover the work anticipated at commencement of the project, a limitation can result. If a complication develops or is discovered after commencement of project work, it is

possible that resultant changes in the scope of work might not be covered by the insurance policy of the restorer.

Change Orders

Work Stoppage: In some situations, limitations, complexities, complications, or conflicts can necessitate work stoppage. In the event an illegal or unreasonably dangerous limitation, complexity or complication exists, occurs, or is discovered on a restoration project, the condition shall be resolved or the project shall be refused or the work shall be stopped.

Restorers shall avoid any situation that results in an activity that is illegal or is likely to result in injury or adverse safety or health consequences for workers. Restorers should avoid any situation that results in an activity that is likely to result in injury or adverse safety or health consequences for occupants.

The reason for a work stoppage and the significant events leading to such a decision should be documented. It is recommended that a work stoppage decision be reviewed by a qualified attorney.

Chapter 12 – Specialized Experts

Pages 188

1) **Introduction**
2) **Indoor Environment Profession (IEP)**
3) **Working with a Specialized Expert**

Chapter 13 – Structural Restoration

Page 192

1) **Introduction**
2) **Initial Restoration Procedures**

Rapid Response: Mitigation procedures should begin as soon as safely possible following the initial moisture intrusion. If building materials and structural assemblies are exposed to water and water vapor for extended periods, moisture penetrates into them more deeply. Materials that absorb water should tend to release it slowly. The more water they absorb, the more time, effort and expense is required to dry them. With extended exposure to moisture, some materials undergo permanent damage that could have been partially or completely prevented with a more rapid response. In addition, in most environment the extended presence of water or excessive humidity can lead to microbial (e.g., bacteria and mold) amplification that can cause general deterioration of environmental conditions over time, potentially leading to significant health and safety hazards for workers and occupants.

Administrative Procedures

Inspection

Health and Safety Considerations

Examining water source

Determining the Category of Water

Regulated, Hazardous Materials and Mold: "The presence of any of these substances does not constitute a change in category; but qualified persons shall abate regulated materials, or should remediate mold prior to drying.

Determining the Class of Water Intrusion

Evaluating for Restorability

Job Coordination

Contents

3) **Remediation Procedures for Category 2 or 3**

Restorer, Occupant Protection: Before entering structures that are known or suspected to be contaminated, either for inspections or restoration activities, restorers shall be equipped with appropriate personal protective equipment (PPE) for the situation encountered; see Chapter 8, *Safety and Health.*

Engineering Controls: Containment and Managed Airflow: Contaminants should not be allowed to spread into areas known or believed to be uncontaminated. Information provided in this section generally assumes the contamination level is severe (i.e., Category 3 water). The procedures in this section may be scaled back, as appropriate, for less severely contaminated environments. Contaminants can be spread in many ways:

- Soild and liquid contaminations can be: tracked on feet, spread on wheels or bases of equipment, carried on contents, bulk materials, or debris during manipulation or removal; and

- Airborne contaminants (e.g., volatile organic compounds, aerosolized liquid, particulates) can be spread by natural circulation, an installed mechanical system, or by using air moving equipment (e.g., airmovers, air filtration devices (AFDs) used as air scrubbers). When drawing moist air out of potentially contaminated cavities using negative pressure, an in-line HEPA filter should be used to remove contamination before exhausting the air into the room.

In Category 2 or 3 environments, restorers should implement procedures to minimize the spread of contaminants. This can be accomplished by isolating contaminated areas, erecting containment, and employing appropriate work practices.

The most effective way to ensure that gaseous and aerosolized contaminant do not spread is to isolate work areas by establishing critical barriers or by erecting containment (plastic sheeting) and maintaining adequate negative air pressure within contained work areas while maintaining a minimum of 4 air changed per hour (ACH). The primary purpose of this level of ventilation is to prevent buildup of excessive aerosolized contaminants by continuously diluting them with uncontaminated makeup air. Additionally, negative pressure of .02" w.g. (5 pascals) is normally considered adequate to prevent the escape of contaminants. The amount of negative pressure is a function of restriction on incoming air in relation to the volume of air exhausted, so it is usually necessary to erect isolation of containment carriers to maintain appropriate negative pressure.

For details on the setup and maintenance of containment and airflow management, restorers should consult the current edition of the ANSI/IICRC S520, *Standard and Reference Guide for Professional Mold Remediation.* The principles of containment found therein, although specifically addressing mold contamination, are generally applicable to environments in which aerosolizing of other types of contaminants is likely.

Bulk Material Removal and Water Extraction: Bulk contamination (e.g., solid waste, silt, debris) should be removed to expose structural surfaces or assemblies for further inspection and evaluation, prior to demolition or detailed cleaning. When extracting contaminated water or vacuuming contaminated dry material, restorers should take appropriate steps to prevent contaminants from becoming aerosolized in work area or other parts of a building by using HEPA vacuum systems or directing a vacuum's exhaust to unoccupied areas of the building's exterior.
Tools and equipment should be cleaned and decontaminated, or contained on the job site before being loaded for transport away from the site.

Pre-remediation Evaluation and Assessment
Humidity Control in Contaminated Structures: The priority for restorers is to complete remediation activities before restorative drying. However, the restorer should control the humidity in contaminated building to minimize moisture migration, potential secondary damage, and microbial amplification. This may be implemented before, during, or after decontamination. Restorers should limit the velocity of airflow across surfaces to limit

aerosolization of contaminants. Restorers should complete the drying process after the remediation have been completed.
(….)
Approaches to reducing the level of potential contaminants that can become aerosolized include, but are not limited to:

- Removing potentially contaminated materials as quickly as possible;
- Cleaning exposed salvageable surfaces;
- Using source containment (e.g., adhesive sheeting, poly sheeting, building house-wrap);
- Using AFDs to constantly filter contaminants from the air;
- Drying the material from behind using structural cavity drying system (SCDS); and
- Using SCDS on negative pressure and exhausting to the outside or into an AFD.

Demolition and controlled Removal of Unsalvageable Components or Assemblies: During demolition, contaminant can be easily dislodged or aerosolized. Restorers should minimize dust generation and aerosolization by using appropriate engineering controls. For example, contaminated carpet can be covered with polyethylene sheeting before removal. Engineering controls may include:

- Using source-control systems, such as HEPA vacuuming surfaces, or covering with polyethylene plastic to isolate contaminations before removal;
- Controlling humidity as described above;
- Using controlled demolition techniques (e.g., electric saw with vacuum attachment);
- Bagging or wrapping wet materials immediately in heavy-gauge polyethylene and removing them from the building for proper disposal; and
- Cutting, rather than tearing or breaking materials into pieces

(…..)
Contaminated materials should be double-bagged if they are going to pass through uncontaminated areas of the building.
Pockets of Saturation
HVAC System Components: In project where Category 2 or 3 water has directly entered HVAC systems, especially where internal insulation is present, it probably will not be possible or practical to disassemble, clean and completely decontaminate HVAC ductwork, systems and possibly even mechanical components. In these situations, the HVAC system should be contained and disassembled, and affected HVAC system components should be removed.

Cleaning and Decontaminating Salvageable Components: Decontamination should be accomplished to the extent possible by cleaning. Restorers should employ cleaning methods that minimize aerosolizing contaminants while maximizing complete removal. However, pressure washing to flush contaminants from salvageable components may be appropriate. (…..) It is recommended that when decontamination cannot be practically completed by cleaning alone, that appropriate antimicrobial (biocide) or mechanical means be employed.

4) **Biocide Application**
Antimicrobial (biocide) Risk Management
Customer "Right to Know" when using Antimicrobial (biocide)
Biocide Use, Safety, and Liability Consideration

Post Restoration/Remediation Verification

5) **Drying and Completion of the Restoration Process (Category 1 and Post Remediation Category 2 and 3)**

Controlling Spread of Water (excess water removal)

Controlling Humidity: (……) While a humidity spike is not uncommon at the outset of a drying project, if it lasts more than a few hours, that may indicate that equipment is not operating or that additional ventilation or dehumidification is required.

Ventilating the structure during the initial stages of processing may be an effective way to reduce the build-up of excess humidity. If conditions are not suitable for using exterior air to control humidity, dehumidification equipment can be used to control the rapid rise of RH that inevitably occurs when airmovers are turned on. When dehumidification equipment is used in this way, it is recommended that equipment with sufficient performance and capacity by installed as soon as appropriate after arrival. This gives the dehumidification equipment time to begin reducing humidity within the structure, while other control processes such as extraction are underway.

Demolition, as Necessary, to Accelerate Drying: It is recommended that consideration be given to whether demolishing and removing structural materials is appropriate in setting up the drying system. Circumstances under which this may be appropriate can include, but are not limited to:

- Unrestorable structural components such as drywall, cabinets, carpet, and cushion. If materials are not restorable, physically removing them from the environment near the start of the drying process reduces the moisture load, and therefore, the time and equipment required to dry materials that are salvageable. (……)
- The materials themselves may not be damaged, but their presence can slow drying of more critical materials or assemblies behind or below them. Examples may include but are not limited to: vinyl wallpaper over wet drywall, sheet vinyl flloring over wet subflooring, wet walls behind cabinets, or wet carpet and pad over strip wood flooring; and
- Sagging ceiling drying is not restorable and represents a significant safety hazard since it could collapse unexpectedly. In addition, ceiling drywall can trap moisture and its presence slows drying of materials above it. It should be demolished and removed as soon as practical.

Final Extraction Process: Multiple final extractions of salvageable materials often are required to decrease drying time, especially for porous materials such as carpet and cushion. Excess water that may have been inaccessible during the initial extraction process often seeps out of systems or assemblies into locations or materials where it can be extracted later.

Determining and Implementing the Appropriate Drying System: When considering the drying system, restorers should determine if the outside environment is favorable to their drying effort or can be used as a means of quickly reducing the humidity levels in the space temporarily. The decision on the approach to us is generally based on:

- Prevailing weather conditions anticipated over the course of the project,
- Humidity levels inside the affected area that are present or can be maintained, and
- Job logistics or other concerns (e.g., ability to maintain security, expected energy loss, owner preferences, potential outdoor pollutants).

There are three approaches to overall drying system management:

(1) **Open Drying System:** An open approach to drying introduces outdoor air without mechanical humification to reduce indoor humidity or remove evaporated water vapor. This ventilation can be beneficial when outdoor humidity is significantly lower than indoor humidity, especially at the very beginning of the job. (….)

(2) **Closed Drying System:** Closed drying systems are commonly used as they provide the greatest amount of control over the drying environment and the best protection from varying outdoor conditions while preserving building security. (…..) A closed drying system is recommended when outdoor humidity levels (i.e., humidity ratio) are not significantly lower than indoor.

(3) **Combination Drying System:** A third approach is to use a combination of the above, especially at the beginning of a project when indoor humidity level are not at their highest. Restorers may consider ventilating the moist air to the outside, while brining in the drier air.

Reducing Humidity through Ventilation: If the humidity ratio of the air outside is lower than the inside, the outside air can be used to reduce the indoor humidity through passive (e.g., opening a window or door) or mechanical (e.g., exhaust fans, ventilation drying systems, heated air exchange systems) ventilation of the workspace.

Using the Installed HVAC System as a Drying Resource: Restorers can use the installed HVAC system as a resource, provided contaminants will not be spread or the drying effort will not be negatively impacted. The HVAC system can add energy or remove it from the environment being dried.

Controlling Airflow, Humidity, and Temperature to Promote Drying: Restorers should control airflow (i.e., volume, velocity, humidity (i.e., dehumidification, ventilation) and temperature (i.e., vapor pressure differential) to work towards the drying goals.

- **Controlling Airflow:** Airmovers are used to circulate air throughout the workspace to ensure drier air is continually displacing the evaporating moisture at the surface of wet or damp materials. (…..)

Airmovers should be setup to provide continuous airflow across all affected wet surfaces (e.g., floors, walls, ceiling, framing). In order to achieve this, it is recommended that restorers position airmovers to:

- Ensure adequate circulation of air throughout the drying environment,
- Direct airflow across the affected open areas of the room,
- Account for obstruction (e.g., furniture, fixtures, equipment, and structural components), if their presence prevents sensible airflow across the affected surfaces,
- Deliver air along the lower portion of the affected wet wall and edge of floor,
- Point in the same direction with the outlet almost touching the wall, and
- Deliver air at an angle (e.g., 5-45°) along the entire length of affected walls.

Upon initiating the restorative drying effort, restorers should install one airmover in each affected room.

- For every 50-70 SF of affected wet floor
- For every 100-150 sf of affected wet walls above approximately 2 feet and ceiling surfaces, and
- For each wall inset and offset greater than 18”.

In circumstances where water migration has primarily affected lower wall sections and limited flooring (e.g., less than 2’ of migration out into the room or area), restorers should install a total of one airmover for each 14 affected linear foot of wall. This calculation is independent of the above SF calculation, and is not meant to be used in the same room or area.

When a calculation for a room or space results in a fraction, the indicated number of airmovers should be rounded up.

(….) The Frequency of subsequent monitoring should be daily until drying goals have been met, but may be adjusted by the agreed scope of work, potential for secondary damage. Job site accessibility, or by agreement between the materially interested parties.

Airmoving devices inherently tend to aerosolize soils and particulates present in the environment. As water evaporates from surfaces and materials such as carpet, more particles often become aerosolized, creating possible health, safety, comfort and cleanliness issues. Restorers should perform a preliminary cleaning of materials and surfaces (e.g., carpet, hard surface floors, exposed subfloors) to reduce the amount of soil or particulates that can become aerosolized, before activating air moving devices. Where preliminary cleaning cannot sufficiently remove soil or particulates, or there are high-risk occupants, restorers can install one or more air filtration devices (AFDs) as a negative air machine, or to control or direct airflow.

- **Controlling Humidity and Determining Initial Dehumidification Capacity**
  Initial dehumidification capacity refers to the amount of humidity control needed for the estimated evaporation load, and may be modified at any point after setup based on psychrometric readings. Three recommendations for initial sizing of dehumidification are offered: (1) Simple Calculation for refrigerant or desiccant dehumidifiers, (2) Detailed Method for Low Grain Refrigerant dehumidifiers and (3) Detailed method for desiccant dehumidifiers. The detailed methods may be used to take into account significant building or weather impact factors for determine initial dehumidification capacity needed.

  Two examples of calculation methods to determine initial dehumidification capacity can be found in the Reference Guide (refer to Chapter 13, *Structural Restoration).*
  (….)

  Simple Calculation
  Initial dehumidifier capacity is calculated using the formula discussed below:

    Step 1: Calculate the cubic feet (ft^3) of air in the area being dried by multiplying its length x width x height.
    Step 2: Determine the Class of the water-damaged environment.
    Step 3: using the IICRC initial dehumidification capacity for Simple Calculation table below, select and appropriate factor and calculate the minimum dehumidification capacity for initial setup of a closed drying system.

- Refrigerant Pint Method: Divide the factor into the cubic footage of the area being dried. This yields the total number of pints of dehumidification capacity needed initially to begin the drying project. Example: 1500 sf Class 2 water project @ 12,000 ft^3÷50 pints (LGR)=240 pints per day at AHAM rating.
- Desiccant CFM Method: Multiply the cubic footage of the affected area by the factor, then divide the result by 60. This yield the total CFM of process air needed initially to begin the drying project. Example: 1500 square foot Class 2 project with 8' ceiling; at 12,000 cubic feet x 2 ACH ÷ 60 = 400 Process CRM.

- **Controlling Temperature to Accelerate Evaporation:** The temperature within a work area, and the temperature of wet materials themselves, also impacts the rate of evaporation significantly. Increasing the temperature of wet materials can be accomplished by using the sensible (thermal) energy gained by airmovers, dehumidification or heating equipment. The greater the temperature of wet materials, the more energy is available for evaporation to occur

  Water in its vapor phase (gas) has much higher energy than water in its liquid water phase. Therefore, significant energy is required for rapid evaporation. To acquire this energy, liquid water absorbs heat from surrounding materials and air when it evaporates.

Adding Energy to Material to Promote Drying: Radiant heat lamps, thermal energy transfer, and other systems employing direct heat application can be used to increase the temperature of wet materials or assemblies.

On-going Inspection and Monitoring: Normally, psychrometric conditions and MC measurement should be recorded at least daily. Relevant moisture measurements normally include: temperature and relative humidity outside and in affected and unaffected areas, and at dehumidifier outlets. Also, the moisture content of materials should be taken and recorded.

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