Mechanical Inspectors Association of Michigan (MIAM)

Fall Conference, 2005

Mold, and the Mechanical Code

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Mold Science

Mold, or fungi, are neither plants nor animals.

Molds are organisms that contain a nucleus and undergo mitotic cell division. They belong to the kingdom of fungi. Molds are similar to the plant kingdom in that they have the ability to undergo photosynthesis. They differ from plants in that they lack chlorophyll. Unlike the animal kingdom, molds have no organs for food uptake.

A group of organisms that require an external food source, water, and suitable conditions for survival and proliferation.

Genus (i.e. *Stachybotrys*), species (*atra*)

Molds can be unicellular or multicellular. The cells are called hyphae, which are usually shaped like filaments. Reproduction can be sexual or asexual. Most molds reproduce asexually. Technically, fungal propagules from sexual reproduction are termed spores, and those from asexual organisms labeled conidia. However, the two terms are typically interchangeable.

There are in excess of 20,000 different genera and 1.5 million species.

Mold spores are generally 2-20 microns in size (a human hair is approximately 100 microns). Spores are highly adaptive for survival. When food sources run out, a fungus responds by switching to reproductive mode, resulting in spores. A one-inch diameter colony can produce 400,000,000 million spores. The small size provides for maximum dispersal, while the hardy cell wall protects them from destruction.

Are all molds toxic? Most molds are not toxic. To sensitive individuals, they may only be simple allergens.

Awareness

It doesn't take more than a cursory glance at newspapers, or trade journals to recognize that mold is still an issue of public concern. With headlines such as "Black Mold Closes Elementary School" and "Mold Toxins Blamed on Infant Deaths," fears over mold have sparked multi-million dollar lawsuits, crippled businesses, and forced insurance carriers, homeowners, and landlords to spend billions of dollars in remediation and repair costs.

The flood conditions from Hurricane "Katrina", in months to come, will again raise our awareness.

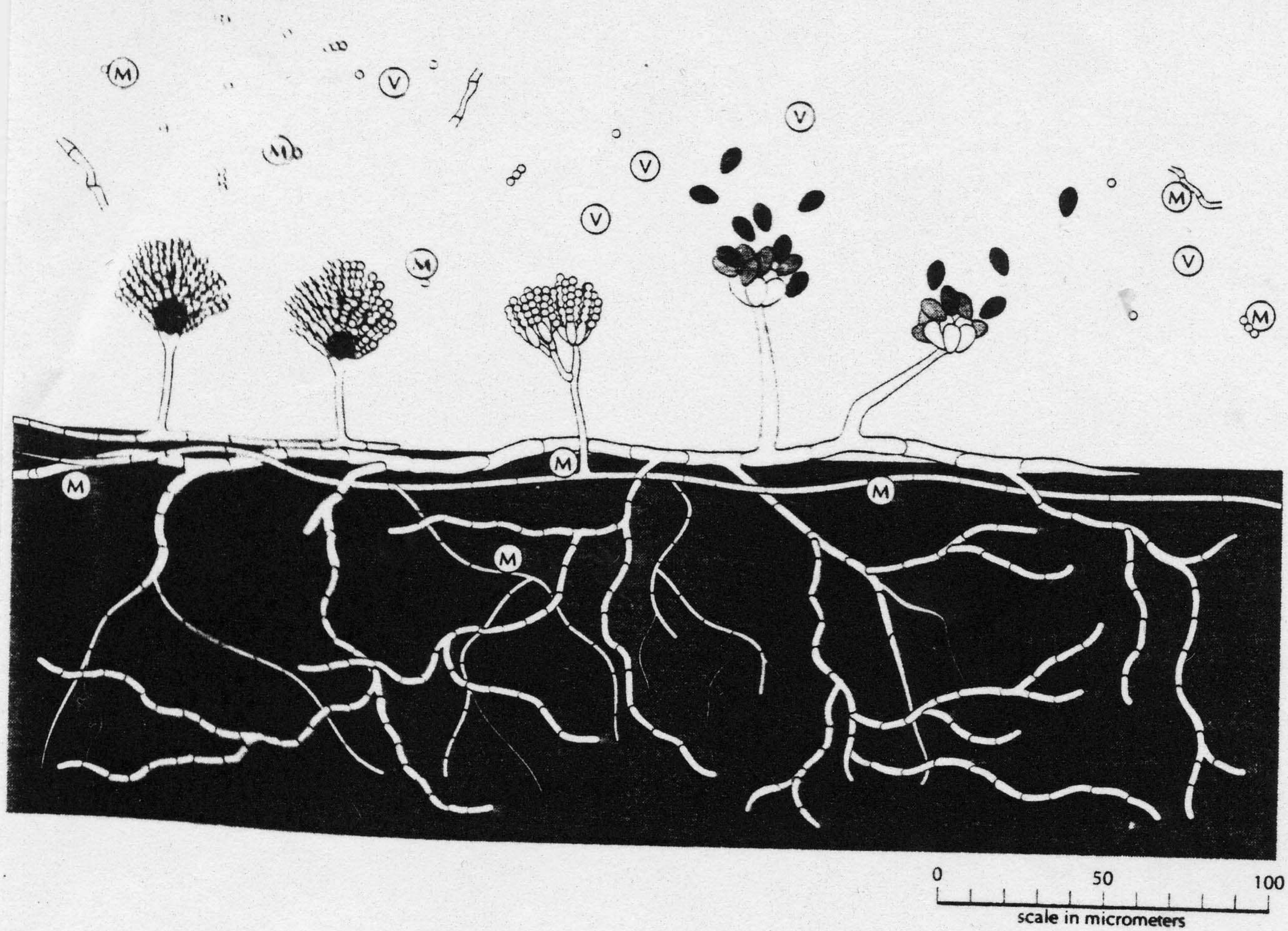
Historically, references to mold go back as far as biblical times, with references to the hazards of mold in Leviticus 13:43. Scientific references to the toxicity of *Stachybotrys* date back to 1930 when livestock deaths were attributed to *Stachybotrys*-infested hay.

While mold was not recently discovered, numerous factors influence its new popularity.

The first factor was a perceived association between the mold *Stachybotrys* and clustered incidences of Sudden Infant Death in Cleveland, Ohio in 1992. The CDC reported that while *Stachybotrys* and some other molds do produce toxins, conclusive evidence was not available to link the deaths with mold. Subsequent research by the medical community has provided evidence to both support and refute the toxic effects of mold exposure.

The second factor was the Melinda Ballard insurance claim that resulted in national media coverage, a lawsuit against Farmers Insurance Company, and a multimillion-dollar judgment for the policyholder. While expert testimony regarding the health effects of mold was not allowed in the trial, punitive damages for bad faith far exceeded the actual property damages.

The third recent event occurred in the spring of 2002, with Michigan Congressman Conyers' introduction of "the Melina Bill" (H.R. 5040 referred to as the Toxic Mold Bill). The Melina Bill called for establishing guidelines for mold exposure, disclosure of mold and water damage in real estate transactions, and licensing of companies that perform mold testing and remediation.



M
V
0
50
100
scale in micrometers

The presence of fungi on building materials as identified by a visual assessment or by bulk/surface sampling results does not necessitate that people will be exposed or exhibit health effects. In order for humans to be exposed indoors, fungal spores, fragments, or metabolites must be released into the air and inhaled, physically contacted (dermal exposure), or ingested. Whether or not symptoms develop in people exposed to fungi depends on the nature of the fungi material (e.g., allergenic, toxic, or infectious), the amount of exposure, and the susceptibility of exposed persons.

Remediation:

In all situations, the underlying cause of water accumulation must be rectified or fungal growth will recur. Any initial water infiltration should be stopped and cleaned immediately. An immediate response (within 24 to 48 hours) and thorough clean up, drying, and/ or removal of water-damaged materials will prevent mold growth.

Five different levels of abatement are described in the NYC* consensus standard. The size of the area impacted by fungal contamination primarily determines the type of remediation. The sizing levels below are based on professional judgment and practically; currently there is not adequate data to relate the extent of contamination to frequency or severity of health effects. The goal of remediation is to remove or clean contaminated materials in a way that prevents the emission of fungi and dust contaminated with fungi from leaving a work area and entering an occupied or non-abatement area.

NYC* = New York City Department of Health Bureau of Environmental And Occupational Disease Epidemology

"Guidelines on Assessment and Remediation of Fungi in Indoor Environments"

Level I: Small Isolated Areas (10 square feet or less)

Level II: Mid-Sized Isolated Areas (10–30 square feet)

Level III: Large Isolated Areas (30–100 square feet)

Level IV: Extensive Contamination (greater than 100 contiguous square feet)

Level V: Remediation of HVAC Systems

a) Small isolated area (<10 square feet)

b) Contamination area (>10 square feet)

Excerpt from NYC Guidelines

"3.5 Level V: Remediation of HVAC Systems

3.5.1 A Small Isolated Area of Contamination (<10 square feet) in the HVAC System

a. Remediation can be conducted by regular building maintenance staff. Such persons should receive training on proper clean up methods, personal protection, and potential health hazards. This training can be performed as part of a program to comply with the requirements of the OSHA Hazard Communication Standard (29 CFR 1910.1200).

b. Respiratory protection (e.g., N95 disposal respirator), in accordance with the OSHA respiratory protection standard (29 CFR 1910.134), is recommended. Gloves and eye protection should be worn.

c. The HVAC system should be shut down prior to any remedial activities.

d. The work area should be covered with a plastic sheet(s) and sealed with tape before remediation, to contain dust/debris.

e. Dust suppression methods, such as misting (not soaking) surfaces prior to remediation, are recommend.

f. Growth supporting materials that are contaminated, such as the paper on the insulation of interior lined ducts and filters, should be removed. Other contaminated materials that cannot be cleaned should be removed in sealed plastic bags. There are no special requirements for the disposal of moldy materials.

g. The work area and areas immediately surrounding the work area should be HEPA vacuumed and cleaned with a damp cloth and/or mop and a detergent solution.

h. All areas should be left dry and visibly free from contamination and debris.

i. A variety of biocides are recommended by HVAC manufacturers for use with HVAC components, such as cooling coils and condensation pans. HVAC manufacturers should be consulted for the products they recommend for use in their systems.

3.5.2 Areas of Contamination (>10 square feet) in the HVAC System

A health and safety professional with experience performing microbial investigations should be consulted prior to remediation activities to provide oversight for remediation projects involving more than a small isolated area in an HVAC system. The following procedures are recommended:

a. Personnel trained in the handling of hazardous materials equipped with:

    i. Respiratory protection (e.g., N95 disposable respirator), in accordance with the OSHA respiratory protection standard (29 CFR 1910.134), is recommended.

    ii. Gloves and eye protection.

    iii. Full-face respirators with HEPA cartridge and disposable protective clothing covering both head and shoes should be worn if contamination is greater than 30 square feet.

b. The HVAC system should be shut down prior to any remedial activities.

c. Containment of the affected area:

   i. Complete isolation of work area from the other areas of the HVAC system using plastic sheeting sealed with duct tape.

   ii. The use of an exhaust fan with a HEPA filter to generate negative pressurization.

   iii. Airlocks and decontamination room if contamination is greater than 30 square feet.

d. Growth supporting materials that are contaminated, such as the paper on the insulation of interior lined ducts and filters, should be removed. Other contaminated materials that cannot be cleaned should be removed in sealed plastic bags. When a decontamination chamber is present, the outside of the bags should be cleaned with a damp cloth and a detergent solution or HEPA vacuumed prior to their transport to uncontaminated areas of the building. There is no special requirements for the disposal of moldy materials.

e. The contained area and decontamination room should be HEPA vacuumed and cleaned with a damp cloth and/or mop and a detergent solution prior to the removal of isolation barriers.

f. All areas should be left dry and visibly free from contamination and debris.

g. Air monitoring should be conducted prior to re-occupancy with the HVAC system in operation to determine if the area(s) served by the system are fit to occupy.

h. A variety of biocides are recommended by HVAC manufacturers for use with HVAC components, such as cooling coils and condensation pans. HVAC manufacturers should be consulted for the products they recommend for use in their systems."

Additional Frequently Reference Consensus Documents

- ACGIH: American Conference of Governmental Industrial Hygienists, "Bioaerosols: Assessment and Control."
- IICRC: Institute of Inspection Cleaning and Restoration, S-500 "Standard and Reference Guide for Professional Water Damage Restoration."
- IICRC: Institute of Inspection Cleaning and Restoration, S-520 "Standard and Reference Guide for Professional Mold Remediation."

EPA: Environmental Protection Agency, “Mold Remediation in Schools and Commercial Buildings.”

CDC: Centers for Disease Control and Prevention; National Center for Environmental Health.

AIHA: American Industrial Hygiene Association, “Field Guide for the Determination of Biological Contamination in Environment Samples.”

Friend or Foe

- Molds are ubiquitous in nature. In and of themselves, molds are not “bad.” They do not become a problem until they AMPLIFY indoors-causing degradation of furnishings and building materials and potentially making people sick.
- Molds are necessary for ecological balance. Without their degradation of organic material, the world would be a heap of garbage.
- Many molds are necessary for production of foods such as bread, beer, and cheeses.
- Mold is responsible for healing drugs such as penicillin.

Mold Amplification Indoors

- Molds are very successful. They have adapted to building materials by developing digestive enzymes to break down cellulose. The branching growth tips provide for expansion and penetration into various building materials. Spores can remain dormant for long periods of time and amplify when conditions are suitable.

Five Growth Requirements For Mold Growth

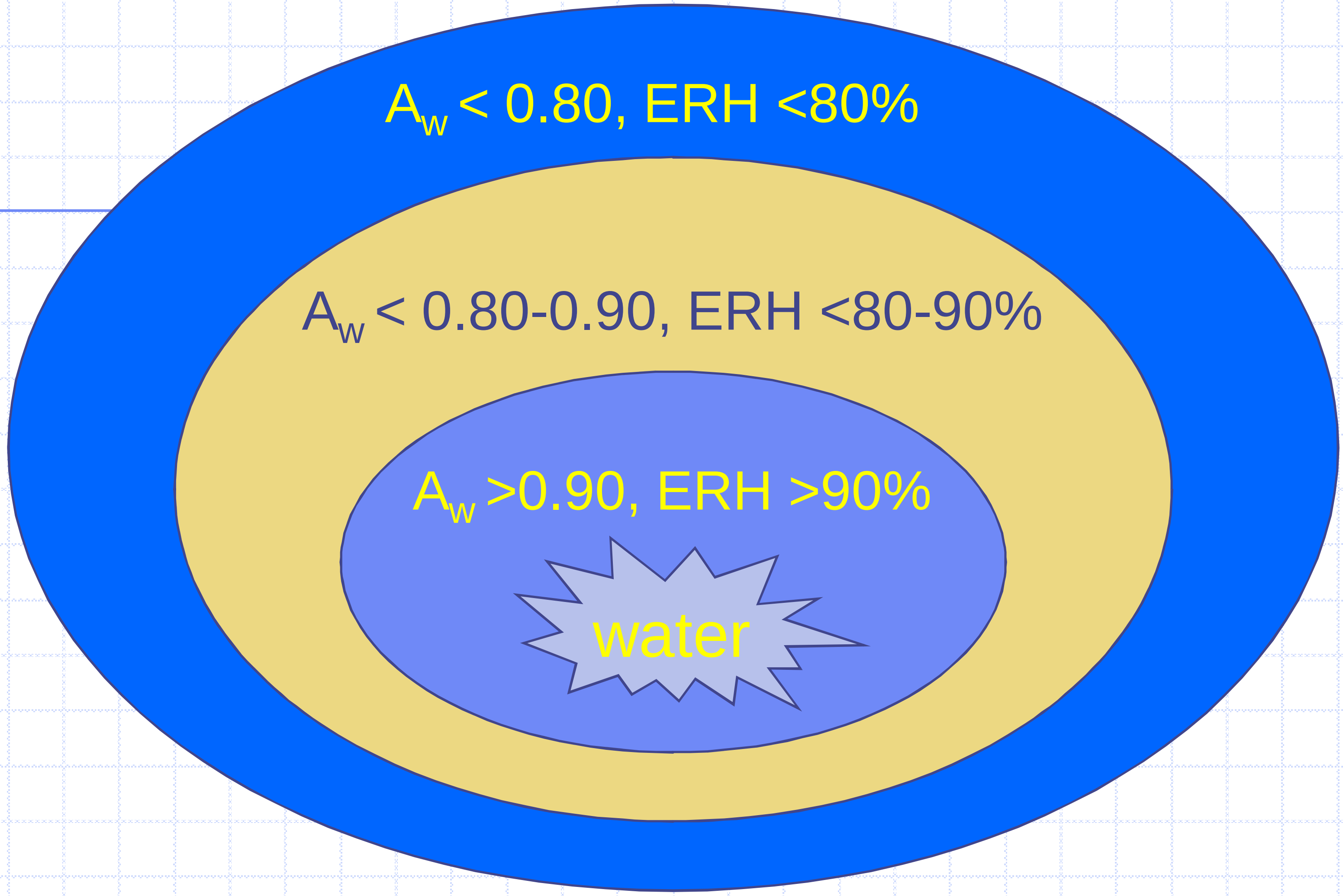
- Nutrients - High cellulose
  - Low nitrogen
  - Porous Building Materials are optimum
- Temperature Requirements are the same as for people 58°-85°F
- Mold Spore
- Correct Oxygen Levels

The first four are never in short supply.

- Moisture (limiting factor)

Moisture:

Moisture can come from direct impact of water onto a substrate (i.e. flood), or from indirect sources (condensation). Mold will amplify on cellulose materials that remain wet for more than 48 hours.



A_w: Minimum water activity level at 25°C

ERH: Equilibrium relative humidity

A_w Levels for Colonization

1. **Low (a_w = <0.85), primary colonizer**

   a. *Aspergillus versicolor* (25°C)

   b. *Eurotium* spp.

   c. *Penicillium aurantiogriseum*

   d. *P. brevicompactum*

   e. *P. chrysogenum*

   f. *Wallemia sebi*

Flannigan et al. Microorganisms in Home and Indoor Work Environments.Taylor & Francis, London, 2001.

2. Intermediate (a_w = 0.85-0.90), secondary colonizer

a. *Aspergillus flavus*

b. *A. nidulans*

c. *A.sydonwii*

d. *A. versicolor*

e. *Cladosporium cladosporioides*

f. C. sphaerospermum

Flannigan et al. Microorganisms in Home and Indoor Work Environments.Taylor & Francis, London, 2001.

3. High (a_w = >0.90), tertiary colonizer

a. *Alternaria alterata*
b. *Aspergillus fumigatus*
c. *Chaetomium* spp.
d. *Exophialiala* spp.
e. *Fusarium* spp.
f. Memnoniella echinata
g. Phialophora spp.
h. Rhodotorula spp
I. Stachybotrys chartarum
j. *Trichoderma* spp.

Flannigan et al. Microorganisms in Home and Indoor Work Environments.Taylor & Francis, London, 2001.

Potential Hazard:

The presence of mold amplification is evidence of a potential hazard.

Cross-contamination should be avoided through proactive prevention (containment).

Existing indoor mold and any material with signs of water staining should be removed.

Health:
Can Mold Make You Sick

Widely Accepted Health Effects:

2000-Mayo Clinic published a study reporting mold to be a major cause of chronic sinusitis.

1999-Institute of Medicine Study included fungi in list of asthma triggers.

Allergic reactions are well documented health effects that can be attributed to mold exposure. Common symptoms can include skin rashes, runny nose, watery eyes, chest tightness, breathing difficulties, and headaches.

Infections:

In immune-compromised hosts: Thermophilic fungi (those that will amplify at elevated temperatures) are opportunistic pathogens that can cause infections in individuals with weakened immune systems (diabetics, chemotherapy recipients, HIV patients, very young, very elderly).

Most people are not affected by exposure to mold, unless they are exposed to a lot of mold. Unfortunately, we are not quite sure what "a lot of mold" means. Furthermore, we don't know if "a lot" of exposure to mold for "a brief time" is worse than "not so much" exposure for a longer time. We're also not sure what "not so much" means. Each person is different; what amounts to a "lot of exposure" for some people is "not so much" for others. Remember, mold is everywhere; we are all exposed to mold every day.

The other part of the problem is that there is no “dose-response” curve for mold and humans. We just don’t know how much exposure to which molds and for how long leads to problems. It’s even more difficult when you realize that no two people are alike. This question is far more difficult than the previous question and it will likely take much longer to answer. Common sense tells us that “too much” mold for “too long” is a problem for most people. Prudent avoidance is the best course of action at present.

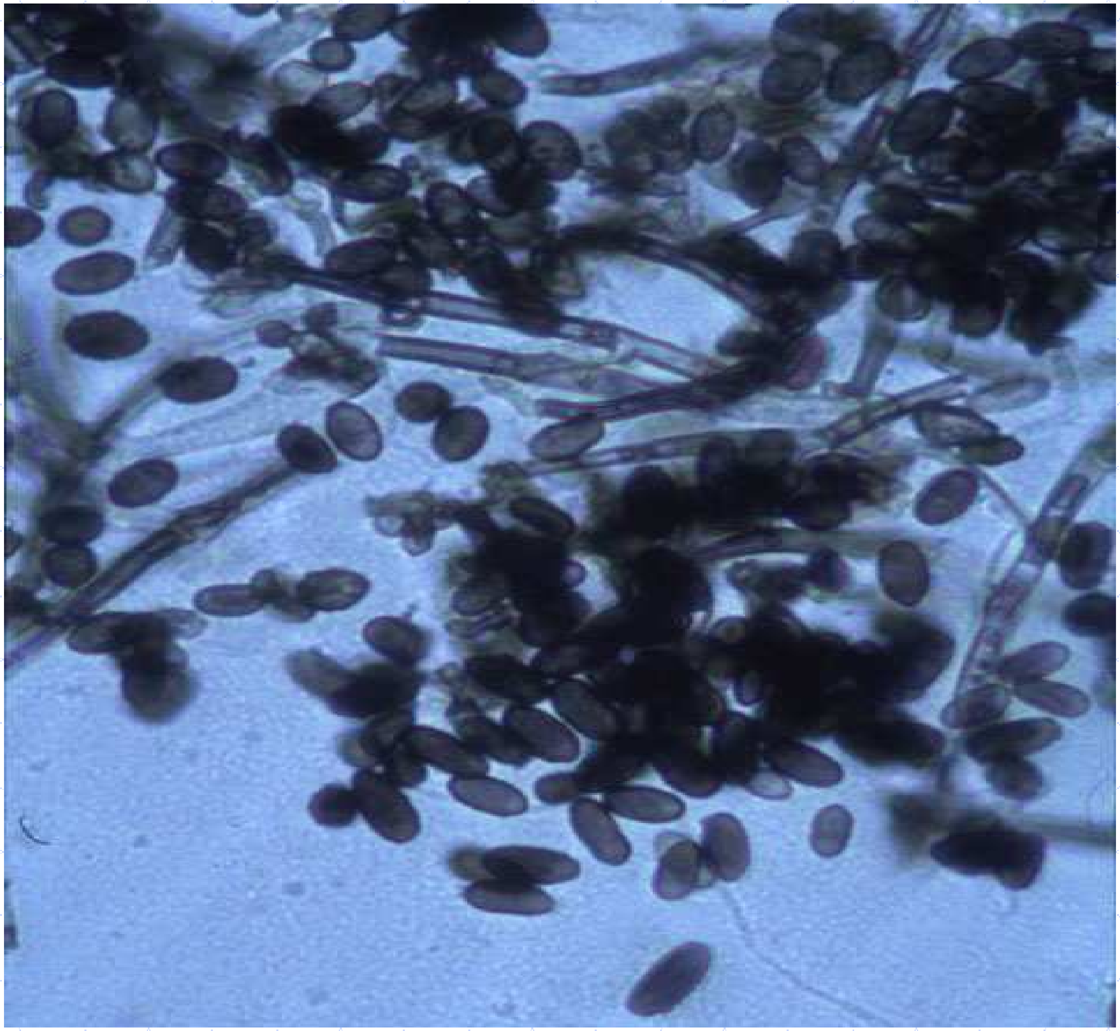
What are the potential health effects of mold in buildings and homes?

Mold exposure does not always present a health problem indoors. However some people are sensitive to molds. These people may experience symptoms such as nasal stuffiness, eye irritation, or wheezing when exposed to molds. Some people may have more severe reactions to molds. Severe reactions may include fever and shortness of breath. People with chronic illnesses, such as obstructive lung disease, may develop mold infections in their lungs.

What should people do if they determine they have *Stachybotrys chartarum* (***Toxic Black Mold***) in their buildings or homes?

Mold growing in homes and buildings, whether it is *Stachybotrys chartarum* or other molds, indicates that there is a problem with water or moisture. This is the first problem that needs to be addressed. Mold can be cleaned off surfaces with a weak bleach solution. Mold under carpets typically requires that the carpets by removed.

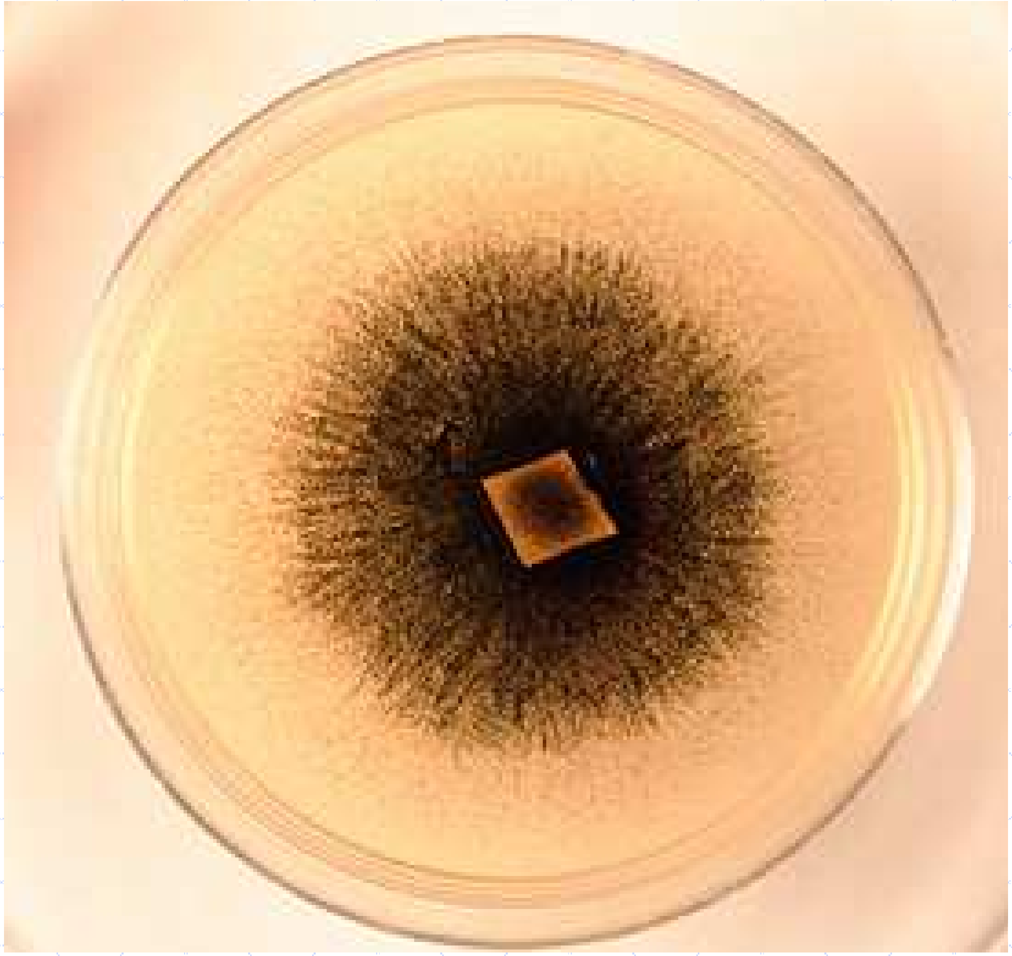
Stachybotrys - 1000 x magnification



Stachybotrys - Growth on Drywall

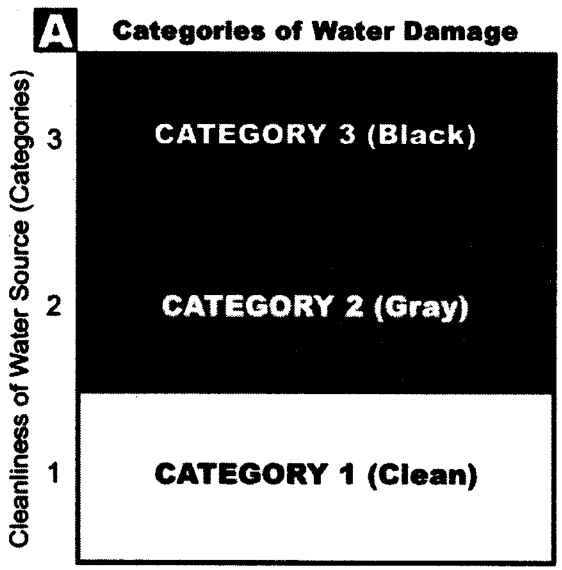
Stachybotrys -99% Moisture

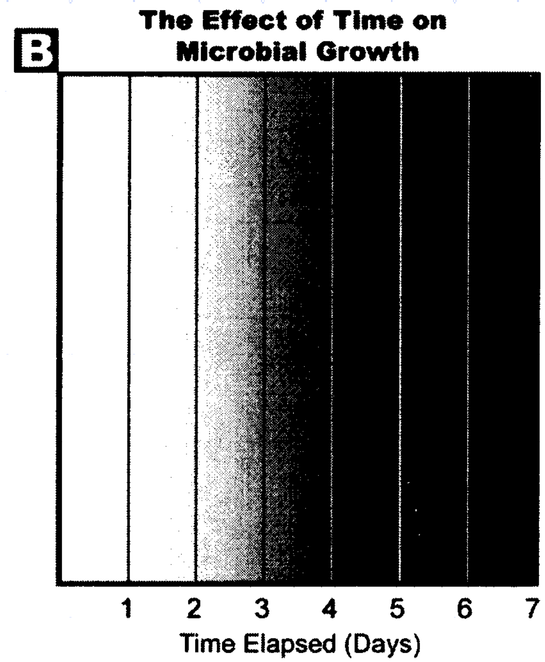
Stachybotrys - Growth on Culture Plate

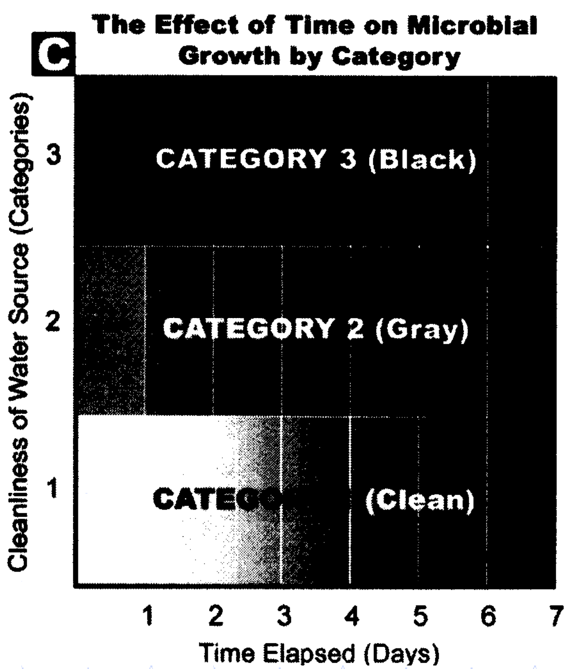


Rapid Response

- NYCDOH states: "Building materials supports fungal growth must be remediated *as rapidly as possible* in order to ensure a healthy environment."
- IICRC S500: Figure 1 indicates the time period for clean water damage to hygroscopic material to develop the microorganism contamination equivalency to gray and black water.
- Diagram B and C indicate microbial growth commencing at 48 hours and at 6 days the clean water is microbially equivalent to black water (sanitary affluents, ground surface water, rising water from rivers and streams).







FACT: ***Microorganisms are always present*** *in the indoor environment.*

A ***Whether water is categorized*** *as clean, gray, or black, when there is a water intrusion and...*

B ***...if it is left unattended, microorganisms will amplify.*** *While the amplification will not be immediately noticeable, the greater the length of time, the greater the amplification.*

C ***With the passage of time,*** *microorganisms present in any category of water intrusion will begin to amplify.*

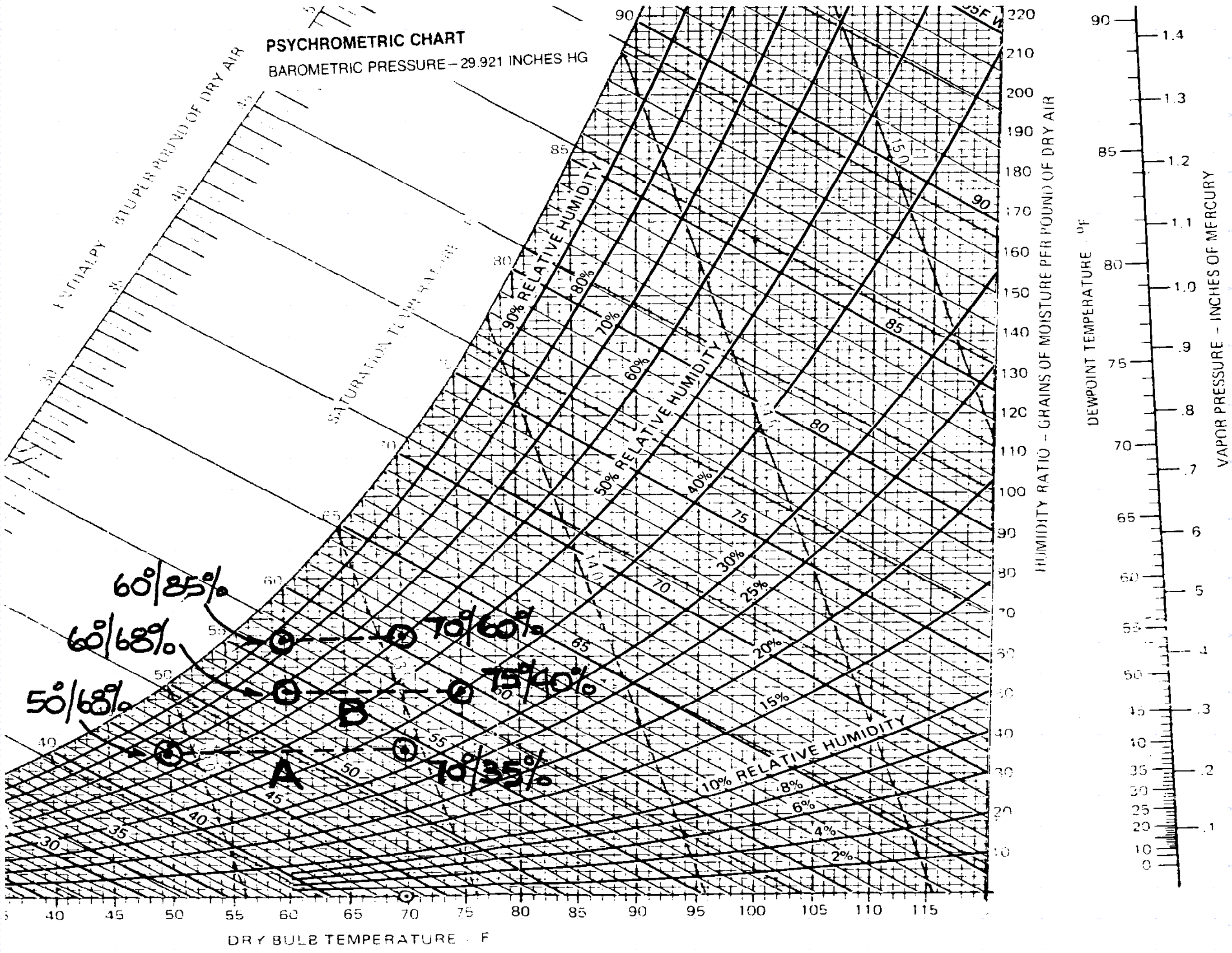
ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) technical paper presented at the ASHRAE-IAQ Conference in 2001 entitled "How Quickly Most Gypsum Board and Ceiling Tile Be Dried to Preclude Mold Growth After a Water Accident."

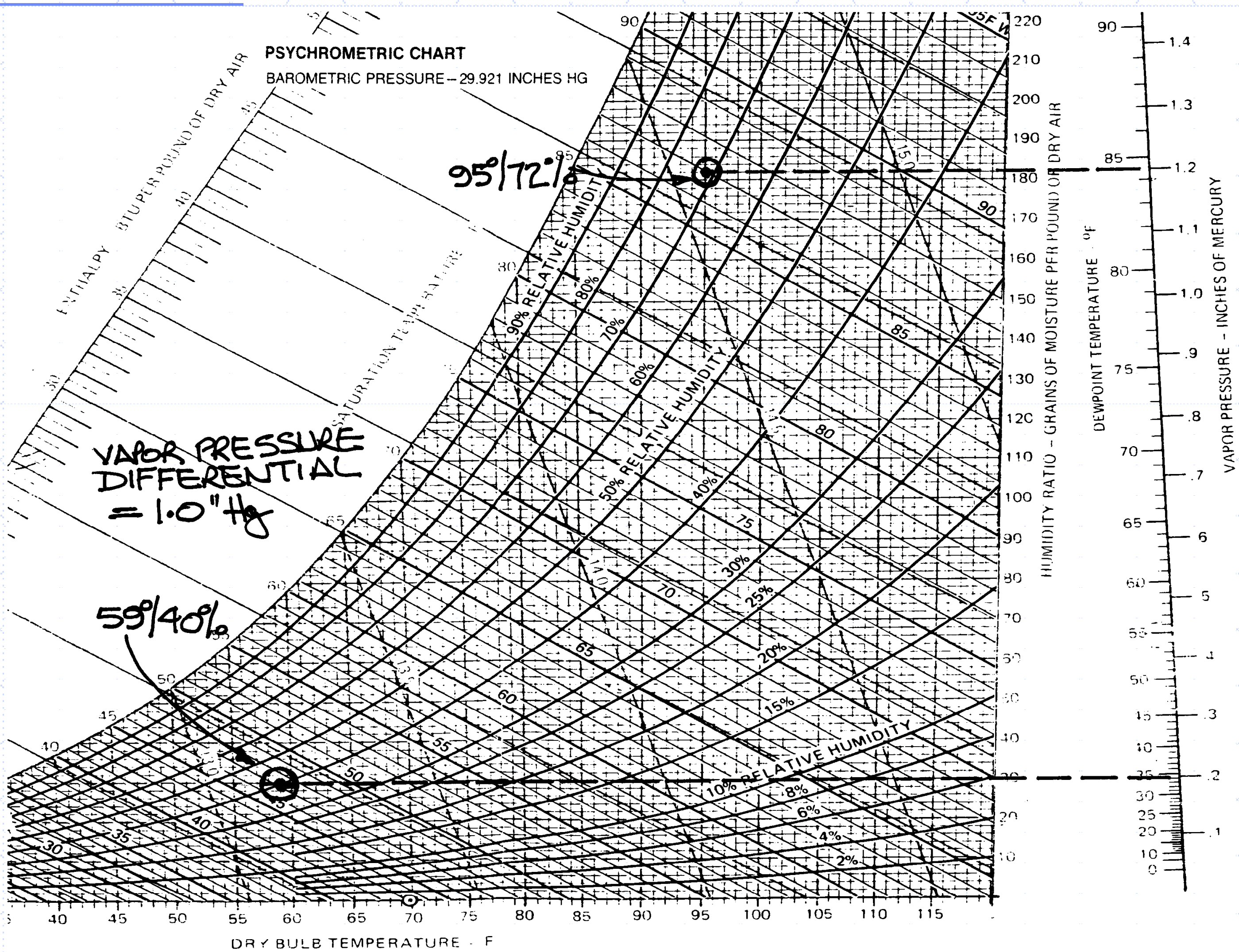
The results of their incubations provide empirical evidence that significant mold growth does occur within 2 to 3 days. This supports the "conventional wisdom" that 2 to 3 days is the relevant time frame. The humidity levels used in the study did not prevent mold growth, once materials were wet.

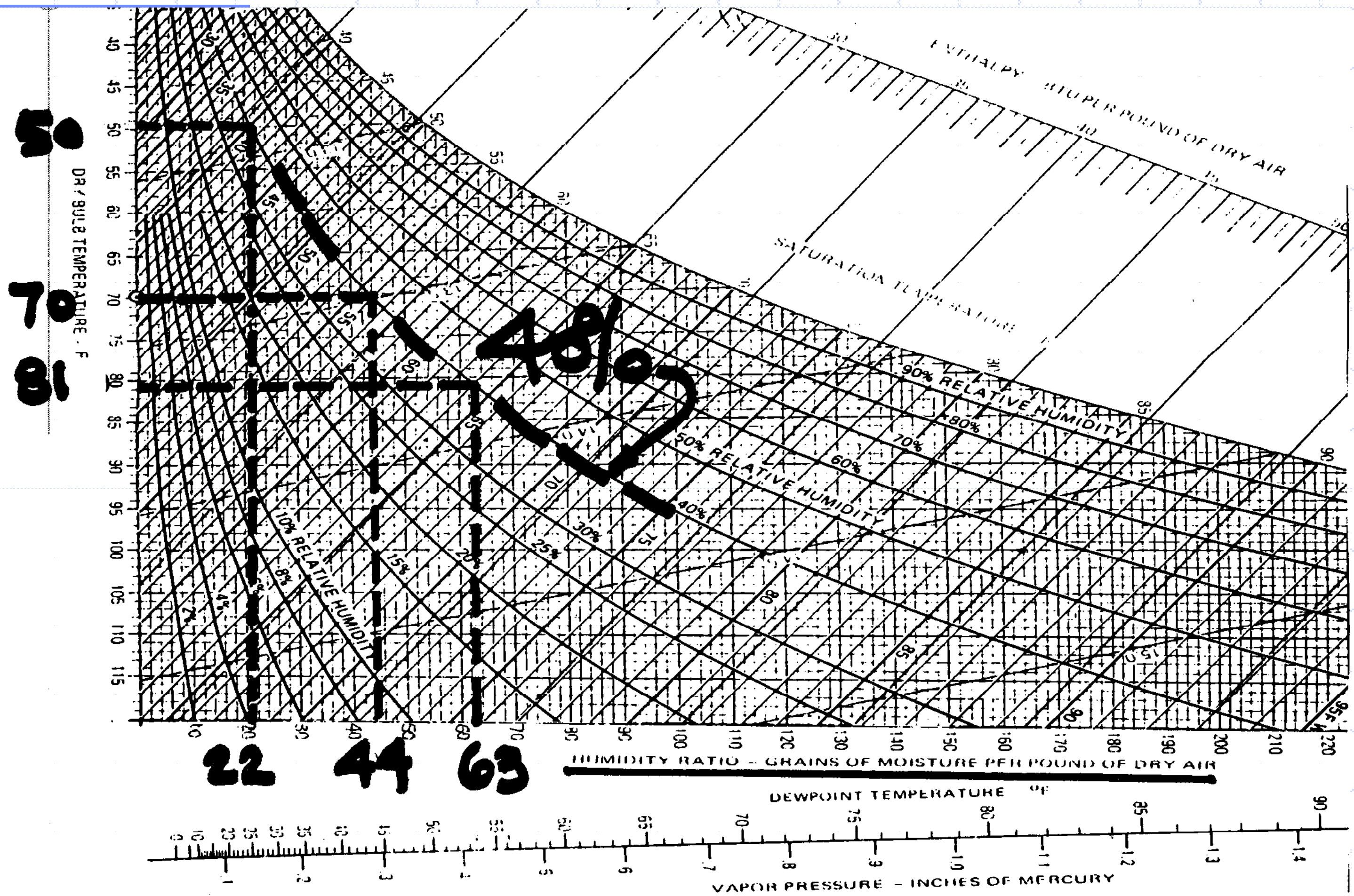
Pasanen et al. (2000) similarly found that drying at 50% RH had little detrimental effect on the molds and even 30% RH permitted some growth. Incubations in the IAQ Conference study also indicated that air in the range of 40% to 45% RH is inadequate to prevent growth on building materials in static conditions.

Thus, the industry standard of reducing moisture levels to 40% as rapidly as possible may not be adequate to prevent mold growth on ceiling tile and drywall. Mitigating the loss can be accomplished by a rapid response, maximizing mechanical water extraction and desiccant dehumidification.

Psychometrics




PSYCHROMETRIC CHART
BAROMETRIC PRESSURE -- 29.921 INCHES HG
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE
95°/72°
VAPOR PRESSURE DIFFERENTIAL = 1.0" Hg
59°/40%
90% RELATIVE HUMIDITY
50% RELATIVE HUMIDITY
10% RELATIVE HUMIDITY
DRY BULB TEMPERATURE - F
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
DEWPOINT TEMPERATURE - °F
VAPOR PRESSURE - INCHES OF MERCURY



ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE
90% RELATIVE HUMIDITY
80%
70%
60%
50% RELATIVE HUMIDITY
40%
30%
25%
20%
15%
10% RELATIVE HUMIDITY
DRY BULB TEMPERATURE - F
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
DEWPOINT TEMPERATURE °F
VAPOR PRESSURE - INCHES OF MERCURY
50
70
81
22
44
63
48%

Codes

"104.2 Rule-making authority.

The code official shall have authority as necessary in the interest of public health, safety, and general welfare, to adopt and promulgate rules and regulations; to interpret and implement the provisions of this code; to secure the intent thereof; and to designate requirements applicable because of local climatic or other conditions. Such rules shall not have the effect of waiving structural or fire performance requirements specifically provided for in this code, or of violating accepted engineering methods involving public safety."

It is my opinion, based on the preceding that mechanical inspectors have a duty to their municipality to designate requirements that prevent water, water vapor, condensation (cooling), and condensation (dew point) from adversely effecting health and safety.

“304.1 General.

Equipment and appliances shall be installed as required by the terms of their approval, in accordance with the conditions of the listing, the manufacturer’s installation instructions and this code. Manufacturer’s installation instructions shall be available on the job site at the time of inspection.”

“501.2 Outdoor discharge.

The air removed by every mechanical exhaust system shall be discharged outdoors at point where it will not cause a nuisance and from which it cannot again be readily drawn in by a ventilating system. Air shall not be exhausted into an attic or crawl space.”

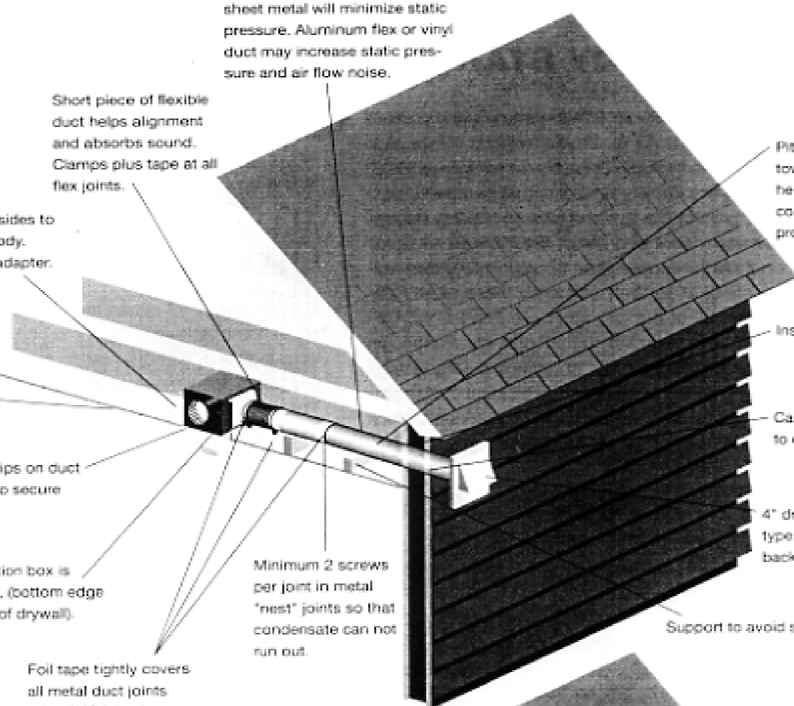


FIG. F

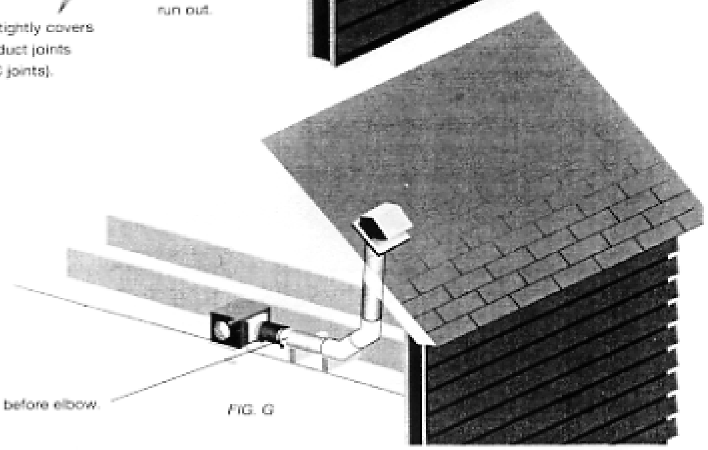


FIG. G

Note: If duct is in the attic, to avoid possible condensation problems, be sure it is either under loose fill insulation or it is fully insulated to minimum of R-5 with duct wrap.

Moisture in attics can be exacerbated by bathroom exhaust fans that do not discharge to atmosphere with a direct connection. Improper installation can cause localized damage to roof sheathing or contribute to higher moisture levels, which impacts the complete attic.

Most bathroom exhaust fans do not exhaust much air and as a consequence, the room’s relative humidity is elevated for extensive periods. For residential applications an exhaust fan should have an external static pressure rating of not less than 0.20 inches.

Discharge of bathroom exhaust fans should not be in soffits. Michigan Mechanical Code (MMC) 2003, 501.3 states in part, "…shall be discharged outdoors at a point where it will not cause a nuisance…" Drawing hot moist air into an attic can create a nuisance if mold starts to grow on the sheathing.

“306.3 Appliances in attics.”

This section of the code does not address the impact of fossil fueled fired devices have on the temperatures in attics, especially in residential construction. In many instances a furnace room is constructed around the furnace in violation of 702.2, 702.3, and 202.

“702.2 Air from the same room or space.

The room or space containing fuel-burning appliances shall be an unconfined space as defined in Section 202.”

"702.3 Air from adjacent space.

Where the volume of the room in which the fuel-burning appliances are located does not comply with Section 702.2, additional inside combustion and dilution air shall be obtained by opening the room to adjacent spaces so that the combined volume of all communicating spaces meets the volumetric requirement of section 702.2. Openings connecting the spaces shall comply with Sections 702.3.1 and 702.3.2 ."

"202 Unconfined Space.

A space having a volume not less than 50 cubic feet per 1,000 Btu/h (4.8 m^3/kW) of the aggregate input rating of all appliances installed in the space. Rooms communicating directly with the space in which the appliances are installed, through openings not furnished with doors, are considered a part of the unconfined space."

Compounding the issue is that many attics are inadequately ventilated (MRC-R806) and insufficient ice protection is installed (MRC-R905.2.7.1).

Personal experience investigating more than 150 residences in the past four years that have mold in the attic or suffered ice damming water intrusion causation has been the result of not complying with the preceding code sections.

“307.2.3 Auxiliary and secondary drain systems.

In addition to the requirements of Section 307.2.1, a secondary drain or auxiliary drain pan shall be required for each cooling or evaporator coil where damage to any building components will occur as a result of overflow from the equipment drain pan or stoppage in the condensate drain piping. One of the following methods shall be used.

1. An auxiliary drain pan with a separate drain shall be provided under the coils on which condensation will occur. The auxiliary pan drain shall discharge to a conspicuous point of disposal to alert occupants in the event of a stoppage of the primary drain. The pan shall have a minimum depth of 1.5 inches (38 mm), shall not be less than 3 inches (76 mm) larger than the unit or the coil dimensions in width and length and shall be constructed of corrosion-resistant material. Metallic pans shall have a minimum thickness of not less than 0.0276 inch (0.7 mm) galvanized sheet metal. Non-metallic pans shall have a minimum thickness of not less than 0.0625 inch (1.6 mm).

2. *A separate overflow drain line shall be connected to the drain pan provided with the equipment. Such overflow drain shall discharge to a conspicuous point of disposal to alert occupants in the event of a stoppage of the primary drain. The overflow drain line shall connect to the drain pan at a higher level than the primary drain connection.*

3. *An auxiliary drain pan without a separate drain shall be provided under the coils on which condensation will occur. Such pan shall be equipped with a water-level detection device that will shut off the equipment served prior to overflow of the pan. The auxiliary drain shall be constructed in accordance with Item 1 of this section."*

This code section should be modified such that item 1 deletes the words "or the coil". Failure of the auxiliary drain pan drain or the separate overflow drain line for a period of time can result in wetting concealed cellulose material which will result in mold growth. Remediation of mold in a attic space is a costly undertaking.

Especially critical is the location of the point of discharge from the auxiliary pan drain and the overflow drain.

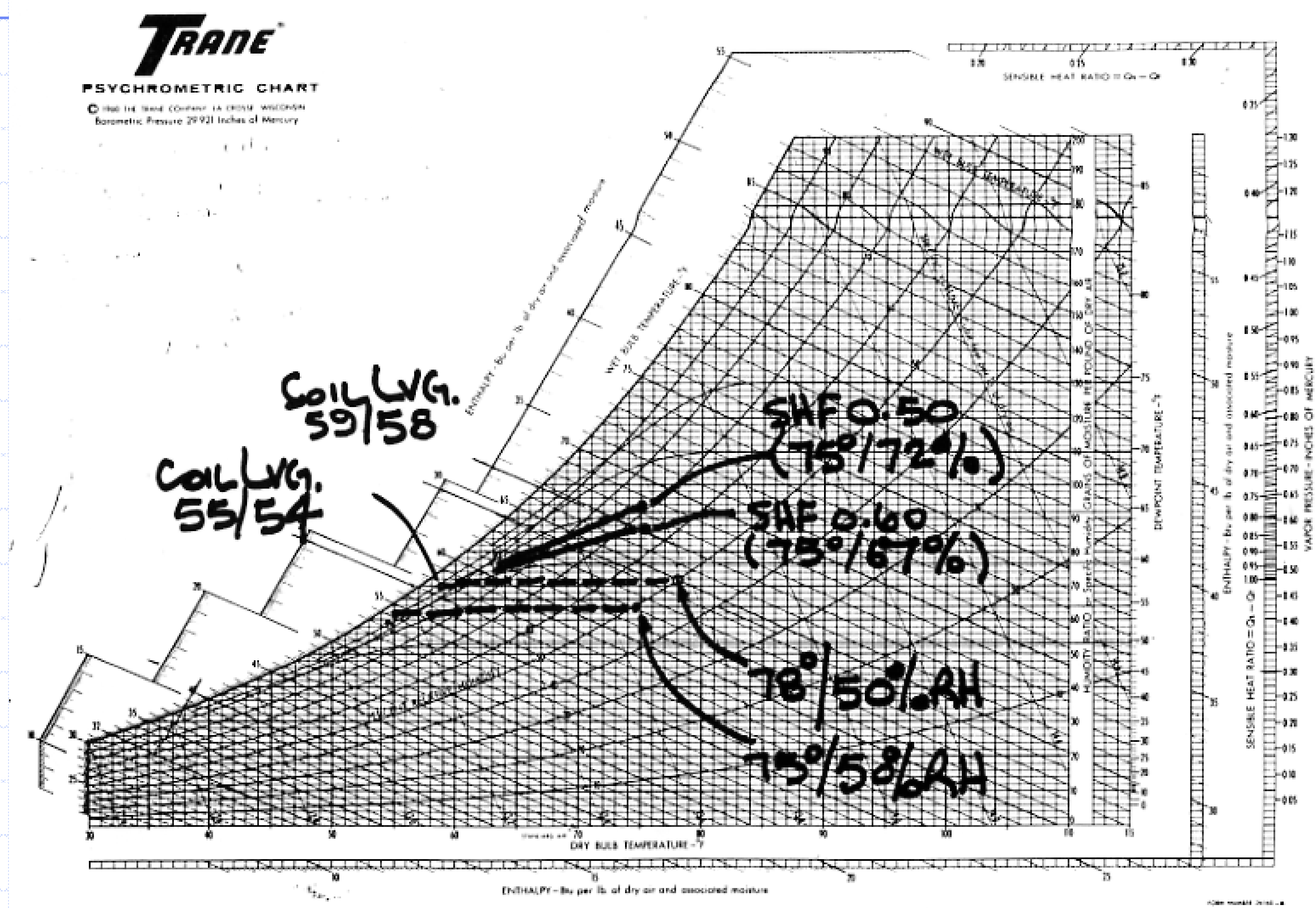
“312.1 Load calculations.

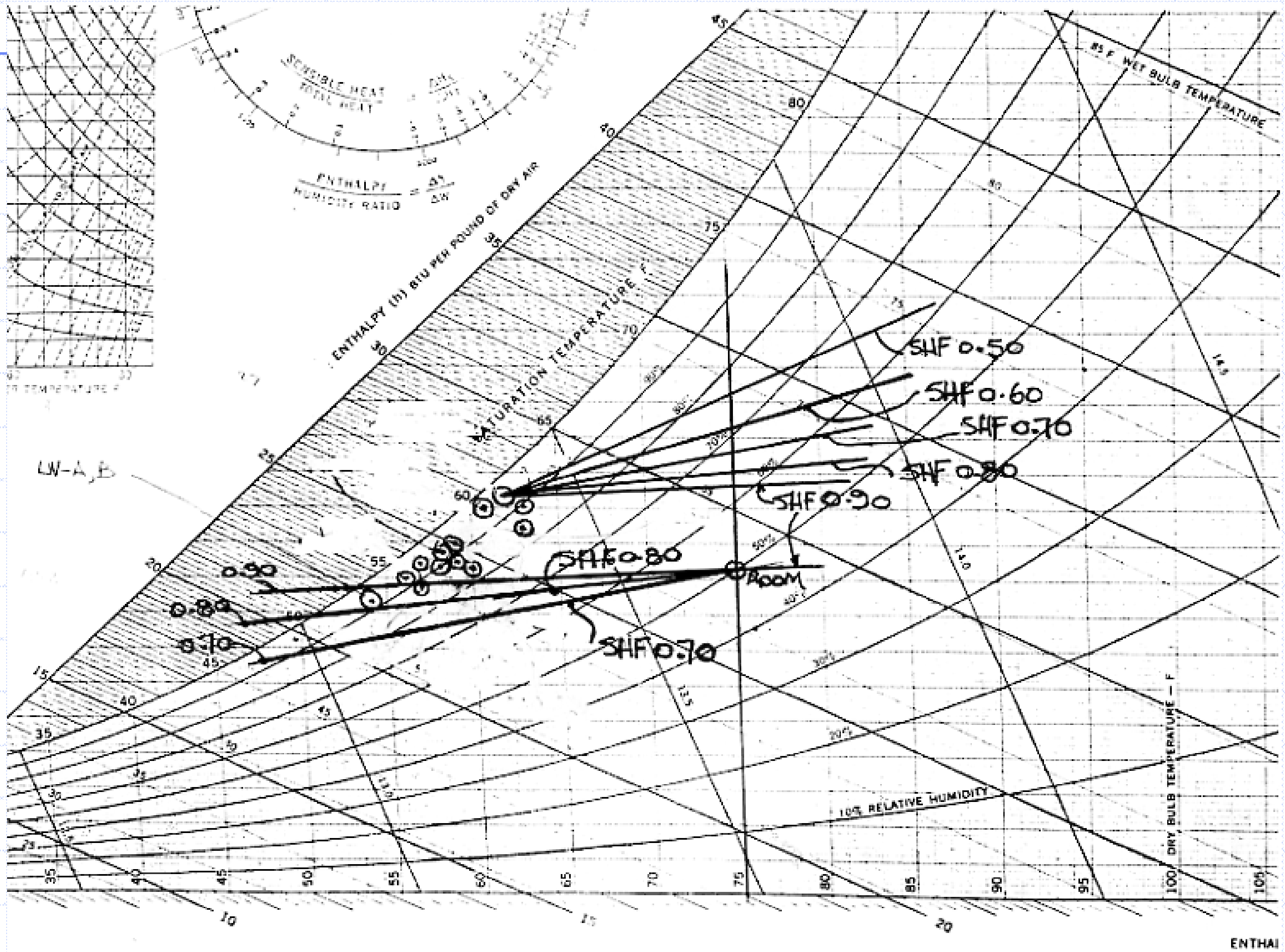
Heating and cooling system design loads for the purpose of sizing systems, appliances, and equipment shall be determined in accordance with the procedures described in the ASHRAE Handbook of Fundamentals…”

“M1401.3 Sizing

Heating and cooling equipment shall be sized based on building loads calculated in accordance with the provisions of ACCA Manual J-1986, the standard of the air conditioning contractors of America, which is adopted in these rules by reference, or other approved heating and cooling calculation methodologies…”

In a non-residential application the designer can schedule the building load and coil leaving air conditions based on the computer printout recommendations and no psychrometric analysis. The cooling coil leaving air conditions can cause the space relative humidity to rise to an uncomfortable level and the resultant moisture will be absorbed by hydroscopic materials until equilibrium is attained. Mold growth on a cellulose material is a good probability where an ineffective vapor retarder is installed.

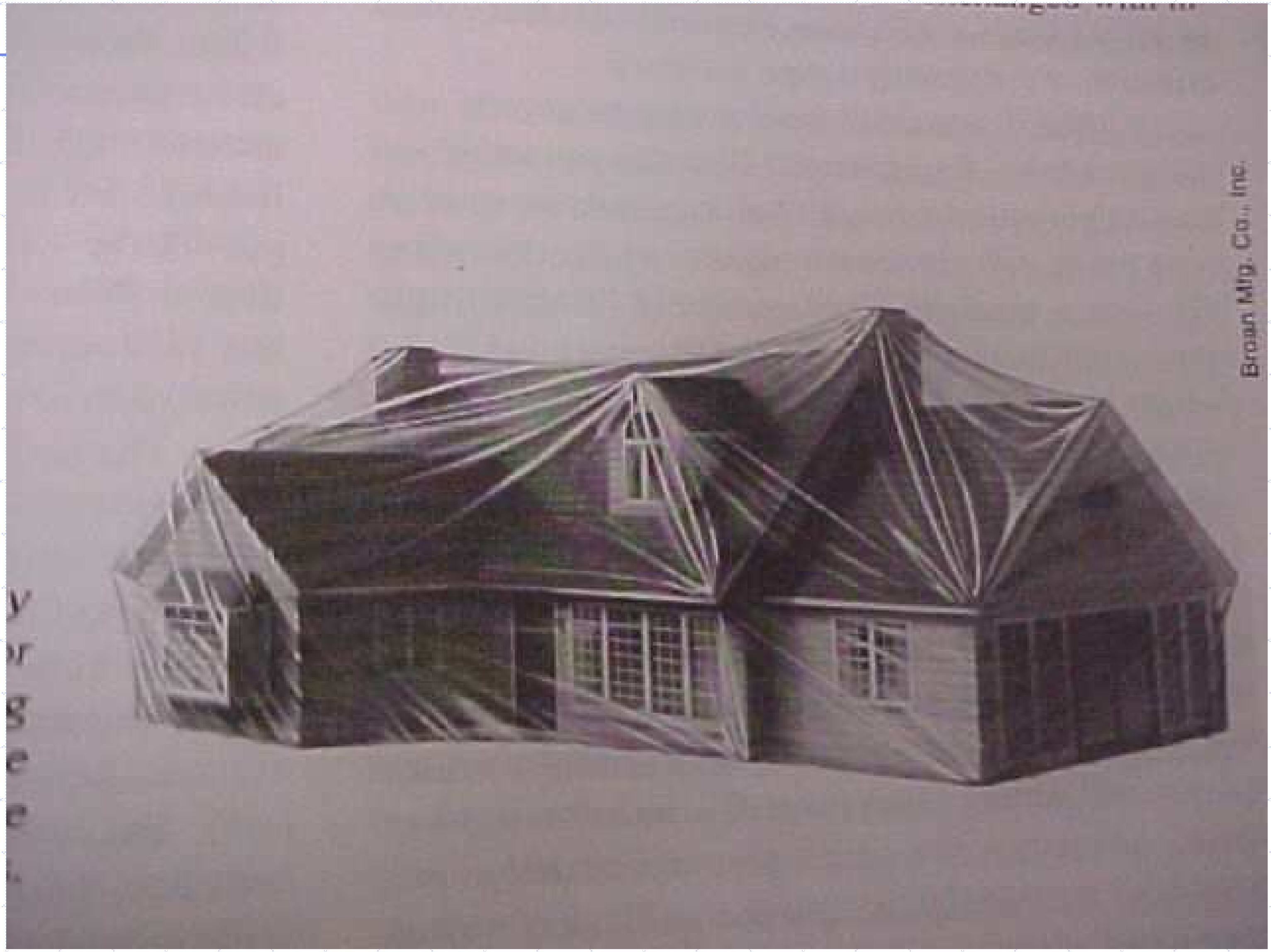

TRANE
PSYCHROMETRIC CHART
Barometric Pressure 29.921 Inches of Mercury
COIL LVG. 59/58
COIL LVG. 55/54
SHF 0.50 (75°/72%)
SHF 0.60 (75°/67%)
78°/50%RH
75°/58%RH
DRY BULB TEMPERATURE - °F
ENTHALPY - Btu per lb. of dry air and associated moisture
SENSIBLE HEAT RATIO
DEWPOINT TEMPERATURE - °F
VAPOR PRESSURE - INCHES OF MERCURY
WET BULB TEMPERATURE - °F


SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO = Δh/ΔW
ENTHALPY (h) BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE — F
85 F WET BULB TEMPERATURE
10% RELATIVE HUMIDITY
DRY BULB TEMPERATURE — F
SHF 0.50
SHF 0.60
SHF 0.70
SHF 0.80
SHF 0.90
SHF 0.80
SHF 0.70
ROOM
0.90
0.80
0.70
ENTHAL

In residential application calculations are rarely done and the wet coil pressure drop is sufficiently high that adequate air flow is compromised.

“403.1 Ventilation system.

Mechanical ventilation shall be provided by a method of supply air and return or exhaust air. The amount of supply air shall be approximately equal to the amount of return and exhaust air. The system shall not be prohibited from producing negative or positive pressure...”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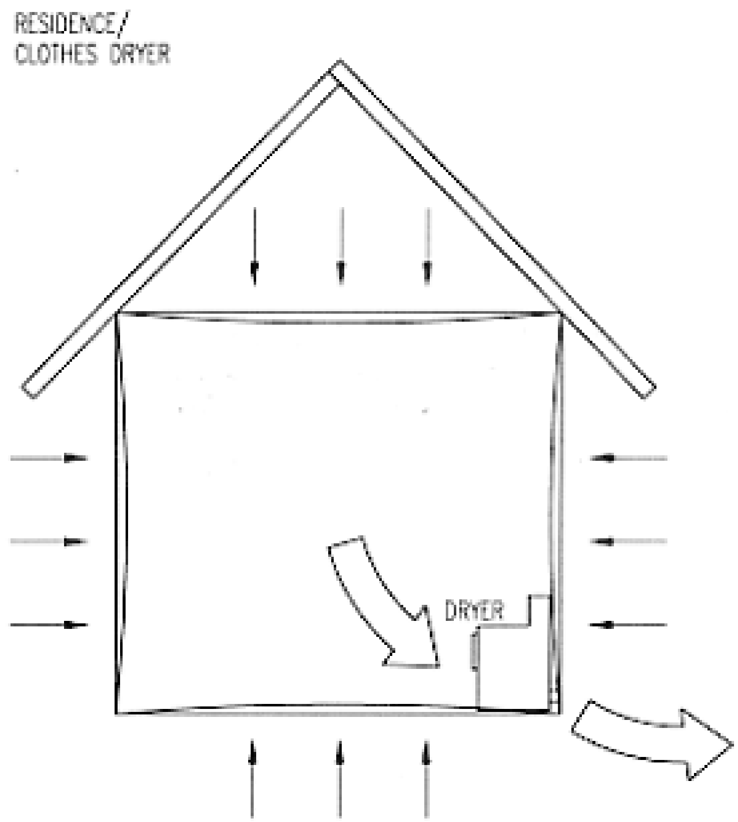
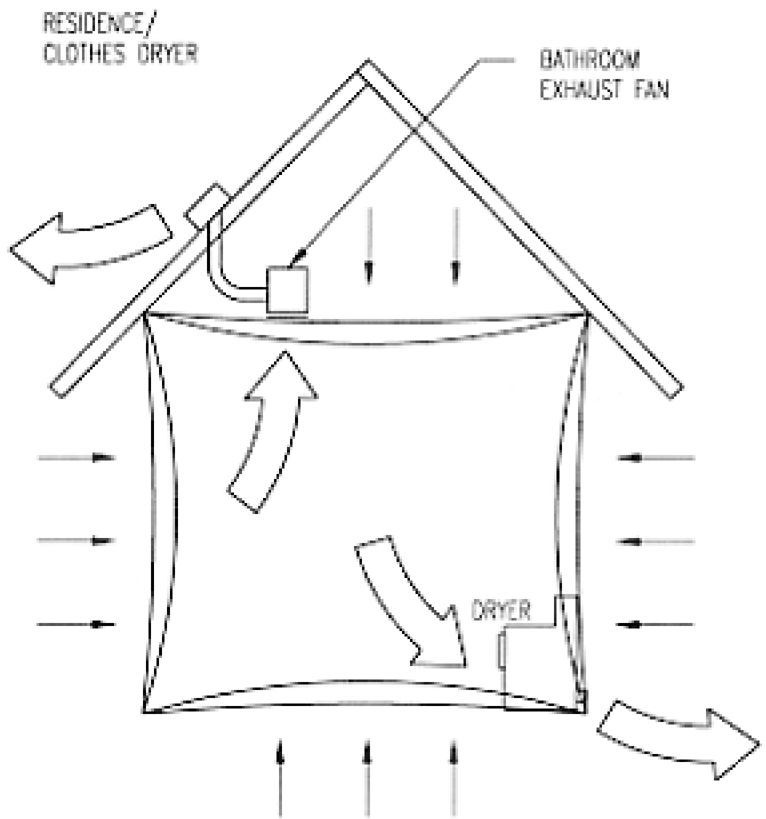

RESIDENCE/
CLOTHES DRYER
DRYER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EXHAUST FAN
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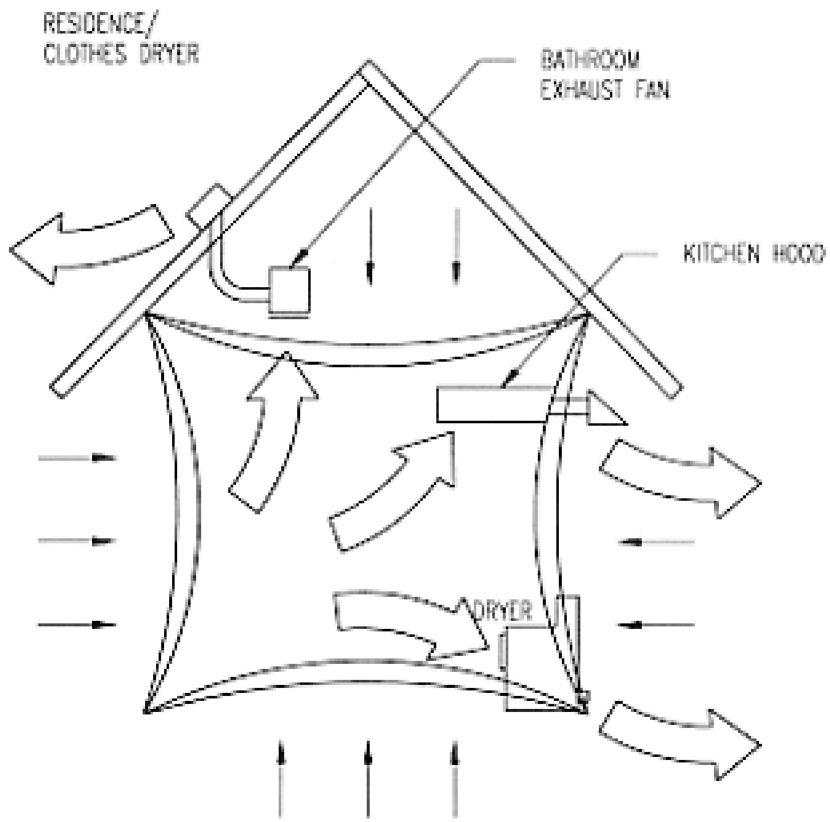


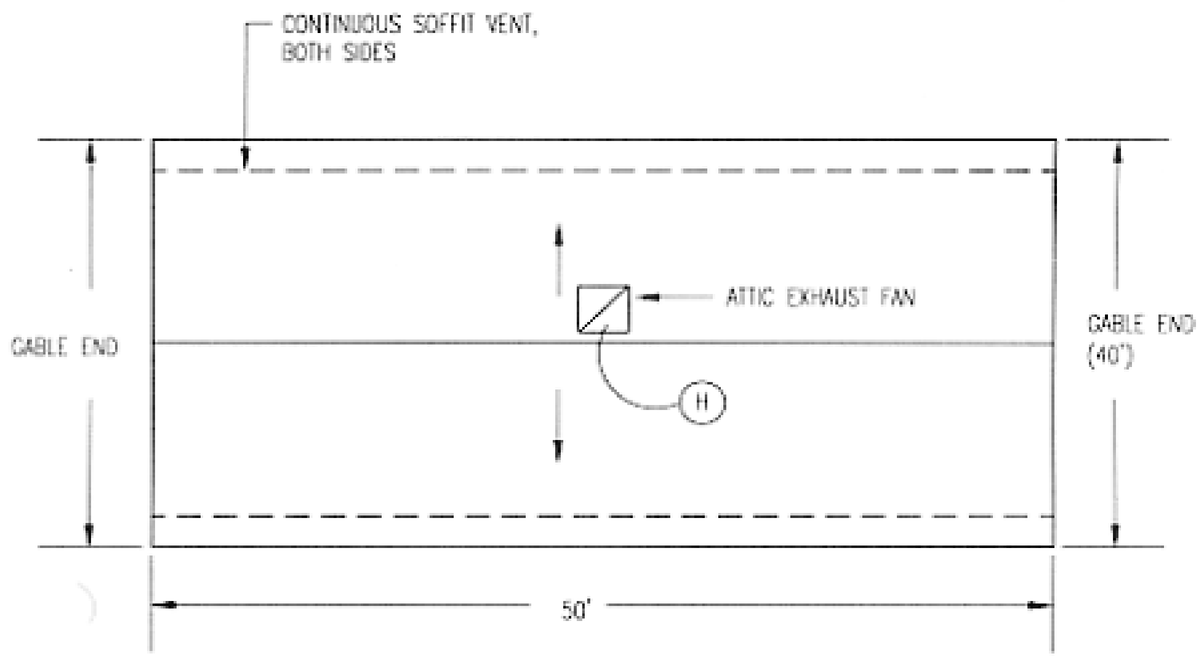
RESIDENCE/
CLOTHES DRYER
BATHROOM
EXHAUST FAN
KITCHEN HOOD
DRYER

“406.1 General.

Uninhabited spaces, such as crawl spaces and attics, shall be provided with natural ventilation openings as required by the International Building Code or shall be provided with a mechanical exhaust and supply air system. The mechanical exhaust rate shall not be less than 0.02 cfm per square foot (0.00001 $m^3/ s{\bullet}m^2$) of horizontal area and shall be automatically controlled to operate when the relative humidity in the space served exceeds 60 percent.”

a) Attics: In residences where mechanical exhaust ventilation is utilized the required exhaust air volume is generally inadequate to adequately maintain a relative humidity of less than 60% in all areas. The result is microbial defacement of the roof sheathing.

ROOF PLAN (2000 SF HOUSE)
NO SCALE



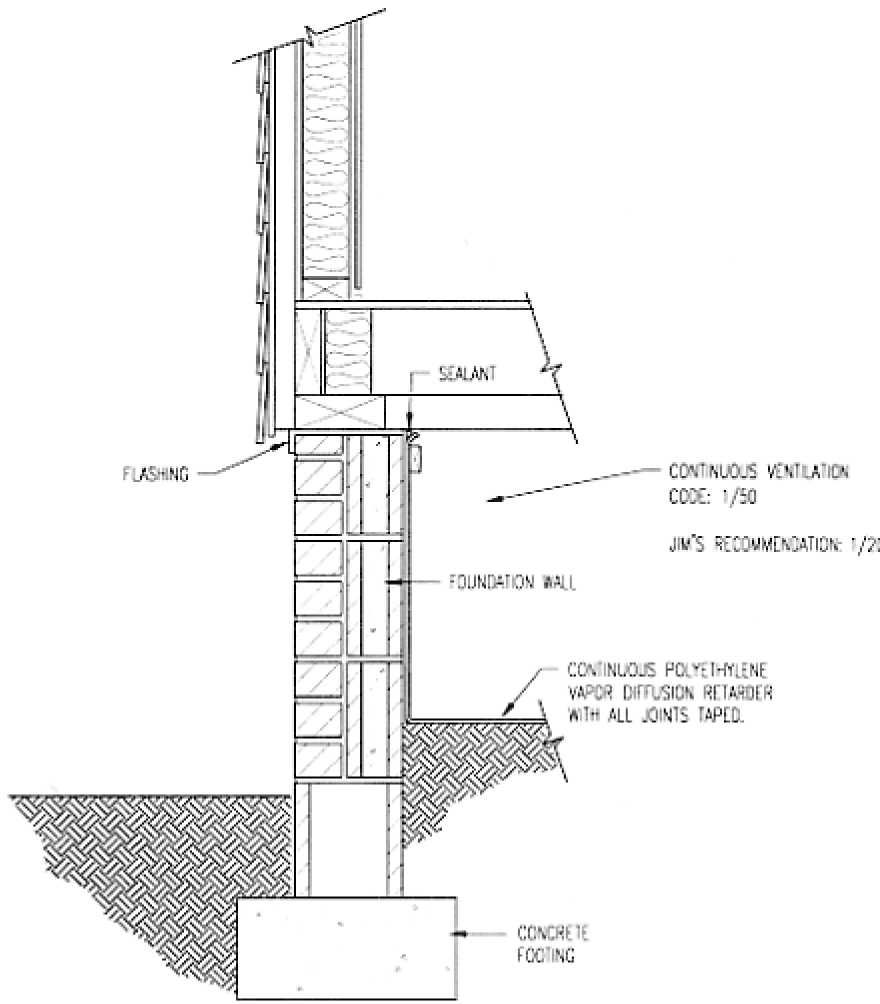
2,000 SF X 0.02 CFM/SF = 40 CFM (EXHAUST)

40 CFM/ (2 X 50 LF) = 0.40 CFM/LINEAL FOOT

b) Crawl Spaces: MRC R408.2 Exception 4.

"4. Ventilation openings are not required where continuously operated mechanical ventilation is provided at a rate of 1.0 cfm (10 m^2) for each 50 square feet (1.02 L/s) of underfloor space floor area and ground surface is covered with an approved vapor retarder material."

Current building science recommendations involves sealing the vapor retarder material around the crawl space perimeter just below the mudsill. Typically, the vapor retarder isn't installed to prevent moisture migration. Increasing the ventilation rate to 1.0cfm for every 20 SF of crawl space dramatically reduces the potential for elevated moisture levels and microbial activity.



CRAWL SPACE VENT DETAIL

NO SCALE

"501.3 Pressure Equalization.

Mechanical exhaust systems shall be sized to remove the quantity of air required by this chapter to be exhausted. The system shall operate when air is required to be exhausted. Where mechanical exhaust is required in a room or space in other than occupancies in Group R-3, such space shall be maintained with a neutral or negative pressure. If a greater quantity of air is supplied by a mechanical ventilating supply system than is removed by a mechanical exhaust system for a room, adequate means shall be provided for the natural exit of excess air supplied. If only a mechanical exhaust systems is installed for a room or if a greater quantity of air is removed by a mechanical exhaust system than is supplied by a mechanical ventilating supply system for a room, adequate means shall be provided for the natural supply of the deficiency in the air supplied."

Table 403.3 requires outdoor introduced to living areas of a residence at 0.35 air changes per hour. A 2000 SF home with 8 foot ceilings would require:

8 x 2000 x (0.35/60) = 93 cfm (outdoor air)

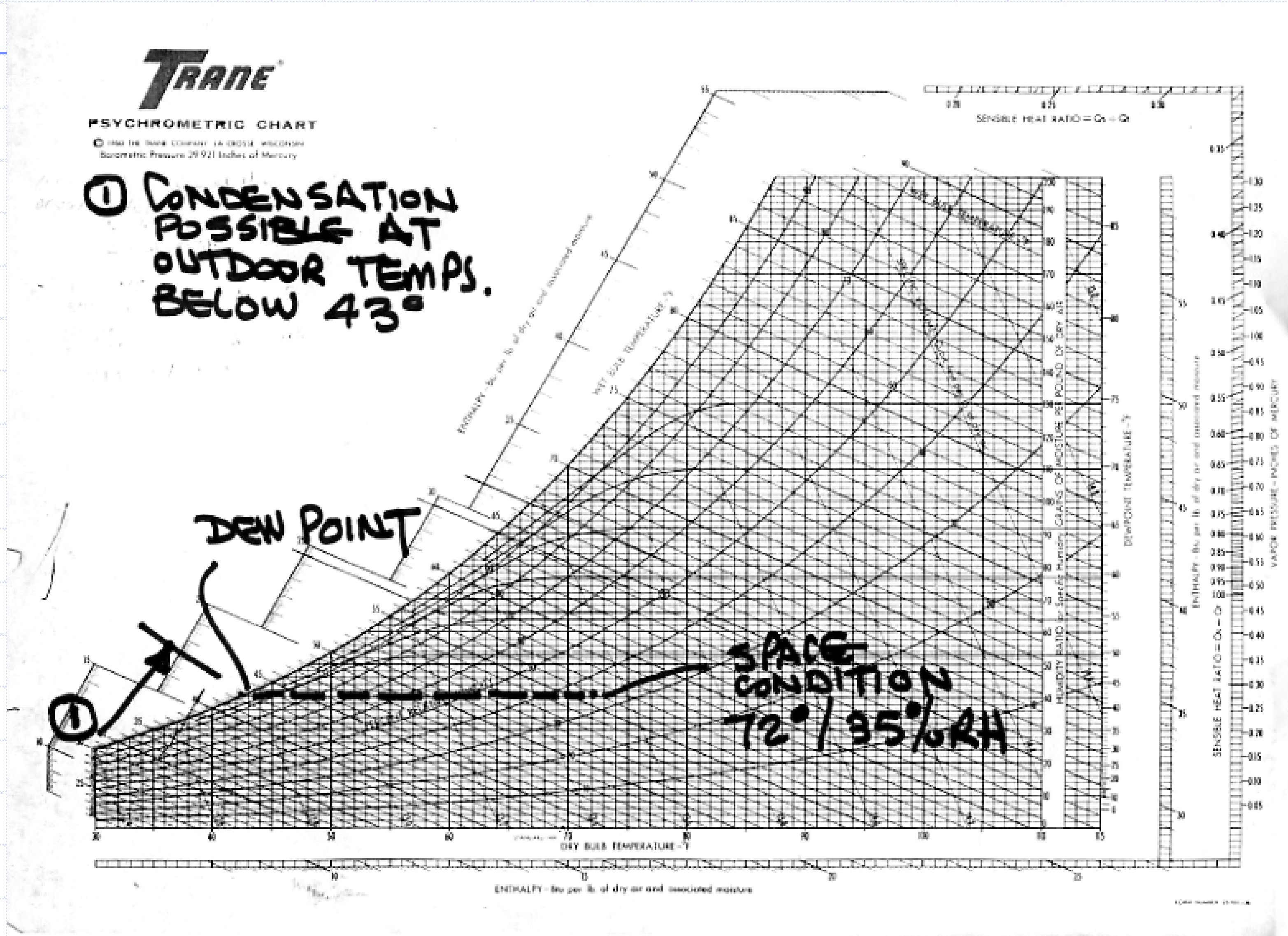
A 6” diameter outdoor intake equipped with a counter-balanced damper, connected to the return duct system is capable of passing 100 cfm at 0.10” w.g. static pressure. The impact of negative pressure has previously been depicted but the magnitude of the makeup air deficiency isn’t delineated.

Outdoor Air: 100 cfm

Exhaust Air:	Clothes dryer	150 cfm
	Bathroom exhaust fan	50 cfm (each)
	Kitchen hood	600 cfm (allowance)
	Total Exhaust	800 cfm

Deficiency: 700 cfm which will enter the building envelope, in the winter months, reduce the temperature of cellulose material at the infiltration point to the dew point or below, thereby providing the moisture required for mold amplification.

Additional outdoor air should be introduced via furnace.


TRANE
PSYCHROMETRIC CHART
Barometric Pressure 29.921 Inches of Mercury
① CONDENSATION POSSIBLE AT OUTDOOR TEMPS. BELOW 43°
DEW POINT
SPACE CONDITION 72°/35%RH
SENSIBLE HEAT RATIO = Qs ÷ Qt
DRY BULB TEMPERATURE - °F
ENTHALPY - Btu per lb of dry air and associated moisture
DEWPOINT TEMPERATURE - °F
VAPOR PRESSURE - INCHES OF MERCURY

Mechanical ventilation has the advantage of being both predictable and dependable because it is not subject to the variables that affect natural ventilation. The volume of air supplied to the space (residence) and the volume of air removed from the space (residence) must be approximately equal.

“603.8 Underground ducts.

Ducts shall be approved for underground installation. Metallic ducts not having an approved protective coating shall be completely encased in a minimum of 2 inches (51 mm) of concrete.”

“603.8.1 Slope.

Ducts shall slope to allow drainage to a point provided with access.”

“603.8.2 Sealing.

Ducts shall be sealed and secured prior to pouring the concrete encasement.”

These code sections do not address the health implications of water in underground ducts even if the ducts are sloped to permit drainage.

Underground ducts must be able to resist the forces imposed on them by materials that encase them and forces created by groundwater and by floodwaters. ASHRAE Handbook of HVAC Systems and Equipment, 2004 page 16.6 “Underground Ducts” states in part:

"… Specifications for construction and installation of underground ducts should account for the following: water tables, ground surface flooding, the need for drainage piping beneath ductwork, temporary or permanent anchorage to resist floatation, frost heave, backfill loading, vehicular traffic load, corrosion, cathodic protection, heat loss or gain, building entry, bacterial organisms, Degree of water- and airtightness, inspection or testing before backfill, and code compliance.

Therefore, it is imperative that all underground ductwork have drainage piping beneath the ductwork to ensure public health as noted previously in code section 104.2.

"603.9 Joints, seams, and connections.

All longitudinal and transverse joints, seams and connections in metallic and non-metallic ducts shall be constructed as specified in SMACNA HVAC Duct Construction Standards – Metal and Flexible and SMACNA Fibrous Glass Duct Construction Standards or NAIMA Fibrous Glass Duct Construction Standards. All longitudinal and transverse joints, seams and connections shall be sealed in accordance with the International Energy Conservation Code."

Joints in a duct system must be made reasonably airtight by sealing. MRC M1601.3 requires the joints to be substantially airtight "…by means of tapes, mastics, …"

SMACNA HVAC Duct Construction Standards – Metal and Flexible section S1.9 and Table 1-2 specifies sealing; but not all joints at various sealing classifications.

It is my opinion that mold inside walls is caused by humid air being pulled into buildings by exhaust systems. The Executive Engineer's Committee of the American Hotel and Motel Association (AH&MA) in an oft-cited survey of 9,000 properties estimated that their members spent over $68 million each year to remediate problems caused by excess moisture and humidity. The mechanisms of mold and mildew are now understood in much more detail. That's why this book emphasizes the importance of *sealing all exhaust and return air ductwork to eliminate the suction in wall cavities that pulls outdoor air into the cavities.*

The survey is titled “Mold and Mildew in Hotels and Motels” (AH&MA, 1201 New York Ave., NW, Suite 600, Washington, D.C. (202) 289-3100, www.ahma.com

“604.11 Vapor retarders.

Where ducts used for cooling are externally insulated, the insulation shall be covered with a vapor retarder having minimum permeance of 0.05 perm [2.87 ng/ (Pa•s•m2)] or aluminum foil having a minimum thickness of 2 mils (0.051 mm). Insulations having a permeance of 0.05 perm [2.87 ng/ (Pa•s•m2)] or less shall not be required to be covered. All joints and seams shall be sealed to maintain the continuity of the vapor retarder.”

Vapor retarders prevent moisture from forming on the exterior of the ductwork and deteriorating the insulating material. The presence of moisture in the insulation can promote microbial activity and on return air ductwork, that is inadequately sealed, can draw mold spores into the ductwork.

The continuity of the vapor barrier cannot be maintained if the joints and seams are not properly sealed against moisture vapor penetration.

"1107.3 Condensation.

All refrigerating piping and fittings, brine piping and fittings that, during normal operation, will reach a surface temperature below the dew point of the surrounding air, and are located in spaces or areas where condensation will cause a safety hazard to the building occupants, structure, electrical equipment or any other appliances, shall be protected in an approved manner to prevent such damage."

Refrigerant suction lines and chilled water piping, will produce water vapor condensation in most environments.


CHILLED WA

As is evident by the preceding, the continuity of the vapor barrier did not prevent moisture formation on the surfaces of the piping.

“1208.1 General

Hydronic piping systems other than ground-source heat pump loop shall be tested hydrostatically at one and one half times the maximum system design pressure, but not less than 100 psi (68 kPa). The duration of each test shall be not less than 15 minutes. Ground-source heat pump loop systems shall be tested in accordance with Section 1208.1.1.”

The importance of witnessing testing of hydronic piping systems cannot be over-emphasized with regard to the prevention of mold within buildings.

HVAC System Components and How They Contribute to Moisture & Mold Problems

Each HVAC system is generally made up of two major parts: the AHU and the distribution system. The various individual components included in these parts can each influence moisture-related problems. These following different parts of an HVAC system can affect moisture and mold problems:

- Outdoor air intake
- Mixing plenum and dampers
- Filters
- Cooling and heating coils
- Distribution system

Outdoor Air Intake:

Outdoor air intakes can become obstructed, thereby reducing outdoor air flow. The reduced outdoor air flow affects not only the ventilation rates of a building but also the critical pressurization control of a building. While operators have a great degree of influence over the outdoor air intake cleanliness and operation of dampers, some problems can be eliminated if insect screens are not used. Bird screens with the larger mesh size are preferable to the small mesh of an insect screen. If insect control is necessary, the filters should be relied upon for this task.

Mixing Plenum:

Many mixing plenums include combination dampers to regulate outside and return air quantities. Building pressurization can be affected if these dampers do not operate properly.

Design of the damper system often considers only that positive pressurization is achieved at maximum air flow conditions.

The designer should always analyze pressurization at minimum air flow conditions to verify that the return and outdoor pressure drops will still result in sufficient outdoor air flows to maintain ventilation and positive building pressurization. The mixing box construction should also avoid using insulation liners to provide a surface less likely to encourage microbial growth. This reduces the chance of having a microbial growth site in the ductwork.

Filters:

The design of the filter system should consider that filters must be installed tightly in the frame to avoid air bypass leakage.

Cooling and Heating Coils:

Cooling coil design is very important not only for overall performance capacity but also for air velocities across the coil. Moisture carryover can be important for cooling coils. Many designers require air flow velocities as low as 425 fpm for cooling coils with air streams up to 20% outdoor air. Cooling coils in 100 percent outdoor air streams may require velocities as low as 200 fpm to avoid carryover of moisture and achieve appropriate dehumidification.

Each cooling coil will have a condensate pan; better drainage is achieved with a center and bottom outlet. As with drain pan design in all climates, the drain trap must be designed with sufficient depth to overcome system pressures, including negative system pressures of a draw-through fan arrangement.

Cooling Coils:

In my opinion, the air-conditioning coil is a major source of IAQ problems.

AC coils provide a cool moist garden for the propagation of mold and other microorganisms. These organisms multiply (amplify) to huge concentrations, creating a hidden build-up of mold throughout the coil. Then as the fan operates it spreads the mold along with the associated mycotoxins* and spores into the air-stream and this is intensified if the mold spores find other damp spots to continue to grow.

In the case of cooling coils, condensation cannot be controlled, but growth of mold can. Ultraviolet light ‘C’ band (UVC) emitters applied to cooling coils continuously irradiates mold and organic mold, killing it at the source.

* Mycotoxins - Secondary product of metabolism.

Ductwork Distribution:

The return air system can often be the source of difficult moisture and mold problems. Systems that use the ceiling plenum as a common return can be hard to balance (that is, provide the required amounts of supply and return air flow). Because the ceiling plenum is negatively pressurized, non-conditioned air from the outside can be drawn through openings in the building envelope, adding extra moisture to the building. That extra moisture can raise the inside RH, making occupants uncomfortable, and also create conditions conducive to mold growth.

Additionally, even small amounts of supply or return air ductwork leakage can affect pressurization in localized areas of a building or even building-wide. Return air ceiling systems in particular must have low pressure drops to avoid many of the pressurization problems they can cause.

Mechanical Engineer/ HVAC Systems (Commercial)

- Control infiltration by pressurizing the building to at least 0.02”wg
- Ventilate and control humidity.
- Use caution in implementing ASHRAE Standard 62.
- Make sure the building enclosure can contain the conditioned air.
- Commission the building envelope to determine if the specified (?) envelope–performance characteristics are met.
- Design HVAC that maintains positive building pressure.
- Utilize dedicated outdoor air ventilation systems.

- Provide increased ventilation in high moisture generating areas utilizing excess air from code mandated occupancy levels.
- Avoid “value engineering” out the HVAC systems that will prevent IAQ problems.
- Kitchens are high moisture producing areas and are typically tempered which results in a much higher moisture level than desirable – (owner economics).
- Building interstitial spaces (envelope) and the mechanical systems distribution/ air flow zone create a negative pressure in all buildings resulting in air flow to the inside.

HVAC engineers should design for positive pressure to retard unwanted air infiltration not to "dry out the exterior wall" as some practioners believe but to control the sizing of the mechanical system. Generally, in most commercial buildings the outside air volume required by code exceeds the building mechanical exhaust and the excess air should be used to retard infiltration. This format doesn't increase energy utilization.

Mechanical Engineer/ HVAC Systems (Residential)

- Control infiltration by pressurizing.
- Evaluate total building exhaust
  - Exhaust fans
  - Kitchen cooking hoods
  - Clothes dryers
  - Fireplaces
- Thermostat with limiting cooling humidity level.

- Run supply air fan continuously (except at night).
- Heat recovery ventilator.
- Automatic timer on bathroom exhaust fan.
- Ductwork outside the habitable spaces.
- Properly sized cooling components with variable speed fans and constant speed condensing units.
- Locate ultra-violet light at cooling coil.

Structural Drying

- Mold forms in 4 days if elevation moisture levels exist as a consequence of structural wetting during construction.
- Desiccant materials attract water of the air as a vapor. Humid air has a high vapor pressure. Dry desiccant has a low vapor pressure.
- Propelled by this vapor pressure difference, water molecules (as a vapor) move out of the humid air to the desiccant which captures the water molecules onto the surface of the desiccant medium by a process called adsorption.

Solid desiccant materials are adsorbents with a tremendous internal surface area providing for the capacity to handle large volumes of water.

A single gram (less than one teaspoon) of dry desiccant can have more than 50,000 square feet of surface area (equivalent to the size of a football field).

After being loaded with water molecules the desiccant is reactivated (dried out) by heating, which raises the vapor pressure of the material above that of the surrounding air.

Desiccant drying controls mold formation.

Final Thoughts

Using the best building science we can not only design and construct buildings that will last but also reduce the risk of moisture-related health problems, including exposure to molds and other allergens. To apply building science, we have to address the interactions among components in a building—looking to manufacturers for solutions at the level of the individual product isn't enough.

Rarely is anyone filling the role of building scientist on design teams today. It's up to architects to either learn to play that role, or hire consultants who can work through details of the envelope and mechanical and plumbing systems with them.

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