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Wallboard dryer operational strategies: Emphasising quality in a low-volume market

When building products manufacturing volumes are low, there is more competitive pressure to produce high-quality wallboard and the importance of maintaining customer loyalty by minimising claims becomes increasingly important. This article describes operational strategies for adjusting the dryer from volume-centric production methods to quality-centric methods during times of lower demand. Emphasis is placed on solutions requiring little or no capital.

Above: In a low-volume market, wallboard producers should emphasise quality over quantity.

Right: Figure 1.

Introduction

In this time of reduced economic activity, there is limited demand for building construction and therefore builders and contractors are adjusting their competitive emphasis from capacity and speed of construction to managing costs and offering superior quality. It follows that building materials such as gypsum wallboard are scrutinised closely for quality and conformance to specification.

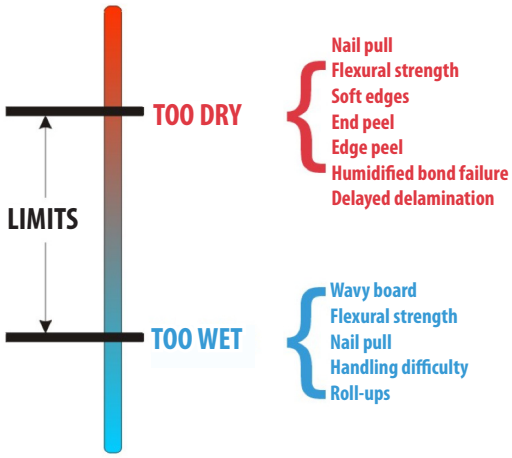
The consequences of quality complaints or claims are compounded in an environment of strong competition for a limited market. This article is a discussion of controlling the factors that result in quality claims. The general subject is dryer performance and although there are a number of aspects of product quality that are interdependent, such as mechanical handling, formulation and other factors, it is dehydration and finished moisture variability specifically that is the main focus.

Among the greatest risks for defective product entering inventory are variations that cannot be easily detected with the senses. Easy-to-detect deficiencies that result in complete paper separation, mechanical damage to edges and gross moisture variations that can be detected audibly or through handling are not emphasised. Finally, the definition of industry terms such as 'dryer balance' are further refined through the introduction of a model that facilitates discussion of the complexities of managing moisture variability.

Define 'quality' of drying

For the purpose of establishing a common vocabulary for optimising dryer performance for quality, the model of 'variability and limits' is introduced:

1. Moisture Limits are defined as the limits of finished board moisture, beyond which some mode of product failure occurs. This is the targeted range of acceptable finished moisture (Figure 1).

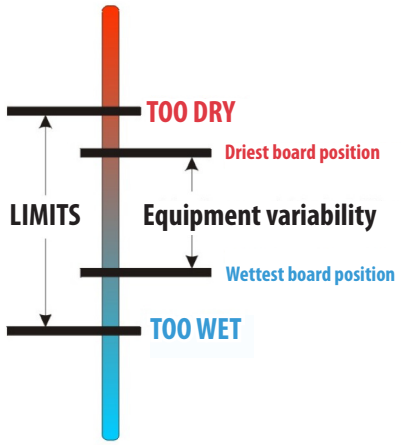


2. Variability is defined as the range of moisture variability in finished product. The term 'variability' will be used interchangeably with 'moisture variability.'

Equipment variability is defined as the range of finished board moisture for a single product at a given moment in time. Wallboard dryers convey multiple streams of boards and therefore are essentially multiple parallel drying processes, each of which is subject to different process variables such as drying time, airflow and temperature. Consequently, when operating at a steady-state, boards from various cross-sectional positions in the dryer may potentially emerge from the dryer with relative differences in finished moisture. The degree of this variation is customarily called 'dryer balance,' and the act of reducing this variation is often called 'balancing the dryer.' Factors affecting equipment variability are static and determined by mechanical adjustments and control methodologies that are not typically operator adjustable, but rather are an aspect of the dryer's configuration and design. The narrower the range of equipment variability, the easier it is to operate the dryer without exceeding quality limits.

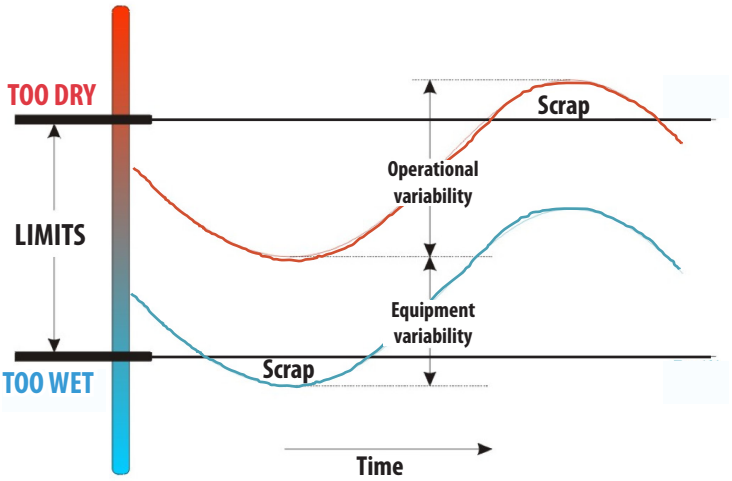
Sometimes the range of equipment variability is greater than the range of moisture limits. In such cases, some of the product is always outside of specification. Such a dryer is very difficult to operate without waste or quality compromise.

In other cases, the range of equipment variability is very narrow, with minimal measurable difference between finished product from all board positions. Such a dryer allows for a wide range of operational variability without exceeding limits and is relatively easy to operate. Figure 2 shows the relationship between moisture limits and equipment variability.



Left: Figure 2.

Operational variability is defined as the differences in finished board moisture for a single product over a period of time. The factors affecting operational variability are dynamically controlled and are usually managed by the dryer operator (Figure 3).



Left: Figure 3.

The total acceptable variability is the sum of the equipment variability and the operational variability, therefore any reduction in equipment variability will result in an increase in the allowable operational variability. In other words, it is easier to make good board with a well configured dryer. The following sections discuss strategies for minimising equipment variability (configuring and tuning the dryer) and strategies for minimising operational variability (operating the dryer). Strategies for increasing the range of acceptable moisture are also discussed.

Strategies for emphasising quality

When a dryer is well configured and well controlled the risk of quality variance is reduced. The following section describes strategies for improving dryer performance to reduce equipment variability of moisture and methods of operation that minimise operational variability.

Minimising equipment variability

Delivery airflow profiling: The act of balancing a dryer is most commonly associated with the adjustment of delivery dampers which control the volumetric distribution of heated delivery air across the surface of the board. The methodology varies air volume to compensate for unwanted temperature variations, commonly called upper-duct stratification (or just stratification), in the delivery air.

Because of the limited effectiveness of the deck dampers to compensate for temperature variations and because of other aspects of configuration that affect equipment moisture-variability, deck damper adjustments will usually not consistently reduce equipment variability until other prerequisite steps are taken. These steps are described below.

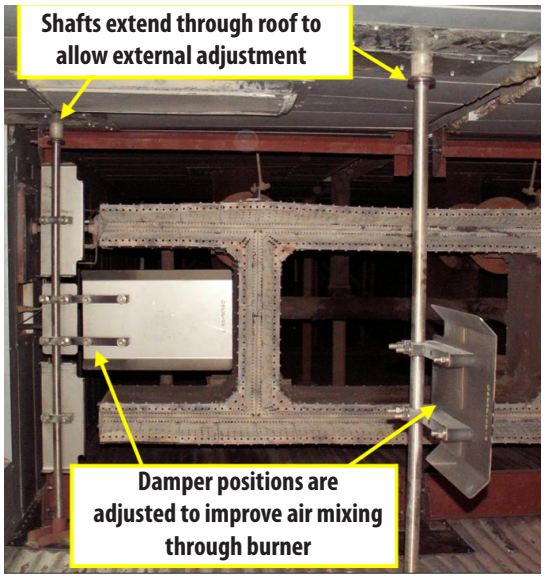
Minimising Stratification - Deck dampers have limited effectiveness for compensating for a range of delivered temperature that exceeds about 15°C, therefore stratification beyond these limits will usually result in wider range of equipment variability.

Stratification is usually caused by incomplete mixing of return air as it passes through air heaters, such as burners. Equipment manufacturers are good at configuring dryers to minimise stratification, however stratification outside of acceptable limits persists, even in new installations.

Air-mixing devices are often installed to mitigate stratification, with various degrees of effectiveness. Multiple iterations are often required to adjust the control surfaces of air mixers, usually requiring frequent delays in production to enter the dryer and make adjustments. This process is expedited significantly when air-mixers with externally-adjustable control surfaces are used (Figure 4 - overleaf).

Moisture profiling - Balancing the dryer through adjustment of delivery air dampers is an iterative process, requiring multiple measurements of the relative moisture distribution across the surface of all board positions. Moisture profiling measurements can be made manually by rejecting boards representing each of the cross-sectional board positions and measuring moisture across the width of each board with a hand-held moisture device. If done correctly, this is an effective and accurate method of measurement, although relatively time consuming and labour-intensive.

Figure 5 shows an example of a moisture profile that



Right: Figure 4 - Externally-adjustable air mixers.

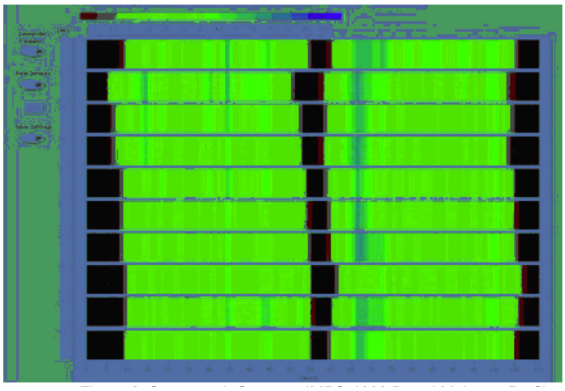
Below: Figure 5 - Moisture profile.

	West									East								
	4	6	12	18	24	18	12	6	4	4	6	12	18	24	18	12	6	4
Deck 10	11.8	14.2	12.2	12.1	11.2	11.2	11.2	10.8	10.2	10.8	10	10.3	10.1	10.9	11.5	11.8	12	11.1
Deck 9	14.6	15.2	15	15.2	15.6	15	14	14	15.2	14.4	13.3	13.8	14	15.6	17.8	18.8	18.8	17
Deck 8	9	9	9	10.6	10.4	10.5	10.3	10.4	9.2	14.8	13.7	13.9	14	13.5	13.5	13.9	14.3	15.6
Deck 7	11.2	11.8	13.3	12.2	10.9	11.2	11.4	11.8	12	10.5	10.2	10.6	11.4	10.7	11.6	11.5	10.8	11.5
Deck 6	14.3	13.1	13.3	13.5	12.5	12.3	12.5	12.1	13.5	11.9	9.9	10.5	10.9	11.3	10.5	10.7	10.3	11.7
Deck 5	12.2	14.6	11.5	12.4	11.2	11.9	11.5	11.2	10.7	10.9	10.7	10.8	11.2	13.5	14	12.9	11	10.9
Deck 4	5.6	14	13.8	14.2	14.2	14.4	16.4	19.2	17.6	16.2	15	14.8	14.6	14.2	15.6	15	14.6	16.2
Deck 3	15.8	15.4	13.1	12.8	11.7	16.3	12.8	12.2	12.6	10.8	11.6	11.6	17.7	11.2	11.7	12.2	11.6	11.4
Deck 2	12	12.8	12.5	12	12.4	12.2	12.2	11.9	11.2	12.2	12	14.8	14.8	14	12.4	13	14.6	12
Deck 1	16	15.6	15.6	14.2	13.4	11.7	11.9	11.7	11.7	11.3	11.6	12.4	15.4	15.2	16.4	16.6	18	15

was taken manually, with each data-point measured individually.

Automated moisture profiling systems, such as the Sensortech Systems IMPS-4000, measure moisture across every board surface and offer a visual representation of cross-sectional moisture distribution. Such automated and instantaneous feedback facilitates measurement-adjustment iterations to be carried out by a single person. Crucially, this can be done at a faster rate than with manual measurements. Accurate moisture profiling requires that the product in the dryer at the time of the sample not be influenced by interruptions in production. Systems such as the IMPS-4000 allow the flexibility to opportunistically measure a moisture profile whenever process conditions are right. A graphical representation of an IMPS-4000 moisture profile is shown in Figure 6.

Below: Figure 6 - Graphical representation of an IMPS-4000 moisture profile.



Dryer deck speed synchronisation: Most modern dryers are equipped with individually-driven deck drives. If the speed of the drives are not synchronised with one-another, any variability in deck speed will result in a corresponding variability in finished board moisture.

Controls that synchronise the dryer deck speeds with the line speed are commonly called butting controls, because a synchronised dryer deck will not have gaps between individual boards, because gaps are 'butted' as they enter the dryer body.

Such variability exists on dryers that are not equipped with controls that synchronise the drives to the line speed and on dryers with synchronisation controls that do not work properly. The effectiveness of efforts to reduce moisture variability through other means is limited unless decks speeds are synchronised. This should be considered a foundation for minimising equipment variability.

Butting controls that consistently close gaps can be retrofitted onto virtually any dryer equipped with individual deck drives.

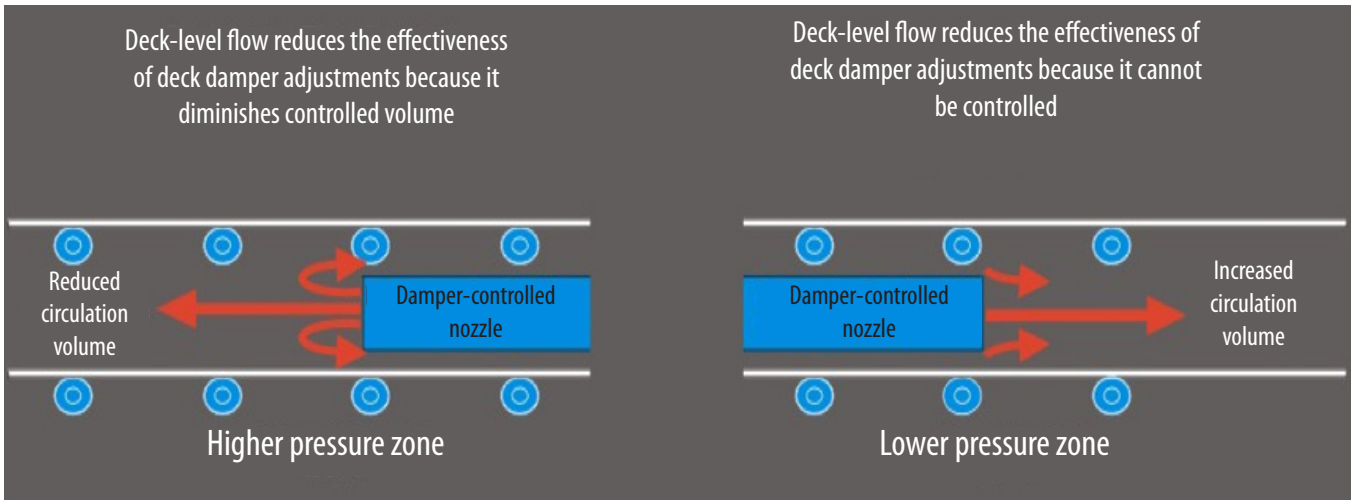
Inter-zone exhaust exchange: If a particular zone's exhaust system is not extracting the same volume of water vapour as is evaporated in the zone, then some of the exhaust volume is exchanged between adjacent zones at the deck level. Such deck-level exhaust transfer circumvents and diminishes the effectiveness of adjustable delivery nozzles, which are intended for equilisation of stratified delivery air. Further, deck-level flow from a delivery nozzle section reduces the applied delivery volume for the zone from which deck-level flow is originating, reducing the drying capacity of that zone (Figure 7 - overleaf).

If equipment variability is minimised for a particular product while deck level flow is present, other products with different evaporation rates may experience different volumes of deck level flow, causing different heat application profiles to the board surface. When significant variable deck level flow is present, the cross-sectional moisture distribution will not necessarily be consistent between products.

Inter-zone exhaust exchange takes place when there is a pressure differential between zones. Control of inter-zone exhaust flow requires measurement of differential pressure between zones, with controls which manage exhaust extraction to minimise differential pressure within the capabilities of the dryer's design. Minimising deck-level flow should be considered a foundation for minimising equipment variability.

Standardised evaporative distribution: Although the finished board moisture variations are minimal for a well balanced dryer, it is likely that the shape of the evaporation curve for individual board positions will be slightly different.

Since each zone has a unique pattern of cross-sectional heat delivery, changes in the proportion of



Above: Figure 7 - Inter-zone exhaust exchange.

evaporative loading will result in changes to the finished board moisture profile. As long as the distribution of evaporation load by zone remains similar across different product types, the range of equipment variability will also remain similar for different products. Standardising the zone evaporation rates for all products and creating a standard operating procedure that maintains the zone evaporation rates is a foundational step for minimising operational variability.

Dryer agility: Some dryers are better suited to frequent product changes than others. This is an important consideration for producers when choosing which production lines will produce large quantities of few product types and which lines will be used for a multitude of specialty products. Some of the factors that determine a dryer's suitability for frequent changes are described below:

• **Thermal inertia:** Dryer rolls retain heat and hinder rapid temperature changes required when transitioning between products. Larger diameter rolls retain more heat and limit a dryer's agility. Dryers equipped with 4 inch (10.16cm) rolls or larger are less capable of transitioning between products without producing variations outside of moisture limits.

• **Thermal turndown:** The capacity for burners to operate at low firing rates is an important factor in a dryer's ability to transition between products effectively.

• **Cooling capacity:** When transitioning between products, it is often necessary to rapidly reduce the operational temperatures of an individual zone to meet the needs of the new product entering that zone. Cool air induction is sometimes required to overcome limitations with thermal turndown and high thermal inertia.

Dryers equipped with heat-recovery systems may not allow for induction other than with pre-heated air. Such dryers that are not equipped with variable cool air induction systems or other means of cooling are not ideally suited to producing specialty products.

• **Control Methods:** Depending on the design limitations of the dryer, such as the factors described above, the minimum achievable loss during interruptions in production is somewhat variable. A reasonable target is typically equal to the number of boards representing the cross-sectional capacity of the dryer (number of decks multiplied by the number of boards wide). Manual operating procedures or automated systems should be evaluated based on this benchmark, with expectations adjusted for equipment deficiencies.

Minimise operational variability

Moisture feedback and control: If automated moisture measurements are to be used to control moisture variability within moisture limits, the full range of operational variability must be reported by the measuring device or method and must be considered in the context of known moisture limits.

For example, if the minimum limit of moisture for a particular product is known to be a certain value because humidified bond failure occurs beyond that value, then the entire drying process must be managed such that the driest board-position never exceeds that limit.

If handheld measurement devices are used as the means of moisture feedback, then the location of the driest board position must be known (through moisture profiling as part of determining the machine variability, described previously) and this board position must be checked frequently for variation beyond limits. The same is true for the wettest board position.

The procedure described above differs from that which is commonly used, in which finished moisture is monitored as the average of multiple readings, or as a random sampling of board positions. This must be emphasised: Average moisture is not an adequate measure of finished moisture because it does not account for machine variability.

Automated moisture profiling systems such as the Sensortech System IMPS-4000 facilitate this process by reporting the equipment variability in the form of minimum and maximum moisture indicators, which are available on-screen for operator interpretation and decision-making and available through electrical signals for integration into control systems.

Determining and maximising moisture ranges

Identifying moisture limits: The limits which

determine the allowable moisture range must be known if the process is to be controlled in a way that minimises the risk of making bad product and that allows for identification of finished product which should be scrutinised for quality variance before entering inventory.

Identifying the limits for each product and production rate requires a trial-and-error approach that is greatly facilitated when dryer process variables and finished moistures are electronically stored in a database.

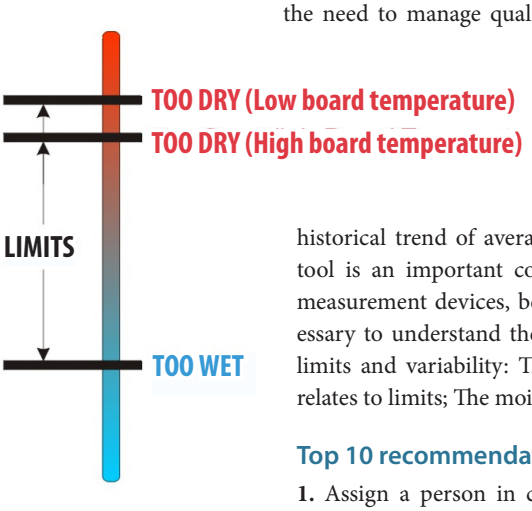
Expanding the range of moisture limits: Although not the focus of this article, it should be recognised that there are process changes outside of the dryer that can expand the range of acceptable moisture limits, such as paper-coating methods and the use of certain additives. Depending on the extent of machine variability, it is sometimes necessary to use such process changes to expand the range of moisture limits beyond the range of machine variability.

The temperature of the board as it leaves the dryer is a factor that affects the range of moisture limits. With finished moisture remaining constant, higher board temperatures are more likely to result in delamination, with the greatest risk being delayed delamination, which is not detectible before packaging, but which manifests after product enters the inventory. Figure 8 shows the relationship between board temperature and moisture limits.

If the dryer configuration permits, the humidity of the last zone may be manipulated to affect the temperature of finished board. This happens because the effect of evaporative cooling is increased at lower humidity.

In most cases, particularly with non-heat-exchanger equipped dryers, there is a correlation between last-zone humidity and energy-efficiency. In such a dryer, highly efficient operation narrows the range of acceptable finished moisture. An important and challenging aspect of managing moisture limits and variability is prioritising the need to manage quality with the need to manage energy consumption.

Below: Figure 8.



The Raytek TIP-450 thermal imaging system provides a cross-sectional profile of board surface temperature as well as a historical trend of average temperature. This type of tool is an important compliment to finished board measurement devices, beacause both factors are necessary to understand the interplay between moisture limits and variability: The temperature of the board relates to limits; The moisture relates to variability.

Top 10 recommendations

1. Assign a person in charge of understanding and managing moisture limits and variability. Equip them with training and information so that they can confidently adjust the mechanical aspects of the dryer to minimise equipment variability. This person should have the authority to implement rigorous dryer operating procedures for controlling operational variability.

2. Access the excellent expertise available through dryer process experts and equipment manufacturers. Find an expert that has a deep understanding of the drying process, equipment and methods of control and that is accessible and amenable. Integrate this individual into your process improvement efforts.

3. Invest heavily in training dryer operators in the nuances of minimising operational variability. Considering equipment variability, hold dryer operators absolutely accountable for maintaining operational variability within limits.

4. Aggressively identify defective product and do not allow it to enter inventory. Create operating procedures that anticipate conditions that may cause operational variability and in those cases, test moisture levels in the board positions which are most likely to vary beyond moisture limits.

5. Implement some kind of automated moisture profiling, such as the Sensortech Systems IMPS-4000. Automated moisture profilers greatly facilitate efforts to reduce equipment and operational variability.

6. Understand that the best moisture measurement technologies available require meticulous installation and frequent calibration. Calibrate in-kiln and out of kiln sensors frequently. Consider training and assigning this task to someone that is directly accountable for finished board moisture variation.

7. Configure and tune the dryer to reduce the range of equipment variability. Understand that deck-damper adjustments are the end-game. Effective butting controls, stratification mitigation, effective exhaust controls and standardised evaporative loading are prerequisites.

8. Control the drying process according to the minimum and maximum range of operational variability, not according to average or random measurements. Control the dryer according to the worst board that is being produced.

9. Fully use historical logging and database tools such as Wonderware ActiveFactory to monitor critical process variables. This information greatly facilitates identification and troubleshooting of conditions that lead to operational variability and allow for refinement of manual and automated operating procedures.

10. If your dryer uses a method of heat recovery that increases humidity in the last zone, quantify how last-zone humidity affects the range of board-moisture limits. If necessary, control humidity to broaden the range of moisture limits. Use a temperature profiler, such as the Raytek TIP-450 to monitor board surface temperature.