Observations from testing dryer section performance

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ABSTRACT: Performance testing can be used to identify problem areas in the paper machine dryer section which affect sheet quality, moisture profiles, and production rates. Dryer surface temperatures and cross-machine profiles, sheet temperatures, and pocket humidity levels and profiles are some of the tools used for documenting dryer section performance.

KEYWORDS: Dryer sections, paper machines, performance, problem solving, profiles, sheets, temperature, test methods.

Few paper machine dryer sections provide consistently good performance in all aspects of the drying process. A new linerboard machine tested while on the startup curve is one of our top-performing machines. Dryer surface temperatures are consistent in both the machine and cross-machine directions. Sheet temperature measurements show well-defined warm-up, constant rate, and falling-rate drying zones. Pocket humidities are low throughout the dryer section and uniform across the machine. The effects of pocket ventilation can be easily demonstrated. Turning off air to the pocket ventilators results in a "frown" humidity profile, while closing edge dampers raises humidities at the edges and lowers them in the center of the pockets.

Unfortunately, most paper machines do not exhibit such good performance. Improved testing techniques in recent years have provided the ability to identify and correct many of the problems that occur in the dryer section. Dryer surface temperatures and cross-machine profiles, sheet temperatures, and pocket humidity levels and profiles are some of the tools that are used for documenting dryer section performance and diagnosing drying problems.

Dryer surface temperatures

Dryer surface temperatures are measured with a contacting thermocouple or resistance temperature device. Cross-machine profiles can be measured by traversing the probe across the dryer surface. Surface temperature profiles generally fall into three categories. Flat profiles such as those found on our top-performing machine indicate good condensate evacuation and uniform heat transfer. Profiles of dryers with poor drainage normally are sloped up toward the siphon (**Fig. 1**), or have a "smile" shape, with the edges of the dryer hotter than the center (**Fig. 2**).

The methodology for measuring profiles and some of the problems that can result from poor drainage have been discussed in a previous article.* These problems include undersized siphons or condensate drops, insufficient differential pressures, poor stationary siphon alignment, improperly applied profiling dryer bars, and grooves inside the dryer edges.

Dryer fabrics hold the sheet in close contact with the dryer surface, improving heat transfer and increasing condensing loads. As a result, unfelted bottom dryers are generally hotter than felted top dryers on board machines (**Fig. 3**). The difference decreases toward the dry end of the machine where tighter draws can be pulled. Heavyweight grades often do not display much temperature difference because of tighter draw (**Fig. 4**).

Some board machines have significant top-to-bottom surface temperature differences even with all dryers felted (**Fig. 5**). Differences between the sheet properties of the top and bottom plies are a possible explanation.

Machines that operate both felted and unfelted dryers with the same siphon size and differential pressures often have excess blow-through steam from unfelted dryers and poor drainage of felted dryers (**Fig. 6**).

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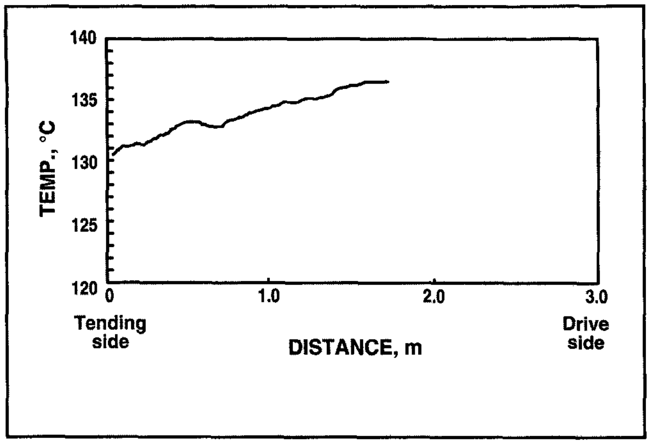
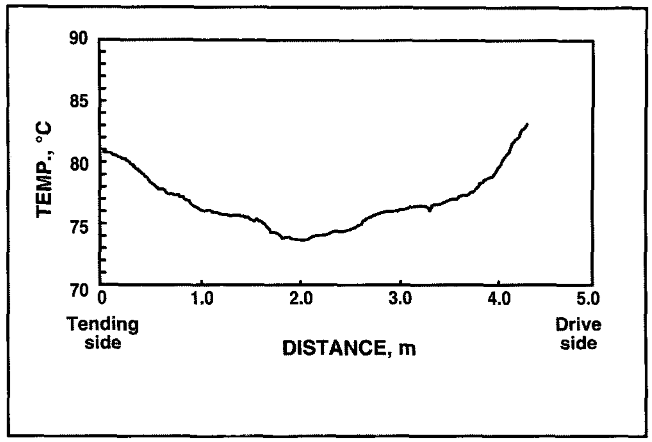
*Rosenberger, G. W. and Reese, J. R., Tappi J. 73(8): 89(1990).

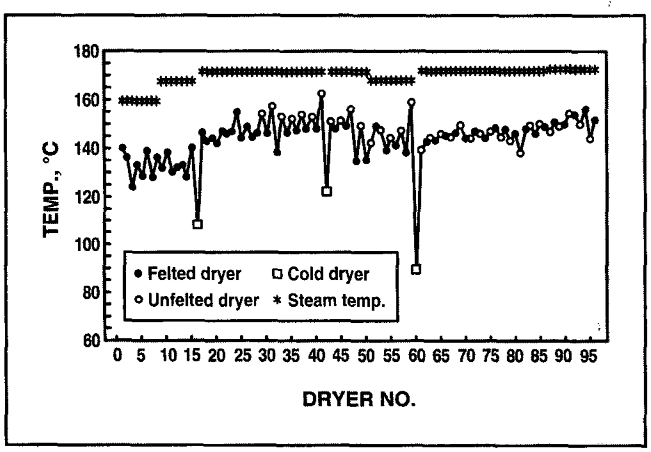
1. Dryers with poor drainage can slope up toward the siphon (single dryer measurement, dryer bars installed, drive-side rotary siphon, insufficient differential pressure).



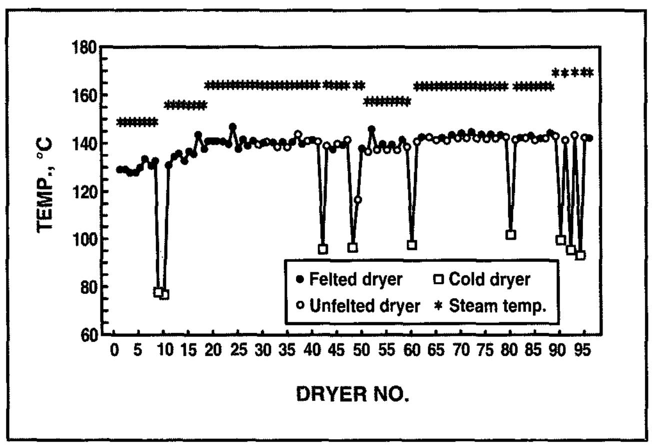
2. Dryers with poor drainage also can have a "smile" shape (single dryer measurement, no dryer bars, drive-side rotary siphon).



3. Dryer surface temperatures on a 42-lb linerboard machine



4. Dryer surface temperatures on a 90-lb linerboard machine



Poor fabric tension can also affect surface temperature profiles (**Fig. 7**). Low tension can result in nonuniform heat transfer compared to higher, uniform tensions.

Testing on high-speed machines indicates that dryer bars are required to ensure uniform heat transfer and temperature profiles. The bars increase surface temperature levels and flatten profiles. The benefits of dryer bars are dependent on machine speed. One high-speed machine increased drying rates and evaporation load by 18%, decreased the average steam-to-dryer-surface temperature difference by 21%, and reduced cross-machine dryer surface temperature variation by more than 80% (**Table I**).

Proper dryer bar installation across the full width of the sheet is required for effective operation. Machines can have hot or dry sheet edges if the sheet extends over the dryer heads. If bars are installed that do not cover the full sheet width, the edge profile can be reversed, with the edge of the dryer colder than the rest of the dryer.

However, dryer bars are not the answer to every drying problem. Some of the poor profiles discussed earlier had bars, but other problems in the dryer section caused poor drainage.

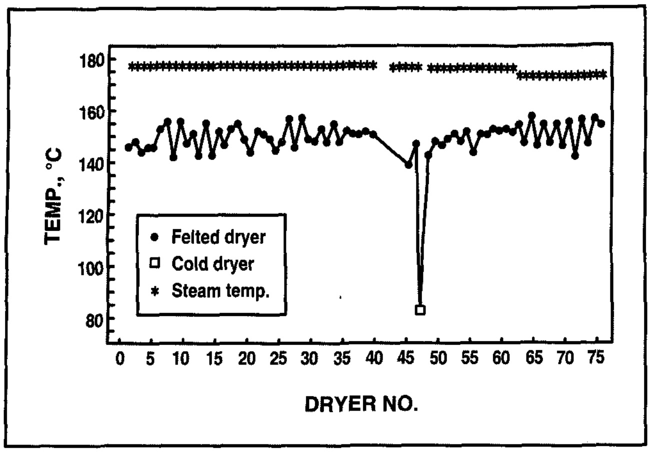
Some dryers have odd surface temperature profiles that are not easily explained (**Fig. 8**). The profiles appear to be characteristic of the dryer can and are repeatable whenever the dryer is measured.

Sheet temperatures

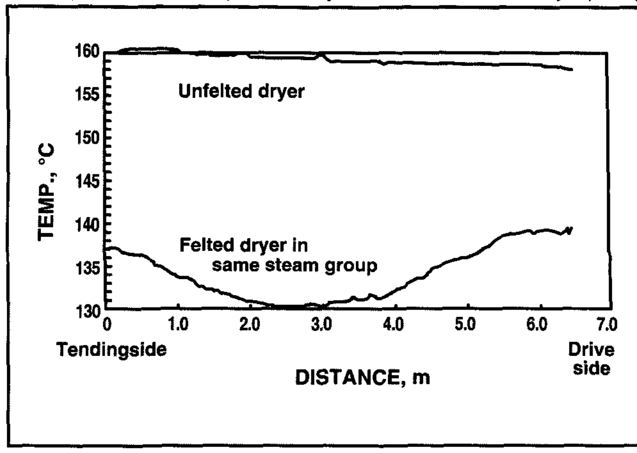
Sheet temperatures provide a good indication of the drying curve of the machine. Temperatures are measured with an infrared gun at the same spot in each pocket as the sheet leaves the dryer. Machine-direction plots usually show distinct drying zones. Temperatures start low at the wet end and increase to evaporation temperature in the warm-up zone. Measured temperatures are nearly constant throughout the prime drying, or constant rate, zone. The sheet is further heated at the dry end of the machine in the falling-rate zone.

The wet-end warm-up zone has been observed to include between 4% and 45% of main section dryers, with an

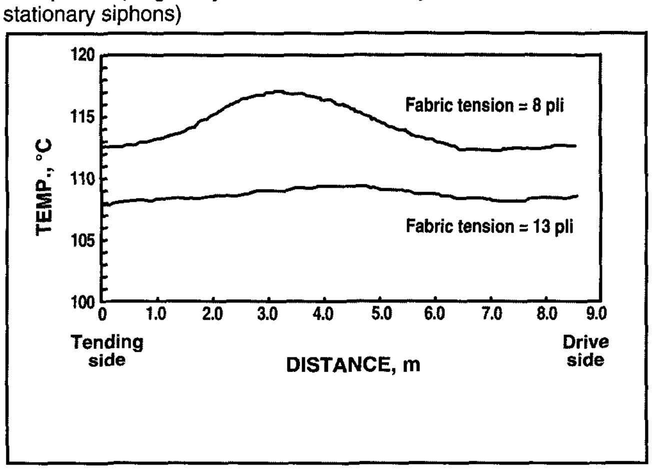
5. Linerboard machine dryer surface temperatures



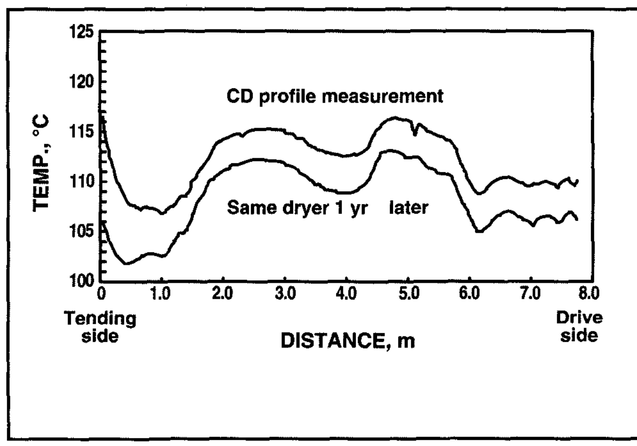
6. Corrugating medium machine cross-machine surface temperature profile (two individual dryers, no dryer bars, drive-side rotary siphon)



7. High-speed newsprint machine cross-machine surface temperature profile (single dryer measurement, dryer bars installed, dual stationary siphons)



8. Newsprint machine cross-machine surface-temperature profile (single dryer measurement, no dryer bars, tending-side rotary siphon)



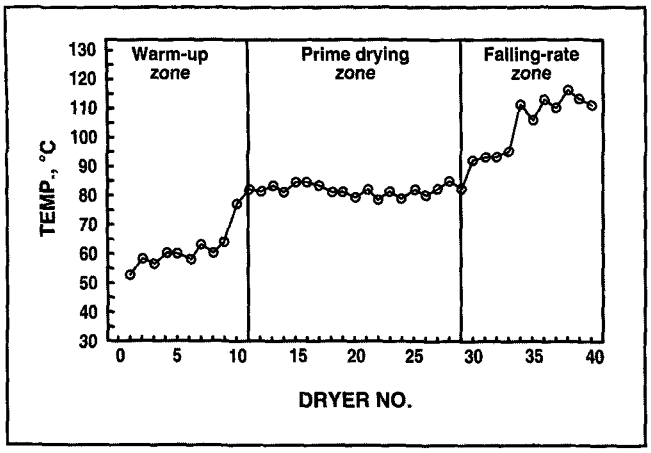
average near 20%. Good drainage and pressure graduation of wet-end dryers is the key to bringing the sheet to evaporation temperature quickly. Drying can be delayed if wet-end pressures are too low (**Fig. 9**) or too high (**Fig. 10**). Problems such as picking, cockle, and sheet floating can occur if the sheet is heated too rapidly.

The dry-end falling-rate zone also averages about 20% of main section dryers on fine paper machines, since the sheet is usually over-dried into the size press to ensure uniform moisture profile and starch pickup. Observed falling-rate zones have included between 0% and 40% of main section dryers. Increasing moisture content into the size press can decrease the length of the falling-rate zone.

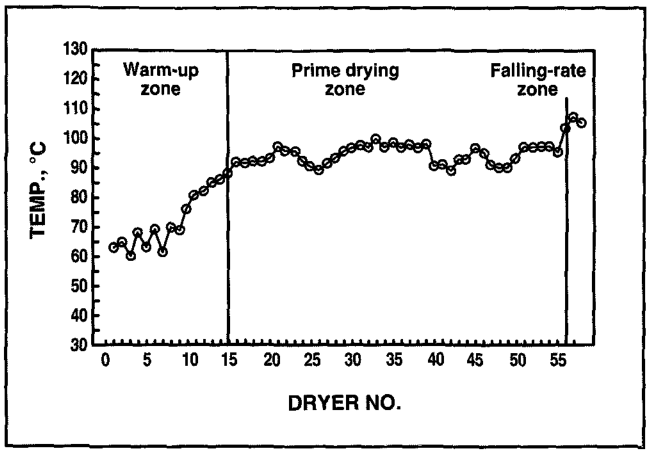
I. Effect of dryer bars on dryer performance indices

	Before dryer bars	*After dryer bars*	*Good level*
Machine speed, m/min	1015	1130	1130
Evaporation, kg/h	24,690	29,100	29,100
Drying rate, kg water/h/m² (at 130 kPa)	16.6	19.3	17.1
Steam-to-surface-temp. difference, °C	21	17	17
Avg. CD temp. variation, °C	15	2.5	2.5
Dryers in prime zone, %	50	65	65–75
Avg. pocket humidity, kg water/kg dry air	0.17	0.22	0.20

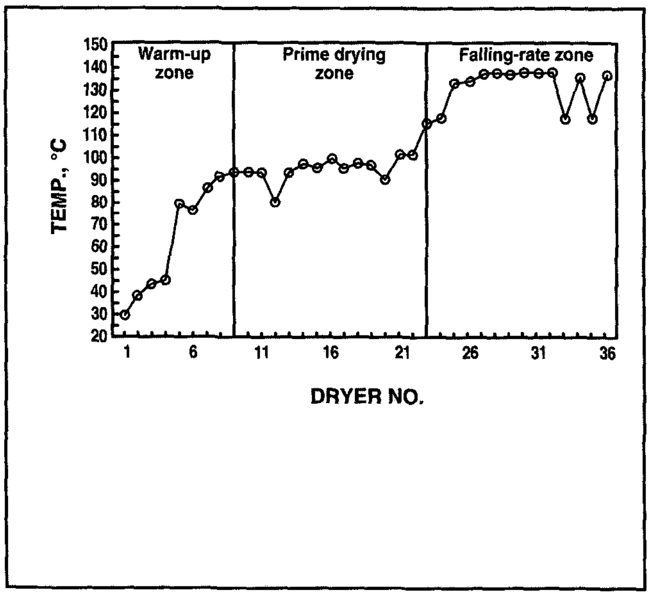
9. Lightweight coated machine sheet temperatures



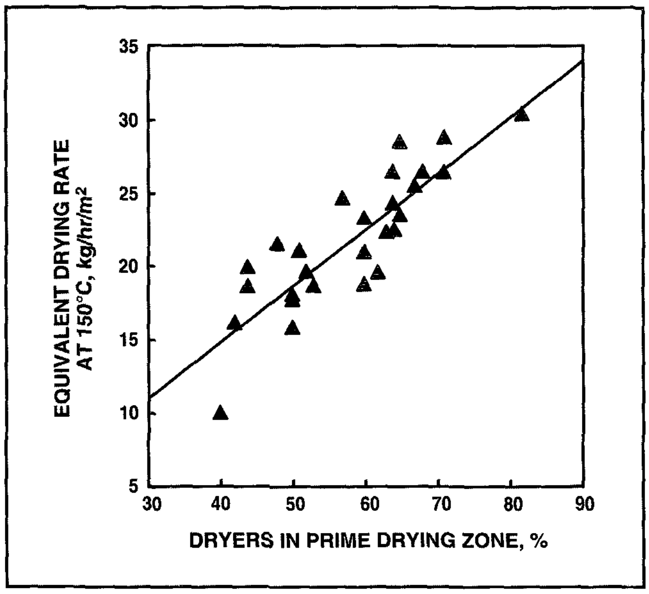
10. Corrugating medium machine sheet temperatures



11. Fine paper machine sheet temperatures



12. Percentage of prime dryers vs. drying rates



The sheet temperature peaks at the dry end on most machines. On some fine paper and bleached board machines with excessive over-drying, the temperatures rise quickly and remain high for a number of dryers (**Fig. 11**).

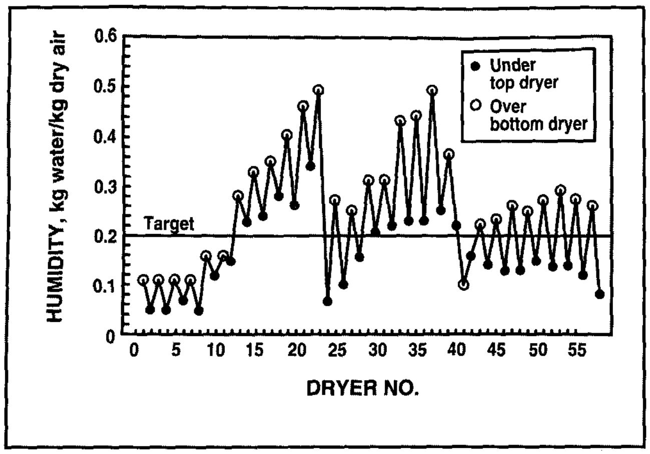
The prime drying zone, between the wet-end warm-up and falling-rate zones, is where most of the evaporation occurs. The prime zone has been observed to include between 40% and 80% of main section dryers, with an average of 60%.

A correlation exists between the percentage of dryers in the prime drying zone and the TAPPI drying rate for a particular grade (**Fig. 12**). Drying rates must be normalized to correct for differences in average steam pressures. Although numerous other factors affect the drying rate, the percentage of dryers in the prime zone has a significant effect. Top-performing machines have more than 65% of the dryers in the prime drying zone, while the worst performers have less than 50%.

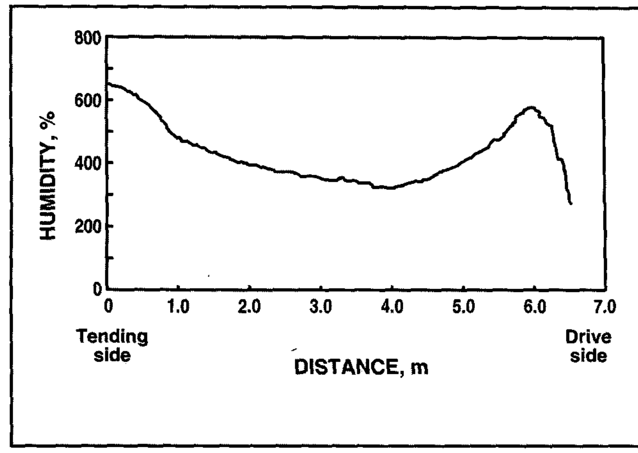
Pocket humidities

Dryer-pocket humidity profiles have four basic shapes, although a number of combinations and variations occur. Well-ventilated pockets have flat profiles with uniform humidities across the full width. Most poorly ventilated pockets have "frown" profiles, with higher humidities in the center of the pockets than at the edges. Some over-ventilated pockets have "smile" profiles with the edges higher than the center. Strong cross-machine air flows through the pocket can result in sloped

13. Corrugating medium machine dryer-pocket humidities



14. Corrugating medium machine cross-machine pocket humidity profile (average of two pockets, pocket ventilators off)



profiles with one side higher than the other.

Poorly ventilated machines have the highest pocket humidities in the prime drying zone where evaporation rates are the highest (**Fig. 13**). Most of the air entering the poorly ventilated pockets is pumped in by the dryer fabrics. Top pockets (over bottom dryers) generally have higher humidities than bottom pockets (under top dryers) since the top fabric pumps hot, humid air from the upper parts of the hood. Bottom fabrics pump cooler, less humid basement air. The top-to-bottom trend can be reversed if bottom fabric permeabilities are lower than those of the top fabric.

Humidities tend to increase toward the dry end through each fabric section as boundary-layer air carried with the fabric picks up humidity through each pocket. The boundary-layer air then becomes drier in the fabric return loop. Modern pocket ventilators are designed to peel off the boundary layer so the increasing trend is not evident. The highest humidities of these new machines often occur at the unventilated drive splits, where felt rolls have been positioned to minimize air pumping.

The objective of a pocket ventilation system is to control the conditions in the pocket without creating sheet flutter. On/off tests have been used to demonstrate the effectiveness of existing ventilators. Profiles become uniform when the ventilators are operated on top-performing machines. Other ventilators have more limited effects or overcompensate for the poor profile.

Opening and closing hood doors has no significant effect on pocket humidities in well-ventilated pockets. However, with poorly ventilated pockets, opening doors can result in low edge humidities and dry sheet edges.

Single-tier dryers do not have true pockets to contain vapor, so pocket humidities are lower than on conventional two-tier machines. However, unless air flows are controlled, opening and closing doors can have a significant effect on humidities close to the sheet.

Felt-roll position in dryer pockets can have a significant effect on pocket humidity profiles. Some machines have been built with felt rolls offset toward the dry end of the pocket to allow the fabric to pump more air. This results in the pocket becoming pressurized. Air flows from the center toward the edges result in "smile" humidity profiles and can contribute to excessive sheet flutter at high machine speeds. Variable-permeability fabrics with offset felt rolls can create some unusual humps in the profile (**Fig. 14**).

Some machines use profiling dampers on pocket ventilators to help control reel moisture profiles. The ability to correct profile is usually limited, but some effect can be seen on well ventilated machines. It is important that all profiling dampers that are supposed to be open are actually open; otherwise unexplained and poor sheet moisture profiles can result.

Conclusion

Dryer-section performance testing helps identify problems with drying capacity, cross-machine profiles, and sheet quality. Surface temperature measurements indicate problems with poor condensate removal and nonuniform heat transfer. Sheet temperatures define the drying curve and help determine whether long warm-up or falling-rate zones are limiting drying rates. Pocket humidity measurements show the results of pocket ventilator design and operation, dryer fabric permeability, and air flows through the hood. Machines with low drying rates or profile problems should be tested to determine causes of poor performance. Performance should be carefully evaluated on machines to be rebuilt to ensure that all basic problems are included in the rebuild scope. TJ

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