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Dryer section performance monitoring

Scope

Dryer section performance has a major effect on production rates, energy efficiency, and sheet quality. Regular performance monitoring can help ensure that dryer section operation is optimized and can direct maintenance and troubleshooting efforts before minor problems become major problems. Monitoring can be done by mill operations, technical, engineering or maintenance personnel; clothing and equipment suppliers; corporate technical groups; and/or independent consultants. Note that this TIP does not cover Yankee dryers.

Information on the importance of techniques for measurement and equipment suppliers for several measurable drying parameters are included. The Supplier Directory at the end of this TIP includes information on test equipment suppliers.

Safety precautions

Follow normal safety precautions when working around paper machinery. Do not allow loose clothing or equipment to contact rotating machinery. Beware of thermal and slip hazards around the dryer section, on the operating floor, and in the basement. Take precautions when working in the hot environment around the dryer section to avoid dehydration, heat exhaustion, and heat stroke. Tag, disconnect, and lock out all dryer drives and steam systems and follow vessel-entry procedures before entering dryers.

Discussion

A good knowledge of dryer section equipment, design criteria, and operating conditions is important for understanding and troubleshooting the dryer section. A list of important dryer section information is shown in Table 1, including data on the dryer arrangement, felting, steam and condensate system, syphons, steam and condensate piping, doctors, dryer bars, and hood and air systems. It is recommended that this information be compiled for each machine and kept in a file for easy access. The information will be useful for anyone who works to optimize or troubleshoot the dryer section.

In addition to a completed information sheet, the following dryer section drawings should be kept on file:

- Dryer Layout Drawings
- Records of Pressure Vessel (dryer) Code Documentation
- Steam and Condensate System P&IDs
- Hood Air System P&IDs
- Sketches of the Rope Runs
- Fabric Tension Charts

Table 1. Dryer section information

General Information	Steam Drops (header to joint)
Mill	Pipe size
Machine	Pipe schedule
Number of Dryers	Sight glasses or drain lines installed
Dryer Diameter	Dryer Section Hoods
Dryer Pressure Rating	Supplier
Felt roll diameter	Type (open, closed)
Size press/breaker location	Design (tongue-in-groove, high performance)
Each Drive Group	False ceiling (half-width, full-width, none)
Section	Basement enclosure
Dryers	Pocket Ventilators
Felting (unorun, top/bottom, unfelted)	Supplier
Fabric suppliers, design, length and width	Type
Fabric permeability (top and bottom)	
Fabric tension (top and bottom)	
Gearing configuration or drive source	
Steam and Condensate Sections	Hood Supply and Exhaust Fan Information
Section	Fan
Dryers	Manufacturer
Separator number and size	Size/Design
Type (thermocompressor, cascade, individual control)	Airflow
Maximum operating pressure	Fan speed
Minimum operating pressure	Static pressure
Syphon and Joint Information	Motor horsepower
Joint size and design	Heat recovery
Syphon type (single, dual, rotary, stationary)	Temperature
Supplier	Supply air source
Position in dryer	Filter presence and condition
Clearance	Individual Dryers
Upleg diameter	Dryer number
Horizontal pipe diameter	Felting
Dryer Bars	Doctoring
Type (full width, profiling)	Dryer bars
Supplier	Air system component (pocket ventilator, blow box)
Dryers	Grooved, blind-drilled, or vacuum rolls
	Dryers with steam disconnected

Operating conditions

A sample data sheet for dryer section operating conditions is shown in Table 2. Sheets specific for each machine should be developed and filled out to provide baseline data on critical grades to allow for effective troubleshooting and problem solving. The top portion identifies the grade being produced and the time and date that data was collected. Weight and moisture profile information is obtained from the machine gauging system. Steam pressure and differential pressure data can be obtained from steam system controllers (local controllers or DCS).

Areas that indicate problems with system sizing, operation, or maintenance should receive particular attention. Such areas include controllers unable to maintain setpoint, supply valves or thermocompressors more than 80% or less than 20% open during normal operation, differential pressure or flow control signals that are out of range, steam venting to the atmosphere or to a condenser, and controllers operated in “manual.”

Table 2A. Dryer section operating conditions (SI units)

Mill _____	Reel Speed _____	mpm _____
Machine _____	Production _____	tph _____
Date _____	Trim _____	m _____
Time _____	Press Moisture _____	% _____
Grade _____	Size Solids _____	% _____
Comments _____	Starch Pickup _____	kg/tonne _____

Weight and Moisture Profiles

	Units	Average	Maximum	Minimum	Shape
Basis Weight	gsm				
Reel Moisture	%				
Bone Dry Weight	gsm				
Size Press Moisture	%				

Pressure and Differential Pressure Control

Section	Dryers No.	Pressure kPa	Setpoint kPa	Output %, a/m	DP/Flow kPa/kg/h r	Setpoint kPa/kg/h r	Output %, a/m
Lead 1							
Lead 2							
Lead 3							
Lead 4							
1							
2							
3							
4							
5							
6							

Control Valve Positions

Section	Make-up	Expected Thermo	Vent	Make-up	Actual Thermo	Vent
Lead 1		X			X	
Lead 2		X			X	
Lead 3		X			X	
Lead 4		X			X	
1						
2						
3						
4						
5						
6						

Table 2B. Dryer section operating conditions (customary units)

Mill _____	Reel Speed _____ fpm
Machine _____	Production _____ tph
Date _____	Trim _____ in.
Time _____	Press Moisture _____ %
Grade _____	Size Solids _____ %
Comments _____	Starch Pickup _____ lb/ton

Weight and Moisture Profiles

	Units	Average	Maximum	Minimum	Shape
Basis Weight	lb/ream				
Reel Moisture	%				
Bone Dry Weight	lb/ream				
Size Press Moisture	%				

Pressure and Differential Pressure Control

Section	Dryers No.	Pressure psig	Setpoint psig	Output %, a/m	DP/Flow psi/pph	Setpoint psi/pph	Output %, a/m
Lead 1							
Lead 2							
Lead 3							
Lead 4							
1							
2							
3							
4							
5							
6							

Control Valve Positions

Section	Make-up	Expected Thermo	Vent	Make-up	Actual Thermo	Vent
Lead 1		X			X	
Lead 2		X			X	
Lead 3		X			X	
Lead 4		X			X	
1						
2						
3						
4						
5						
6						

Dryer section operation should also be observed during sheet breaks, paying particular attention to pressure and differential pressure control response, system venting, condenser operation, and sheet threading.

Operator rounds

Routine operator rounds are an essential part of a complete monitoring program. These rounds are particularly helpful in identifying problems before they become severe. In addition to the steam control and production information included on the sample operating conditions report, a number of areas are recommended to be included in backtender rounds, as shown in Table 3. Where possible, targets and acceptable ranges should be provided on operations checklists so that operators can recognize problems when they occur.

Table 3. Suggested dry end operator rounds

-
- | | |
|-----------------------------------|---|
| • Any Valved-Off Dryers | • Levels in Separator Sightglasses |
| • Draws for Each Section | • No Condensate Being Sewered |
| • Drive Amps for Each Section | • Supply and Exhaust Fans Turning, Coils not Plugged, Filters Okay, Dampers Set Correctly |
| • Dryer Fabric Tensions | • Supply Fan Temperatures |
| • Felt Guides | • Steam Pressures, Differential Pressures, Controller Outputs |
| • Felt Stretchers | • Header Pressures |
| • Doctors Engaged or Disengaged | • Desuperheater Temperatures |
| • Doctor Oscillators | • Confirm Controller and Actual Valve Positions for One Steam Section Each Shift |
| • Rope Condition | • Hood and Basement Doors Closed. |
| • Rope Stretchers | |
| • Lube Oil System | |
| • Any Steam Leaks | |
| • Flow in Condensate Sightglasses | |
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Process historian data

Process historian data provides information on dryer section performance for a range of basis weights and operating conditions. It is valuable for assessing the operation of the dryer drainage system and identifying operating conditions that lead to excessive energy use or poor dryer performance. The suggested process historian data collection method is shown in Table 4. The process variables that should be monitored will depend on the configuration of the dryer drainage system and the field instrumentation available. The process historian data should be collected in a spreadsheet where the data can be filtered, plotted, and analyzed. The data should be filtered by the sheet break signal.

The differential pressure or blowthrough steam valves that discharge to the condenser, or atmosphere, are important in assessing energy efficiency. These valves should remain closed under all operating conditions. The system is wasting steam if these valves are open. If thermocompressors are used, they should be in control under within a 20% to 80% range for all operating conditions with the sheet on the dryers. The differential pressures should be maintained at proper levels over the entire pressure and speed range. TIP 0404-31 Recommended Dryer Differential Pressures should be used to determine if differential pressures are at proper levels.

Table 4. Process historian data collection method

Data Acquisition	
Time Stamp	Include
Format	Excel spreadsheet
Frequency	One hour
Duration	Three months
Data Values	Snapshot not averages
Production Data	
Grade Number or Name	
Basis Weight	Reel
	Before Size Press (if applicable)
	Before Coater (if applicable)
Reel Speed	
Sheet Width	Reel
Production Rate	Ton / hour
Moistures	Reel
	Before Size Press (if applicable)
	Before Coater (if applicable)
Sheet Break Status	Break / Run
Steam Supply	
Steam Flows	For all steam supply headers
Steam Header Pressure	For all steam supply headers
Steam Header Temperature	For all steam supply headers
For Each Dryer Pressure Group	
Pressure	Process value
Pressure Controller	Output
Make-up Valve	Position
Differential Pressure	Process value
Blowthrough Flow (if present)	Process value
Differential Pressure Controller	Output
Blowthrough Flow Controller (if present)	Output
Differential / Blowthrough Vent Valve	Position
Thermocompressor (if present)	Position
Vacuum Condenser (if present)	
Vacuum level	Process value
Water Valve To Heat Exchanger	Position
Cooling Water Outlet Temperature (if present)	Process value
Cooling Water Inlet Temperature (if present)	Process value
Hood & Pocket Ventilation	
Pocket Ventilation Temperature	Process value for each fan system.
Exhaust Fan Speed Or Damper Position (if controlled)	Process value for each fan system.
PV Fan Speed Or Damper Position (if controlled)	Process value for each fan system.
Hood Exhaust Humidity (if measured)	Process value for each humidity sensor.

Calculations can be built into the spreadsheet of the process historian data to assess dryer energy efficiency. The water evaporation can be calculated using the basis weight, speed, sheet width, and sheet moistures. It is necessary to input a value for the press moisture to complete this calculation. TIP 0404-07 “Paper Machine Drying Rate” describes the method for calculating the water evaporated. The steam consumption per pound of water evaporated can be calculated for each operating condition. The target steam consumption for the dryer cylinders is 1.2 to 1.4 kg of steam / kg of water evaporated and 0.15 to 0.18 kg of steam / kg of water evaporated for the hood supply and pocket ventilation systems; less if heat recovery is present.

If a vacuum condenser is present, monitoring the vacuum level and water valve position can provide insight into condenser operation and energy consumption. The water valve should be at a low percent open (10% to 25% typical) during normal operation. A water valve that operates at a higher opening would indicate a potential problem. Energy loss, a dirty heat exchanger, air leakage, or an improper control setpoint are the possible causes. The vacuum level should be maintained at the control setpoint for all operating conditions. An operation condition where the vacuum setpoint cannot be maintained could indicate a high energy loss from the steam system.

The pressure control valves for each pressure control sections should be in a good control range of 20% to 80% open for all operating conditions. Valves that are fully open or closed would indicate poor control.

Performance measurement

In many ways, it is easier to measure and troubleshoot dryer section performance than other portions of the paper machine. Measurements and good performance indicators are well defined and can be obtained by mill or corporate personnel, equipment suppliers, and fabric suppliers.

Dryer section performance indicators and second quartile performance levels for fine paper, linerboard, corrugating medium, and bleached board grades are shown in Table 5, for reference as benchmark indicators.

Moisture content

An accurate indication of entering and exiting moisture content is critical to dryer section analysis since the primary function of the dryer section is to evaporate water from the sheet. A history of press moisture levels is critical for optimizing both the press and the dryer sections. Press moisture samples should be taken as the machine goes down for each maintenance outage. TAPPI TIP 0404-01 “Determination of water removal by wet presses” provides a procedure to determine water removal. As many cross-machine samples as is convenient should be taken to provide profile information. Note that a 1% error in press moisture yields a 4%–5% error in estimating drying load. Sampling errors, rewetting of the sheet in getting samples, or edge effects can cause grab samples to be inaccurate.

Recent advances in measuring devices have allowed use of gamma or near-infrared gauge to measure moisture levels out of the presses and, in some cases, throughout the dryer section. Care should be taken in the interpretation of results, as some error may be inherent in the measurements, particularly on lightweight grades. It may not be possible to take these measurements in all sections due to limited access. However, on multi-ply grades there is the danger of not penetrating well through the measured top layer into the middle plies.

Dryer section water balances can also be used to calculate sheet moisture out of the press section.

A uniform reel moisture profile is critical for uniform sheet properties. The moisture target depends on end-use requirements, but in all cases uniformity is needed. Moisture profile problems can result in operational and quality problems including reel building, “soft” rolls, “corrugated” rolls, calender blackening, converting difficulties, and rejected paper. Many machines over-dry the sheet to compensate for moisture profile problems. This practice results in higher steam consumption and reduced production. TAPPI TIP 0404-57 “Troubleshooting cross-machine direction moisture profile problems” discusses CD profiles in more detail.

Table 5A. Dryer section second quartile performance levels (SI units)

<i>Index</i>	<i>Units</i>	<i>Fine Paper Main</i>	<i>Fine Paper After</i>	<i>Liner-board</i>	<i>Corrugating Medium</i>	<i>Bleach Board</i>
Moisture in	%	60	38	58	58	60
Exiting Moisture CD Range	% range @ % avg	0.2 @ 2.0	1.0 @ 5.0	2.0 @ 7.0	2.0 @ 7.0	1.0 @ 5.0
TAPPI Drying Rate	kg water/hr/m ² @ kPa	27 @ 515	32 @ 450	28 @ 965	24 @ 965	25 @ 825
Steam-to-Surface Temp. Difference	°C	22–28	19–25	22–28	22–28	19–25
CD Temperature	°C	2.8	2.8	2.8	2.8	2.85
Condensing Load	kg cond/hr/m ²	29	17	36	32	32
Dryers in Prime Zone	% of total	75	80	75	75	70
Average Pocket Humidity	kg water/kg dry air	0.20	0.20	0.20	0.20	0.20
CD Humidity Range	kg water/kg dry air	0.05	0.05	0.05	0.05	0.05
Peak Pocket Humidity	kg water/kg dry air	0.25	0.25	0.30	0.30	0.30
Average Hood Exhaust Humidity	kg water/kg dry air	0.13	0.10	0.13	0.13	0.13
Peak Exhaust Humidity	kg water/kg dry air	0.14	0.11	0.14	0.14	0.14
Hood Balance	% supply to exhaust air	70	60	70	70	70
PV Temperature	°C	82	82	93	93	93
Fabric Tension	kN/m	1.75	1.75	2.1	2.1	2.1
Energy Consumption	kg steam/kg water	1.3	1.0	1.3	1.3	1.3

Streaky CD moisture profiles most often originate at the wet-end of the machine and are caused by and coupled to bone-dry weight variations and/or poor press felt condition. Typically, gentle “frown” or “smile” profiles originate in the dryer section or in the press section from misadjustments in press roll crowns.

Proper press crowns, close-clearance syphons, full-width dryer bars, positive pocket ventilation, and uniform fabric tensions help to ensure uniform profiles through the dryer section. Steam showers, remoisturizing showers, and profiling infrared dryers can be used to correct non-uniform moisture profiles, although sheets using these corrections are more likely to have non-uniform sheet properties than sheets that have uniform profiles throughout the process. Profiling infrared dryers are expensive to operate and are primarily used when non-contact drying is required such as for early coating drying. Infrared is sometimes used for incremental drying, but it is generally not recommended

Table 5B. Dryer section second quartile performance levels (customary units)

<i>Index</i>	<i>Units</i>	<i>Fine Paper Main</i>	<i>Fine Paper After</i>	<i>Liner- board</i>	<i>Corru- gating Medium</i>	<i>Bleach Board</i>
Moisture in	%	60	38	58	58	60
Exiting Moisture CD Range	% range @ % avg	0.2 @ 2.0	1.0 @ 5.0	2.0 @ 7.0	2.0 @ 7.0	1.0 @ 5.0
TAPPI Drying Rate	lb water/hr/ft ² @ psig	5.5 @ 75	6.5 @ 65	5.7 @ 140	5.0 @ 140	5.2 @ 120
Steam-to- Surface Temp.Differenc e	deg F	40-50	35-45	40-50	40-50	35-45
CD Temperature Range	deg F	5	5	5	5	5
Condensing Load	lb cond/hr/ft ²	6.0	3.5	7.4	6.5	6.5
Dryers in Prime Zone	% of total	75	80	75	75	70
Average Pocket Humidity	lb water/lb dry air	0.20	0.20	0.20	0.20	0.20
CD Humidity Range	lb water/lb dry air	0.05	0.05	0.05	0.05	0.05
Peak Pocket Humidity	lb water/lb dry air	0.25	0.25	0.30	0.30	0.30
Average Hood Exhaust Humidity	grains/lb dry air	900	700	900	900	900
Peak Exhaust Humidity	grains/lb dry air	1,000	800	1,000	1,000	1,000
Hood Balance	% supply to exhaust air	70	60	70	70	70
PV Temperature	deg F	180	180	200	200	200
Fabric Tension	Pli	10	10	12	12	12
Energy Consumption	lb steam/lb water	1.3	1.0	1.3	1.3	1.3

Controlling moisture content into the size press is critical for uniform starch pickup and main section drying capacity. Wetter areas of the sheet tend to pick up more starch, so it is important to have a uniform profile. Over-drying the sheet to below 2% average moisture significantly decreases main section drying capacity since a disproportionately large number of dryers are required to remove the last portion of water from the sheet. It can be difficult to measure moisture contents below 2% accurately. In cases of suspected loss of main section drying capacity, every attempt should be made to verify that moisture level is accurate. Significant capacity loss can occur in the case of severe overdrying and inaccurate moisture indication. While this is a difficult application for moisture gauges, sheet temperature has been used successfully to control over-drying.

Moisture content of the sheet exiting the size press is a function of the sheet moisture and temperature entering the size press, as well as starch solids, viscosity, and pickup. Increasing starch solids (for a given amount of starch solids pick-up) reduces the amount of water to be evaporated after the size press. Metering-type size presses typically have much less water to evaporate and have higher drying rates than puddle size presses (for equal solids and pick-up). Note that typically, due to lower solids, a puddle-type size press leaves more water in the sheet, thus