

# Airmover Calculations in Structural Drying Projects

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*Understanding the value of Area-Method Airmover Sizing Calculations to achieve appropriate airflow on water damage restoration projects*

A White Paper

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## Abstract

The role of air moving equipment in the structural drying process has been demonstrated convincingly for more than 20 years, though the determination of the amount of airflow or number of airmovers to deploy on a project has been elusive, as evidenced by the changing guidelines over the course of the three previous S500 editions. To complicate this further, (1) airmover technology has made numerous advancements providing a wide-range of power, airflow and form factor characteristics and (2) the application of drying science and technology to complex buildings that have suffered a water intrusion is just now in its maturing stage. These complexities and advances require rethinking various activities and methodologies.

## Purpose

The purpose of this whitepaper is to present the rationale for determining the range of airmovers needed on various classes of water intrusion based on the square feet (SF) of affected surface area rather than the linear feet (LF) of room perimeters. It will not review or recommend specific brands, styles or performance of airmovers nor is it intended to be a procedural reference guide for determining airmover deployment.

This white paper will review:

1. Changes in the S500 guidelines over the previous three editions,
2. Role of airmovers in structural drying projects,
3. Published literature within the drying industry that can offer a foundation on which to make decisions for airmover decisions,
4. Research performed by one manufacturer of equipment that can help restorers understand some of the characteristics of airflow and velocity at the surface of materials.
5. Application of the new guidelines to be published in the 2014 4<sup>th</sup> Edition of the Professional Standard & Reference Guide for Water Damage Restoration in a side-by-side comparison with the 2006 3<sup>rd</sup> Edition.
6. Frequently asked questions about the SF guidelines

This Consensus Body (CB) invites all stakeholders of this document to participate in future revisions to assist with further articulating what is technically responsible, practical and therefore in the best interest of our shared industry.

## 1. Changes in the S500 Guidelines over the Previous Three Editions

### First Edition S500 – 1994

In the first edition of the S500, the committee recognized increasing evaporation from “wet surfaces” was the key to drying the structure and offered guidance for airmover deployment as a function of the affected “square feet.”

Reference Guide, Chapter III Restorative Drying Equipment, Section A.2:

*“Airmover (carpet dryers): Professional quality, heavy-duty, high velocity airmovers increase the rate of moisture evaporation from wet surfaces. They do not reduce relative humidity and, therefore, are used in conjunction with an open or closed dehumidification system if secondary damage is to be avoided.”*

Paragraph C. Quantity and installation:

*“To ensure rapid, cost effective drying without secondary damage specific types and quantities of airmovers are recommended, depending on the type, porosity, location and square footage of the surface being dried. ... The minimum quantity of airmovers recommended for various flooring surfaces are as follows:*

- 1. Non-porous and semi-porous flooring – at least one airmover per 400-500 square feet is recommended. ... Give consideration to closets or small storage areas where airflow may be restricted.*
- 2. Direct-glue carpet installations – in installations where disengagement normally would damage or destroy carpet or cushion, at least one airmover is recommended per 300 square feet of carpet area, or one per room if smaller than 300 square feet. ... Give consideration to closets or small storage areas where airflow may be restricted.*
- 3. Stretch-in carpet – a minimum of one airmover is recommended per 300 square feet of carpet surface area, or one per room if smaller than 300 square feet. ... Give consideration to closets or small storage areas where airflow may be restricted.”*

### **Second Edition S500 – 1999**

In this edition, there were no standard of care or recommendations related to the use of airmovers during the drying stage of a job. It only described their general characteristics and role in promoting evaporation.

Chapter 6 – Water Damage Restoration Drying Equipment and Tools:

*“Air movers: air movers are the most common equipment used in water damage restoration to promote evaporation. Air movers use a squirrel cage fan and, generally, the air is directed through a snout. Air movers create a laminar air flow to assist in surface and sub-surface drying of textile floor coverings as well as surface drying of building materials.”*

### **Third Edition S500 – 2006**

In the third edition of the Standard, the consensus body returned to offering guidance and raised the determination of airmovers to the level of the industry standard of care. A calculation metric and direction on positioning airmovers was developed.

In section 12.1.20 it states:

*“Airmoving devices used to create a general drying environment, when practical, should be set up so that continuous rapid airflow is provided across wet surfaces. In many structural drying situations, one of the most difficult areas to dry is the lower part of the wall where it meets the floor. Restorers should install one airmover for each 10 to 16 linear feet of wall, with the outlet of each airmover pointing in the same direction. With the airmover almost touching the wall, restorers should aim its outlet at the wall at a 15-45 degree angle, depending upon the airmoving device used (centrifugal, axial). In addition, restorers should consider installing at least one airmover for each small bathroom, closet or other offset or inset.”*

Many in the industry welcomed this guidance as it gave an easily calculable method that any materially interested party to a water damage job could use. However, it had deficiencies as many restorers expressed concerns that (1) it did not provide for larger rooms where airflow in the field of the floor could be inadequate, (2) it did not allow for variations due to class of water intrusions, and (3) it was inadequate for use in many commercial buildings where variations in materials, construction and configuration is the norm.

The inadequacy of this calculation method for airmovers was evident to many in the industry. The “linear foot” calculation method has resulted in the underutilization of airmovers on some projects and an abusive overuse on others. Generally, when deviations from the standard of care were needed restorers placed the necessary equipment on the job and documented the reason(s) for the deviation.

## **2. Role of Air Movement in Structural Drying**

Structural drying is a process that utilizes evaporation, the process by which water changes from its liquid phase to its gaseous phase. Evaporation is influenced by several factors:

- The level of moisture (i.e. relative humidity) in the air
- Water vapor pressure differential between the surface of the wet material and the surrounding environment
- Temperature of the wet material
- Air movement across the surface of the wet material
- Access to surfaces of wet materials

The application of air movement at the surface of wet materials is a critical component to the drying process. Evaporation is a surface phenomenon, and surfaces are measured in area (e.g. square feet). Therefore using linear feet of wall as the primary criterion for establishing air movement requirements is illogical.

- 1) Drying is the process of removing excess moisture both at the surface and from within the materials and assemblies.
- 2) The conditions conducive to effectively and efficiently drying at the surface of some materials and assemblies differ from the conditions conducive to effectively and efficiently moving excess moisture within the materials or assemblies.
- 3) Rapid air movement across wet surfaces of materials or assemblies is a critical component of effectively and efficiently drying the surface of those materials and assemblies.
- 4) Rapid air movement across the surface of materials becomes less important relative to vapor pressure as the focus of removing surface moisture gives way to reducing moisture content in low evaporation materials.
- 5) Using the same criteria to establish air movement during the constant and the falling rate drying of materials and assemblies does not consider changing conditions.
- 6) The linear foot formula for air movement of a room fails to consistently account for the actual surface area of wet materials and assemblies in different classes of water intrusion.

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.

It is important to quickly control the moisture in the air and use sufficient airflow to dry the surfaces of materials to reduce water activity thus lowering the potential for microbial growth. According to ACGIH's *Bioaerosols: Assessment and Control* book in section 10.3.3, "Practically speaking, if  $a_w$  can be kept below  $\sim 0.75$ , microbial growth will be limited; below an  $a_w$  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  $a_w$  and the quickest way to stop microbial growth is to get rapid air movement across the wet surfaces. If the surfaces of hygroscopic materials (e.g., gypsum board) can be dried and maintained below this, microbial growth can be quickly halted; even though the core of the material may still have elevated moisture content.

As the job progresses and the environment is stabilized, materials can be dried by managing the humidity, airflow, and energy (heat). Further into the drying it is important 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 is significantly less 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.

### 3. Review of Existing Published Research

Several studies and research efforts have been well documented, discussed and reviewed in regards to drying rates. The majority of these studies have been conducted to understand both the rate of drying and the effects of drying rates on specific materials. The target materials in most of this research are wood, food, and pharmaceuticals.

There are several common observations throughout this research. These include the need for an air mass that is relatively dryer than the target material, and the presence of appropriate air velocity along the wet surface.

The speed of airflow along the surface shows high degrees of consistency between many credible sources within the peer-reviewed literature listed below. Generally, airflow velocities of 600FPM or higher during the initial, constant rate drying period are appropriate. This is characterized by the presence of liquid water in and on the material. Subsequently, minimum airflow of 100-250 FPM are considered appropriate during the falling rate drying period, characterized by minimal free (liquid) water, with mostly bound water remaining.

Source	Minimum	Maximum	Material	Note:
Dr. Fred M. Lamb: <i>The Importance of Velocity in Drying</i>	200 FPM	600 FPM	Wood	[Airflow] is useful above 40 percent moisture content. At 20 percent and below, air velocity beyond the minimum has little effect on drying rates.
Ylva Steiner: <i>Optimizing the Air Velocity in an Industrial Wood Drying Process</i>	393 FPM	984 FPM	Wood	... drying rate is dependent upon air velocity at moisture content above approximately 40% and this effect gradually decreases down to 20%. Steiner references a 5 M/S velocity in practical applications and a goal of 2 M/S as nominal for energy efficiency and drying rate.
William T Simpson: <i>Effect of air velocity on the drying rate of single eastern white pine boards</i>	None Provided	600-700 FPM	Wood; White Pine	Generally discusses the effect of air flow velocity is minimal when the MC of the material is below approximately 40%.
Arun S. Mujumdar: <i>Handbook of Industrial Drying</i>	200 FPM	600 FPM	Wood	Discussion of typical airflow velocities in industrial kiln drying applications.
Robert H. Perry: <i>Chemical Engineering Handbook</i>	200 FPM	1000-2000 FPM	Solids	"At high air velocity, the drying rate is faster, but becomes limited by internal diffusion and a steep moisture gradient forms."

Figure 1: Peer Reviewed Literature Summary

The conclusions provided regarding airflow velocity are predominantly based upon observation of drying rates at various air speeds. These studies unanimously agree that higher rates of speed do not necessarily yield significantly faster drying. In short, the more speed is added, the more diminished return in drying rate. Thus, each paper evaluates the point at which additional speed is no longer substantially relevant. Generally, this maximum is observed at approximately 400-600 FPM.

Further, the papers evaluate the minimum speed when dealing with low moisture content (falling drying period). Again, the reduction of airflow has little impact on drying rate until a minimum threshold is achieved. This minimum is universally noted in the listed papers as 100-250 FPM.

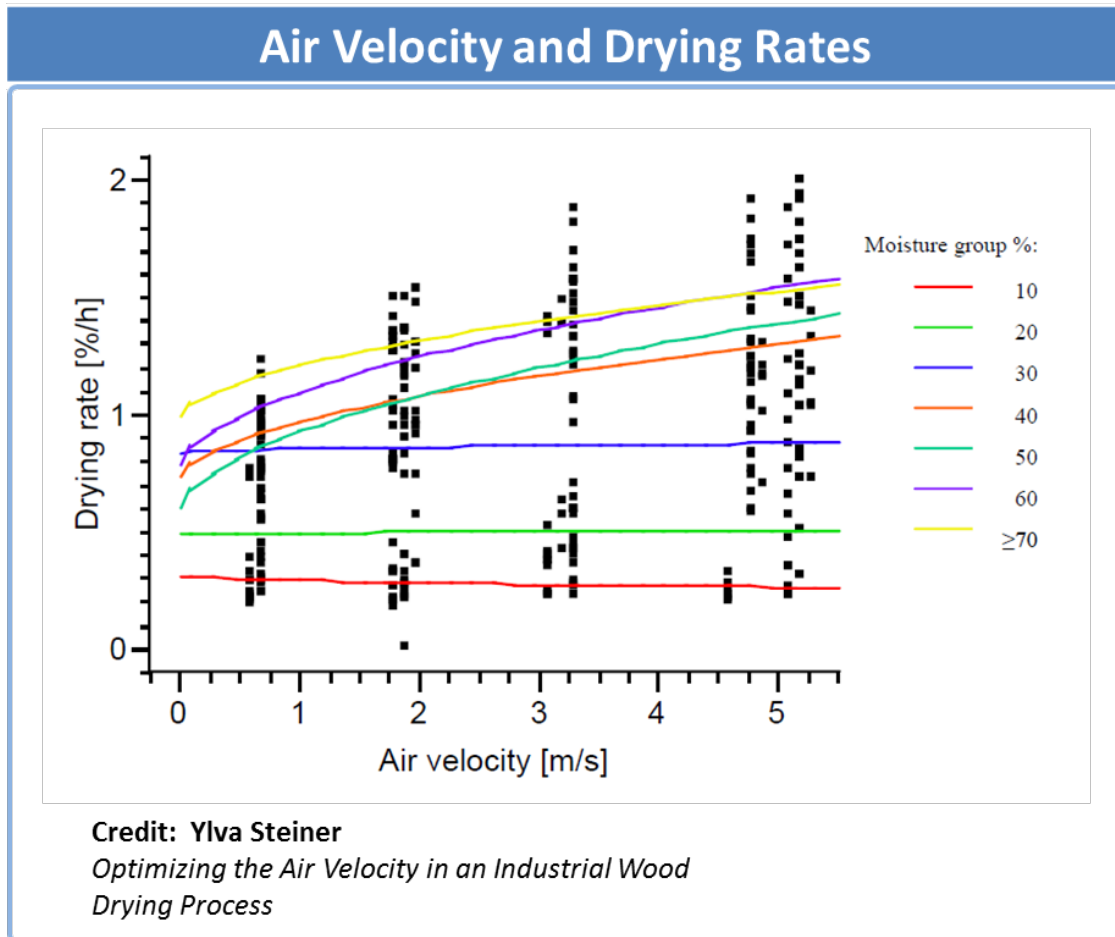


Figure 2: Air Velocity and Drying

Note: 1m/s = 197 FPM

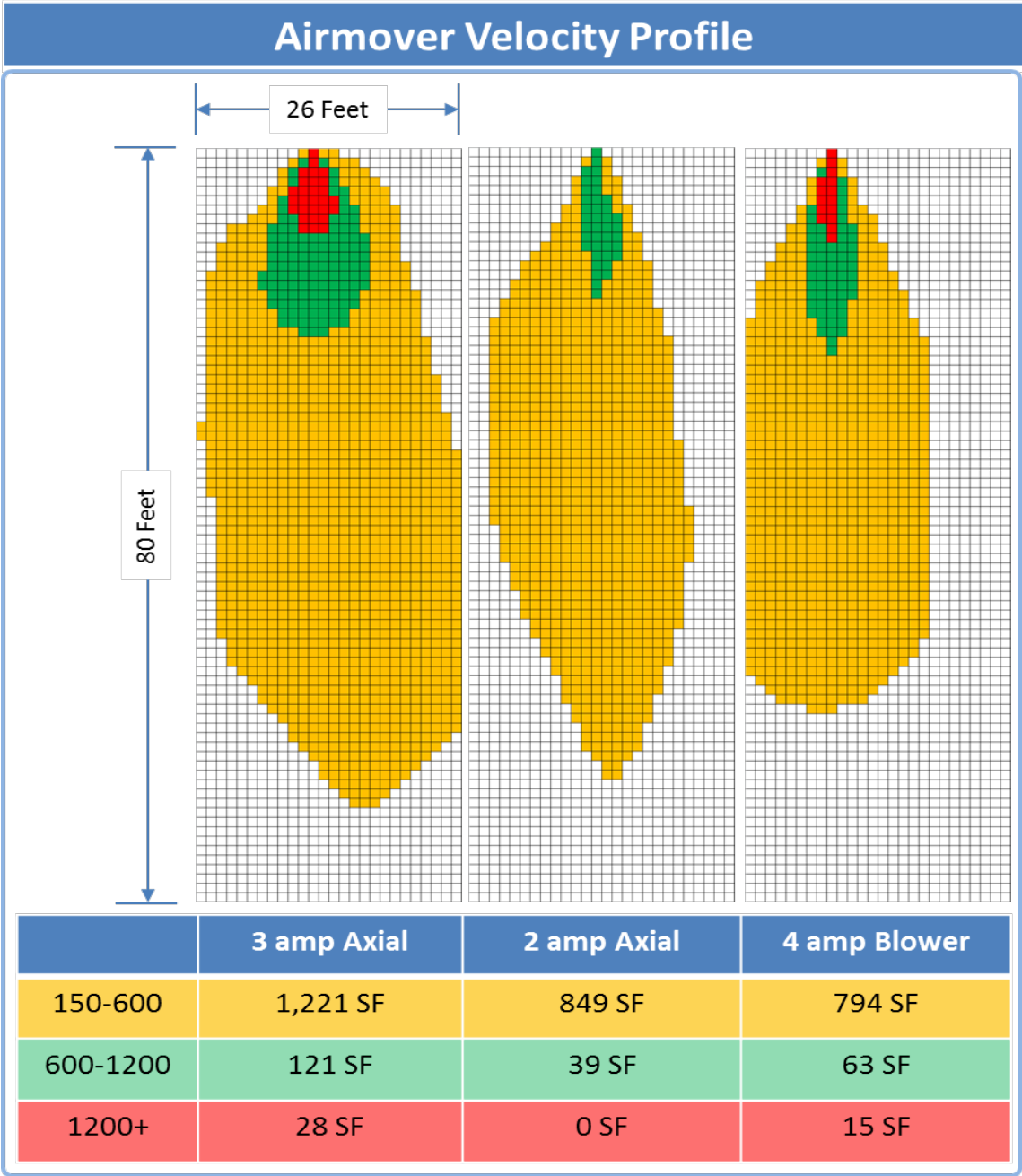
#### 4. Research Performed by Manufacturer

Documented industry research is limited currently in the restoration field. However, some research does exist. Research performed by Dri-Eaz Products, Inc. in the fall of 2013 shows that the general air moving devices available to restoration professionals today easily cover 800-1200 SF of area with airflow rates above 150 FPM. Further, this research shows these same devices adequately provide 600 FPM or higher across an area of 60-120 SF.



These values illustrate that a single air moving device, under optimum conditions, can address 60-120 SF of wet surface area during the initial, constant drying rate, and 800-1200 SF of wet surface area during slower, falling drying rates.

It is important to note that this data was obtained using a smooth, unobstructed concrete flooring surface. The values represented, therefore, are the absolute maximum potential coverage for each airmover type.



Testing Performed by Dri-Eaz Products, Inc. 2013

Figure 3: Airmover Velocity Profiles

## 6. Frequently Asked Questions

*Why change what is working fine now?*

The fact is the linear foot calculation method works on some projects very well (e.g. small, residential, class 1 intrusions), some projects in most cases and on some does not work at all (e.g. larger, commercial, class 3 intrusions). Additionally, the majority of the questions that the S500 committee receives daily and are often the subject of intense negotiations between stakeholders are those related to the number of airmovers used on a project. The fact that the various stakeholders have developed a degree of accommodation with each other, via “after-the-fact” negotiation or discounting should not be construed as being “tried and proven” or that the appropriate amount has been used.

*Is there any science or research to back this up?*

There is extensive and well-documented science and research ranging over many years related to drying technology of various products (e.g. food, wood, paper, concrete) but the challenge in our industry is that a building is a built-up, complex structure that is unique in many aspects. The structural drying industry is an applied discipline that draws on the more fundamental sciences of physics and chemistry. There are no “laboratories” in which all aspects of a drying process can be controlled and the airflow component be closely monitored. Even among the ASD flood houses there exist many variables (e.g. materials, age, weather, location, wetting practice) that cannot be consistently controlled. Many peer reviewed documents and research papers currently available were reviewed by the S500 CB and is part of the impetus for recommending these changes. To the contrary no documentation or literature is available to support a linear foot calculation methodology.

*Will this result in longer drying times?*

Under no scenario does the CB anticipate this will negatively impact a drying project. In fact, the new language allows for consideration of a far greater number of variables to more closely prescribe sufficient airflow to each unique project. As shown in this whitepaper, in projects with substantial wet surface area, the draft calculation would result in more airmovers than the current edition. The direction is that the guidance on air movers is for initial drying (the same as for dehumidification recommendations), then on subsequent visits the air movers would be managed (i.e. moved, removed, concentrated) to facilitate the drying progress. Longer drying times using this calculation compared to the 2006 edition calculation could only be due to a failure to properly monitor and manage the equipment on the job.

*Will this limit setting up the appropriate amount of equipment?*

The CB is confident that the guidance given will actually facilitate the appropriate number of airmovers being placed on all classes of water intrusion. Concerns that the draft language will reduce the amount of airmovers needed on a project are probably not taking into account the full context of the draft language.

*Doesn't the present language, with its "10-16LF" range provide the needed air movement for more surfaces than just the floor?*

In some cases the range is sufficient to provide air movement on all wet surfaces. However, if the room is large or if there is considerable wet surfaces above a couple of feet (e.g. upper walls, ceiling) it may be completely insufficient. Since evaporation occurs at the surface of materials, air movement needs to be related to and directed at wet surface area.

## Conclusions

After reviewing the literature, research and other industry data, the Consensus Body has made the following conclusions:

- Surface area is more relevant to airmover sizing than linear feet of the room perimeter.
- Airflow requirements are greater during higher evaporation rate stages.
- This calculation method for determining equipment requirement is appropriate for initial placement only.
- Adjustments to air movement are to be made throughout the drying project.

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