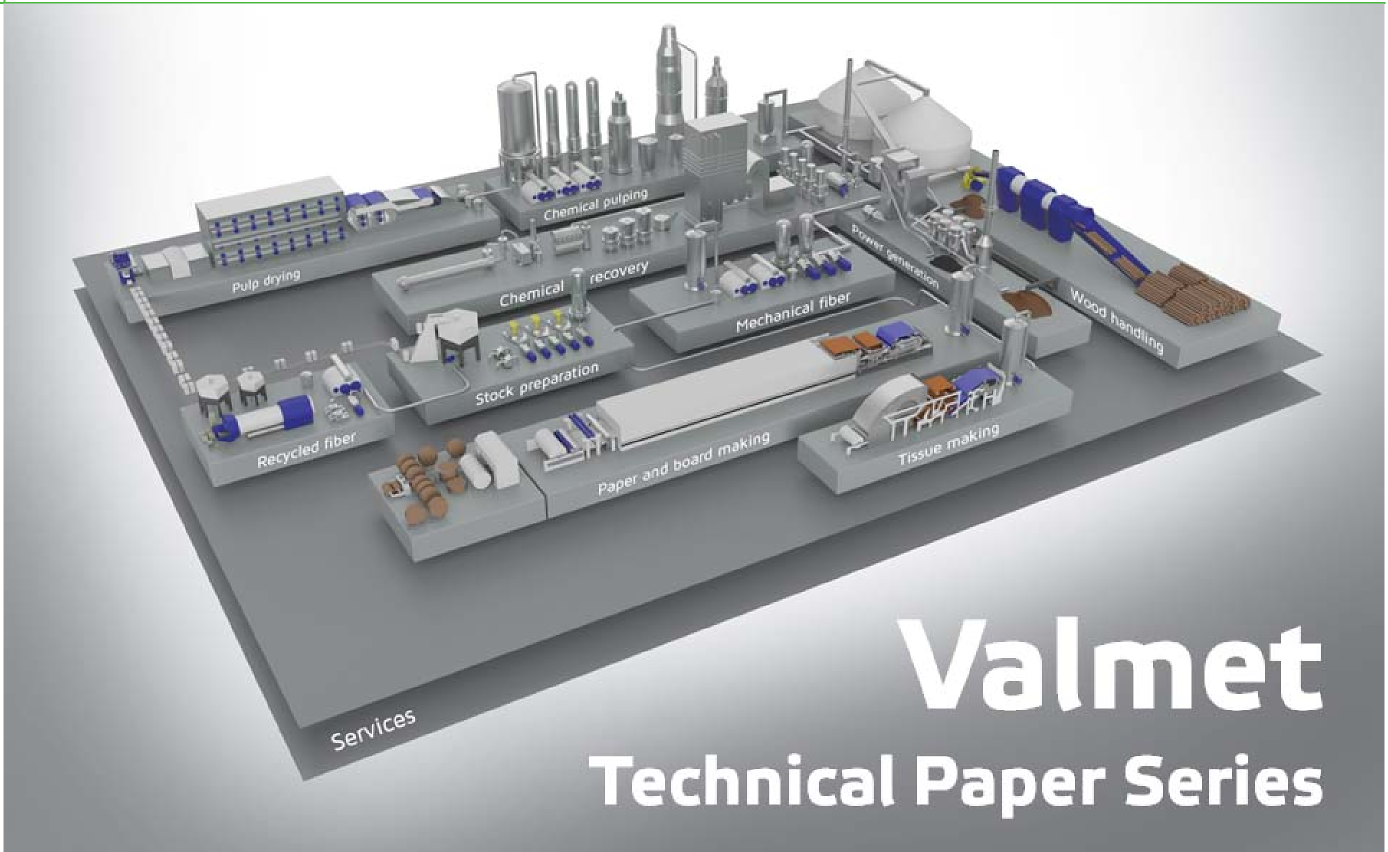

Process Engineering – Valmet As Your Drying Partner

Executive Summary

Valmet has acquired substantial benchmarking data on energy and machine efficiency in the drying process from decades of studies and analysis work. Stable runnability is a combination of many factors that operate smoothly together. Maintaining even stability and keeping the process at an optimum level require regular analyses and the right actions.

These Air system support services are more than just analytical studies of existing systems. Efficiency audits and runnability studies pinpoint immediate corrective action items and clear suggestions for future energy management and cost savings projects. Among other areas, these studies can review your production and maintenance procedures, process parameters as well as runnability and quality issues.

This white paper will review the family of studies in the area of process engineering and customer service available from Valmet. The concept of using Valmet as a "drying partner" will be discussed. Finally, an excerpt from a comprehensive drying systems study report will be presented in order for the reader to appreciate the level of detail, analysis and actionable recommendations that is standard in these reports.

Introduction

Valmet has acquired substantial benchmarking data on energy and machine efficiency in the drying process from decades of studies and analysis work. Stable runnability is a combination of many factors that operate smoothly together. Maintaining even stability and keeping the process at an optimum level require regular analyses and the right actions.

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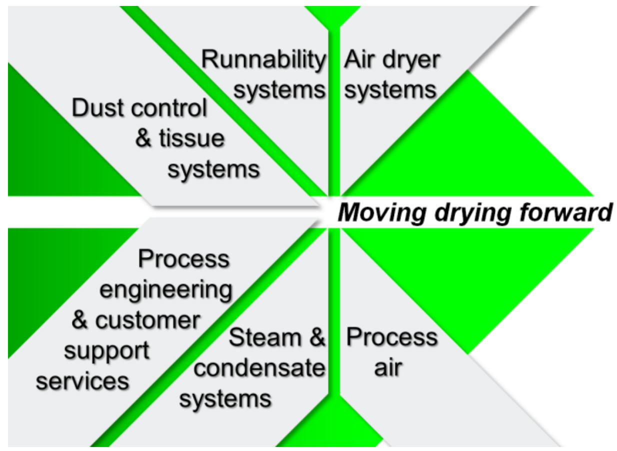

Figure 1. Valmet practices a total system approach combining all air systems disciplines into one comprehensive group.

The tiered approach to studies

Process engineering customer services include dryer performance studies, hood air systems studies, machine room ventilation studies, steam and condensate studies and dryer energy consumption studies.

For most studies Valmet offers two tiers of comprehensiveness - "The Snapshot" and "The Benchmark." However, for the dryer performance evaluation four tiers are available: "Snapshot", "Basics", "Benchmark" and "Comprehensive".

The difference between the tiers is the amount of onsite testing, report content and cost to the mill. The lowest tier study might be as affordable as a few thousand dollars, where a complete comprehensive – studying all aspects of the drying process – can run tens of thousands of dollars. You get what you pay for, as will be seen later in this paper when we review excerpts from an actual comprehensive report.

More than just studies…

For Valmet, air systems process engineering services comprises more than just studies and audits. Basically, any time a Valmet engineer visits your mill to service your equipment – it falls under the category of "process engineering services." This may be servicing vacuum rolls, dust collection systems, steam systems or runnability components, for example.

Two other process engineering services involve training and agreements. To achieve the best drying results with the lowest energy consumption prioritized operator actions and supporting systems are needed. Proper training helps the operators to run the machine with best practices.

Regular preventive maintenance is needed to keep the system efficiency high. It is important to find the right operational values to get the best out of your machine. Mill audits, regular visits by Valmet experts or a remote computer connection with consultation help you to maintain the best operational levels. Who better than the world leader in air systems design, development and installation to teach your operators and maintenance personnel how to attain and sustain the highest drying performance?

Similarly, Valmet is the obvious choice when contemplating taking your dryer performance to the next sustainable level, by choosing an annual dryer performance service agreement.

Valmet is your drying partner

A half century of Air Systems experience in the pulp and paper industry has made Valmet the leader in scope, technology and customer support. In co-operation with other Valmet divisions, the Air Systems group provides a complete line of products to optimize machine performance and reduce energy costs.

With over 550 Dryer Section Performance Evaluations, over 100 Machine Room Ventilation Audits, and hundreds of troubleshooting and service visits, Valmet Air Systems has an extensive background in onsite service. As your drying partner, Valmet can supply all your drying needs – whether upgrades, service, training or annual performance agreements.

Figure 2. Valmet air systems experts have performed hundreds of onsite studies worldwide, and accumulated a global benchmark database.

In paper and board making, resources such as raw materials, water and energy will have to be used in a more efficient way than today. The good news is that there is a lot of potential for saving energy. Machine air systems provide excellent opportunities for reducing costs and increasing profitability. However, these opportunities need to be investigated – simply because the systems are running, i.e. making paper, they are not necessarily running efficiently. You have to look for the opportunities… and for this you need a partner.

Valmet has the personnel with the expertise needed, and is ready to partner with you to improve and sustain your drying processes. Typically this would start with an audit to compare your air systems with worldwide benchmarks, and then apply the best operational parameters with the present equipment while building a foundation for future air systems savings projects.

Drying process reports and audits

An air systems check-up and performance study employs a set of specialized diagnostic tools to identify, both from a mechanical and process perspective, and promptly report any critical drying and ventilation system problems. System settings and performance are analyzed in relation to original startup parameter settings for the hood, steam coils, fans, blow boxes, heat exchangers, etc.

Immediate same-day flash reports which focus specifically on critical equipment/situations both from a mechanical and process perspective, help papermakers to carry out preventive maintenance, setup and readjust equipment appropriately, and get more uptime out of their paper machines. Over the intermediate to longer term the reports will help train their operators, apply an analytical approach to maintenance, and utilize basic statistical maintenance tools.

A typical air systems report will include an itemized list of actionable recommendations to review and take to mill or corporate management for funding, or proceed with smaller high value actions from a maintenance budget. To keep the process running at an optimal performance level, appropriate maintenance and repairs will be recommended to achieve the best performance with the existing equipment. Rebuilds and upgrades will be specified in order to update the drying process to supply current market demands. And where applicable, new drying technologies will be proposed to take performance and efficiency to the next level, providing significant improvements with viable payback times.

Example of mechanical and functional air systems checkup

The production/maintenance manager of an Italian paper mill (**Figure 3**) had partially solved his moisture profile problems (**Figure 4**) by increasing sheet dryness at the reel, thereby also increasing energy consumption and compromising final product quality.

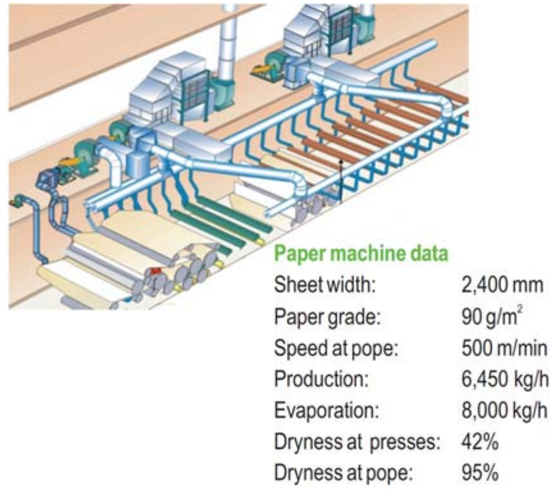

Figure 3. Paper machine operations data for case example.

The manager consequently asked Valmet to carry out a mechanical and functional air systems check-up, which revealed that:

- a partially broken steam coil (flash) discharged into the pocket ventilation air system
- a blocked regulation damper caused unbalanced air flows
- the level of exhaust air flow was too high, and
- a broken heat exchanger caused exhaust air to be discharged into the incoming flow of fresh air, thus increasing its moisture content.

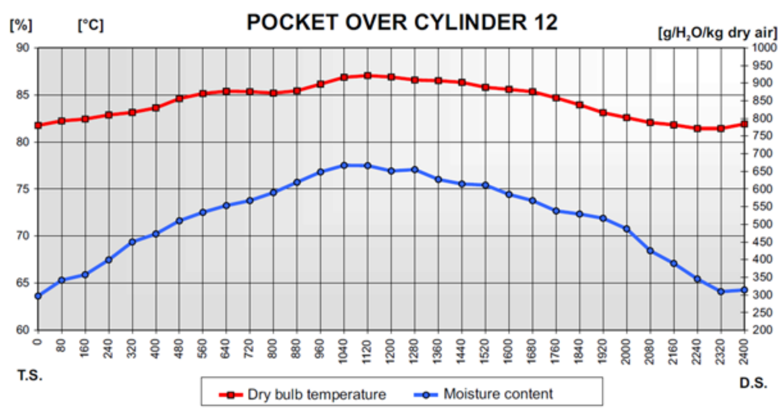

Figure 4. Poor moisture CD profile in the example case

As a result of this checkup undertaken by Valmet experts, problems were identified and solved. Corrective measures were discussed and agreed with the customer and addressed in the analysis report. The following immediate actions were taken:

- steam flow was shut off between the first and second coil and to the condenser, and more fresh steam was consequently used (temporarily)
- the regulation damper was repaired, which increased ventilation air flows
- aerothermal equilibrium was reached
- the heat exchanger was repaired (temporarily)

The following recommended actions were highlighted for the customer:

- replacement of the flash coil
- replacement of the existing heat exchanger with a more efficient one
- introduction of a stabilizer to improve runnability
- partial replacement of the pocket ventilation system to improve the ventilation in the zone with a higher evaporation rate
- installation of exhaust air moisture and flow controls to ensure a proper aerothermal and energy balance

Case summary

The immediate benefits from the checkup and study were that the paper moisture profile was corrected, which increased production by 2.3%, or roughly EUR 819,000 in monetary terms. Additionally controls were balanced, leading to total (thermal + electric) annual energy savings of about EUR 24,000 (although steam consumption increased).

In the short-term, the heat exchanger and steam coil replacement produced EUR 83,000 per year of further savings (with an investment of EUR 65,000).

Benefits achieved in the longer term included adjustments which led to 30% fewer paper breaks, a 1.3% production increase, and an optimized energy and aerothermal balance, saving an estimated EUR 218,000 per year.

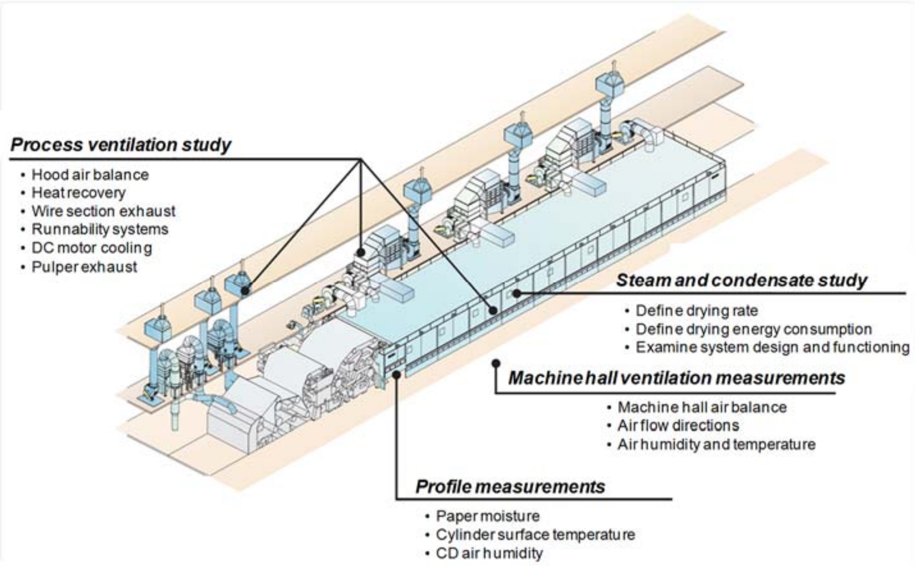

Figure 5. Examples of some of the available air systems studies and measurements

Customizability of the tiered study approach

Field survey techniques make it possible to measure and collect data from all major factors influencing drying, and then to analyze the data by the aid of the dryer section and heat recovery simulation programs developed. They make it possible to analyze the present operation of the dryer section and ventilation, and to calculate beforehand any effects which various changes may bring about.

There is a wide selection of studies; some of which are shown in **Figure 5**. Each field survey will include measurements of the air systems and systems closely connected to it (**Figure 6**), such as the dryer section and its steam and condensate system.

In some cases, multiple study elements may be appropriate, in order to achieve specific results. With the tiered approach to air systems studies, elements from different studies may be combined, producing a mill-specific custom study that suits the budget and goal being sought.

For example, in examining the performance of the dryer section, the drying capacity is often the most interesting matter. The best way to evaluate the machine drying capacity or to identify deficiencies or, on the other hand, to calculate the potential capacity if all parts of the drying process are in order, is to perform a Drying Section Simulation and a Steam and Condensate System Study.

Figure 6. Highly trained experts will collect data onsite before producing their analytical report. In this case dryer surface point measurement is occurring.

In this example, the analysis is based on information from the dryer section simulation model. The parameters of the simulation models are determined on the basis of data measured from the machine. This ensures that the simulation results obtained from the model correspond to actual conditions. The onsite Valmet expert would check steam and condensate system design and performance, paper temperature after each dryer, dryer surface temperature as point measurement and pocket air humidity as point measurements. The report generated as a result of partnering with Valmet for a drying evaluation would provide opportunities to improve the drying capacity and would determine the optimum and most energy efficient way to run the dryer section steam and condensate system.

Comparison of tiers

Let's say you have a typical machine with 40 to 50 dryers, and you're looking at the most popular study – the Dryer Performance Evaluation. This particular study is available in four tiers. Let's compare the least expensive to the most comprehensive version of this study, i.e. the Snapshot and the Comprehensive tiers.

In the Snapshot (Tier I) study, one Valmet technical specialist will be onsite for three days while the mill provides testing assistance. A field report of test data is issued at the conclusion of the week. The report would consist of basic conclusions and recommendations, with charts and test results included in the appendix. This would be approximately four to six pages in length plus appendix. The field data measured includes:

- Typical DCS info to complete drying rate
- Single point surface temp, pocket humidity, sheet temp and blow box underpressures
- Basic air systems measurements (volume and temps only) and equipment condition
- Steam and condensate system verification and condition

Now let's compare this to the Comprehensive (Tier IV) study. In this case two Valmet technical specialists work onsite for three days, and an engineer takes three weeks in the office for analysis and to generate the report which will include one or more future drying predictions. The report, typically about 45 pages plus appendix, also includes:

- Conclusions and recommendations
- Summary of recommended projects, benefits and approximate cost
- Full written explanation of each system layout
- Full written explanation of test results and observations
- All tables and charts embedded into report
- Explanation of cross direction point measurement variations
- S&C and air system schematics
- Full written future S&C and air system requirement section
- Appendix information.

Naturally, the field measurements for the Comprehensive study are correspondingly more detailed, including:

- Typical DCS info to complete drying rate.
- Two or three point surface temp, pocket humidity
- TS & DS blow box measurements.
- Single point sheet temperature measurement.
- Air systems measurements and equipment condition.
- Air systems layout, duct splits, component locations and dryer configuration for air system schematic.
- Hood construction and condition.

- Hood zero level.
- Steam and condensate system verification and condition.
- Verify valve positions from DCS information.
- Sight glass flow characteristics.
- Separator rate of rise tests.
- Notes on wet end ventilation effectiveness.

Bear in mind that as your drying partner, Valmet will 1) only undertake the measurements that are needed for the goals you have set for the study, and 2) combine different study areas to customize the analysis process to most effectively achieve your targets for the study.

Now, let's use the remainder of this white paper to present some excerpts of an actual Comprehensive study, which should allow you to make your own decision regarding Valmet's air systems competency, level of professionalism and value provided…

Excerpts from sample Comprehensive report

The following content is pulled from an actual Comprehensive Dryer Performance Evaluation and includes real data, analysis and recommendations that are representative of what you can expect to receive when requesting the top tier of air systems study. The report begins with a summary, conclusions and recommendations, followed by an introduction and detailed analysis of each section reviewed, followed by an appendix.

The actual report in this case was 84 pages long, including the appendix, and included detailed analysis of the dryer performance, steam and condensate system and hood air systems. In the interest of space, we will only present some of the conclusions / recommendations, introduction, and the detailed analysis of dryer performance.

1. Introduction

No. "X" Paper Machine is a 1956 vintage Beloit machine, which produces fine paper. The most common grade produced is 50 lb, which is typically run at 2,600 ft/min. The top speed of this machine is 3,000 ft/min. There was a rebuild in 1982 that included a new headbox and a top wire former.

Major Grades Produced				
Basis Weight (lb/3300ft^2)	40	50	60	70
Percent Run	15	65	15	5
Average Speed (fpm)	2600	2600	2550	2550

Table 1-1a. Major grades produced

Component	Type	Manufacturer
Headbox	Step Diffuser	Escher Wyss
Former	Twin Former H Top Wire	Escher Wyss
Press Section	Straight-Through Tri Nip	Beloit

Table 1-1b. Wet end components

The dryer section has a total of forty-seven (47) five-foot diameter dryers, thirty-nine in the main and eight in the after-sizer dryer section. A 75 psig header supplies steam to the dryer section. The dryers are rated at 75 psig. The main section steam and condensate system is a cascade type and the after section is set-up as thermocompressor loops, but the thermocompressors are shutdown. Both dryer sections have Ross insulated closed hoods. The main section has three exhaust systems and two pocket ventilation supply systems. The after section has one exhaust system and one pocket ventilation supply unit. **Tables 1-1 a-e** list the grades produced by and main components of Paper Machine "X".

Section	Dryers	Fabric	Permeability (cfm/ft^2)
1	1-7	UnoRun	Not provided
2	8-19	Top/Bottom	Not provided
3	20-39	Top/Bottom	Not provided
4	40-47	Top/Bottom	Not provided

Table 1-1d. Drive Sections

	1st	2nd	3rd
Press Load (pli)	200	425	450

Table 1-1c. Press Loads

Group	Dryers	Type	Syphons	Dryer Bars
1	1 to 4	Individual Control	Rotary	None
2	5 to 14	Cascade	Stationary	6 & 8 to 14 None 5 & 7 Full
3	15 to 39	Cascade	Rotary	19 to 21, 28, 29 & 35 to 39 None 23 & 25 to 27 Front 22, 24 & 30 Middle 15, 16, 17, 31 & 32 Back 18, 33 & 34 Full
4	40 & 41	Individual Control	Rotary	None
5	42, 44 & 46	Thermocompressor	Rotary	None
6	43 & 45	Thermocompressor	Rotary	None

Table 1-1e. Steam Groups

2. Conclusions and Recommendations

Conclusions	Recommendations
1. PM "X" has an excellent drying rate for a machine with poor pocket ventilation and only some dryer bars, but there is still room for improvement.	• Install full width dryer bars in all active dryers. • Update the pocket ventilation to modern more effective systems.
2. The overall average steam to dryer surface temperature difference is 43.8ºF. An average difference of 35 to 40ºF is possible with dryer bars.	• Install full width dryer bars in all active dryers.
3. The difference between the sheet temperature leaving the press and the surface temperature of the first dryer is too high. We observed dust in the area indicating sheet picking was occurring.	• Sheet warm-up strategy needs to be revised. Use lower pressure in the first dryers. • Consider installing a steam box to increase the sheet temperature entering the dryer section or increase the stock temperature.
4. The average pocket humidity for all the double felted pockets is 0.38 lb water vapor per lb dry air. The average for the prime drying zone is 0.43 lb water vapor per lb dry air. For good performance humidities should be in the 0.20 to 0.25 range.	• Replace existing ineffective pocket ventilation with new Valmet Uniflow Pocket Ventilators complete with new supply systems.
5. The average main hood exhaust humidity for No. "X" Paper Machine is 1,223 grains water vapor/lb dry air, this is well beyond the recommended limit of 600 to 700 grains for the existing hood.	• Install a new main dryer section hood complete with front lifting panels and rear sliding doors. • Increase main dryer section exhaust flow, the airflow required will depend what is done with the hood.
6. The energy consumption on PM "X" is high.	• Increase in the temperature of the sheet leaving the press. • Utilize air to air heat recovery for pocket ventilation. • Disconnect the steam from the bottom UnoRun dryers.
7. Wet end runnability needs improvement, sheet instability was observed between the press to dryer transfer and at the 1st to 2nd drive transfer.	• Install Valmet PressRun, UnoRun and GroupTransfer Blow Boxes complete with the associated air systems and transfer roll modifications. • Separate the common rope run on the 1st and 2nd drive groups.
8. The existing steam and condensate system was operating fairly well but there are deficiencies and room for improvement. Because of inflexibility within the system, dryers are shutoff instead of reducing pressures.	• Valmet recommends installing stationary syphons and dryer bars in all the active dryers that are not yet equipped with them.

Conclusions (cont.)	Recommendations (cont.)
9. The wet end steam group needs to be reworked to improve sheet warm-up and reduce blowthrough.	• We recommend disconnecting all the bottom UnoRun dryers and reusing the hardware from dryers 2 and 4 for individual control on dryers 5 and 7. Dryers 5 and 7 would be removed from the intermediate group and added to the pre-dryer group.
10. The intermediate steam group straddles two different dryer sections with some UnoRun and some conventional double felted dryers. The current differential pressure is providing proper blowthrough to the top UnoRun dryers but is excessive for the double felted dryers.	• We recommend individual control for the top UnoRun dryers and separating them from the intermediate steam group. • In the meantime a differential pressure of 4 psi would better satisfy both conditions.
11. Individual condensate line sizing is nearing the upper limit for two-phase flow losses in the wet end and after section dryers and the losses are too high in the intermediate and the main group.	• Reducing differential pressure in the intermediate group will reduce blowthrough flow. • Install stationary syphons in the dryers not yet equipped with them. • If the rotary syphons remain in service we would recommend increasing the size of the individual condensate lines.
12. Most of the individual steam line sizing and steam group headers sizing is what we would consider marginal with the exception of the flash headers.	• The steam lines will benefit from the installation of stationary syphons with the reduced blowthrough flow requirements.
13. The after section thermocompressors were not in service during the time of the study. Installing the stationary syphons and operating all after section dryers would allow thermocompressors to operate.	• The motive steam needs to be changed from the 400 psi line to the 160 psi line and the thermocompressor sizing would need to be reviewed.
14. The condensate separators were all maintaining level during operation, however some of them are undersized for the condensing loads.	• The size of the No. 1 and No. 2 condensate separators should be increased.
15. The main hood is in very poor condition as a result of running it well beyond its humidity limit, the roof panels are sagging and the hood steel is corroding. There are holes in the hood and many of the rear sliding doors have been removed.	• Install a new main dryer section hood complete with front lifting panels and rear sliding doors.
16. The main hood air balance is 42%, which is low. The air measurements were made when the No. 2 P.V. system was not running. The estimated main hood balance with both P.V. systems operating would be in the 85 to 90% range, which is too high.	• Close the fresh air bleed-in on Hood Exhaust No. 3.

Conclusions (cont.)	Recommendations (cont.)
17. The zero level is low. A large amount of hot humid air escapes from the main hood and enters the machine room.	• We recommend a new hood complete with front lifting panels and rear sliding doors. • The basement enclosure needs to be repaired to provide a tighter seal. • Operators should get into the habit of keeping the basement enclosure doors closed.
18. The hood exhaust heat recovery towers are in poor condition and need to be replaced. There is potential to recover a peak of 43.1 x 106 BTU/hr or 1.88 x 1011 BTU/year. Assuming an energy cost of $7.00/million BTU the total savings per year would be $1.3 million.	• We recommend new three-stage heat recovery for the main hood including air to air, air to glycol and air to water.

2.1 Recommended Projects

Project	Benefit	Approximate Cost
• Install full width dryer bars in all active dryers.	• Improved heat transfer and drying rate. • Reduces energy costs. • Uniform surface temperature.	$2,750/Dryer
• Replace existing ineffective pocket ventilation with new Valmet Uniflow Pocket Ventilators complete with new air supply systems.	• Improve pocket humidities. • Increase drying by up to 3%.	$610,000
• Consider installing a steam box in the press section.	• Increased sheet temperature entering the dryer. • Improved pressing. • Profiling capability. • Decrease dryer section energy consumption.	$84,000 for steam box supply system Steam box not by Air Systems Group.
• Install a new main dryer section hood complete with front lifting panels and rear sliding doors.	• Less hood exhaust required than for the existing hood (120,000 to 160,000 cfm for a new hood vs. 280,000 cfm for the existing hood). • Improved machine room conditions. • Better heat recovery potential. • Less building make-up air required.	$780,000 to $900,000 Depending on construction type (medium humidity vs. high humidity).

Project (cont.)	Benefit (cont.)	Approximate Cost (cont.)
• Install Valmet Press Run Web Stabilizer, UnoRun and GroupTransfer Blow Boxes complete with air systems.	• Reduce press to dryer section draw. • Reduce sheet breaks and improve machine efficiency.	$600,000
• Separate the common rope run on the 1st and 2nd drive groups.	• Allows for draw between groups and improve sheet runnability.	Not by Air Systems Group.
• Install stationary syphons in all the active dryers that are not yet equipped with them.	• Improved steam system flexibility. • Reduce blowthrough flows and energy costs. • Eliminate need to install larger piping. • Keep all dryers active and increase carbon seal life.	$7,600/Dryer
• Disconnect steam from all the bottom UnoRun dryers and reuse the hardware from dryer 2 and 4 for individual control on dryers 5 and 7. Dryers 5 and 7 would be removed from the intermediate group and added to the pre-dryer group.	• Reduce blowthrough to the condenser. • Improve sheet warm-up strategy and prevent sheet picking. • Decrease energy cost by $56,000 based on a 350 operating day year and an assumed energy cost of $7.00 per 1,000 lb of steam.	$60,000 Engineering only, no equipment or piping included.
• Installing the stationary syphons and operating all after section dryers would allow thermocompressors to operate, however, the motive steam needs to be changed from the 400 psi line to the 160 psi line and the thermocompressor sizing would need to be reviewed.	• Reuse blowthrough steam instead of venting it to the condenser reduces energy costs.	$24,000 Engineering only, no equipment or piping included.
• The size of the No. 1 and No. 2 condensate separators should be increased.	• Prevents flooding in an upset condition.	NA More info needed.
• The basement enclosure needs to be repaired to provide a tighter seal.	• Improved zero level. • Reduce amount of humid air spilling into the machine room.	$600,000
• We recommend installing new heat recovery towers on the main hood exhaust including air to air, air to glycol and air to water.	• Potential to recover 1.88 x 1011 BTU/year, assuming an energy cost of $7.00/million BTU the total savings per year would be $1.3 million.	$1,450,000 Does not include machine piping.

2.2 Recommended Maintenance Projects

Project	Benefit	Approximate Cost
• Close the fresh air bleed-in on Hood Exhaust No. 3.	• Increases exhaust flow from the main hood. • Reduces humidity level in the main hood.	N/A
• Operators should get into the habit of keeping the basement enclosure doors closed.	• Improves hood zero level. • Reduces amount of water vapor spilled from the hood into the machine room.	N/A

Notes regarding approximate costs:
- Costs are rough estimates only for equipment supplied by Valmet.
- Costs do not include electrical equipment, roll relocation, civil work or asbestos removal.
- Costs do not include field installation labor or demolition.

3. Dryer Performance

Dryer performance is evaluated by calculating dryer performance indicators and comparing them to good performance values (**Table 3-1**). Valmet has developed these good performance values from testing several other similar paper machines. Good performance values are compared to the measured values to identify potential areas for improvement.

Table 3-1 shows the measured values as compared to good performance values. The indicators are calculated for the production of 55 lb/3,300 ft^2.

Indicator	Measured Value	Good Performance Value
Effective drying rate (lb H_2O/hr/ft^2)	6.61 at 40.8 psig	5.03 at 40.8 psig
Average steam to dryer temperature difference (°F)	43.8	45 to 50
Average surface temperature CD variation (°F)	2.0	5.0
Number of cold or out of service dryers	8	0
Average pocket humidity (lb H_2O/lb d.a.)	0.38	0.20 to 0.25
Peak pocket humidity (lb H_2O/lb d.a.)	0.98	0.30
Pocket humidity CD variation (lb H_2O/lb d.a.)	0.05	0.05
Average main hood exhaust humidity (grains H_2O/lb d.a.)	1223	600 to 700
Peak main hood exhaust humidity (grains H_2O/lb d.a.)	1254	750
After hood exhaust humidity (grains H_2O/lb d.a.)	302	600 to 700
Main hood air balance (% supply to exhaust)	42	60 to 70
After hood air balance (% supply to exhaust)	0	60 to 70
Dryer energy consumption (BTU/lb H_2O evap.)	1251	1200

Table 3-1. Dryer Performance Indicators

3.1 Drying Rate

Drying rate is defined as the amount of water evaporated per hour per square foot of dryer surface. It indicates how efficiently the dryer surface area is used to evaporate water from the sheet.

A high drying rate in itself does not necessarily indicate good performance. Steam pressure, which determines steam temperature, is also important when assessing dryer performance. A given drying rate requires a certain level of steam pressure. Best performance is obtained by maintaining the highest possible drying rate with the lowest possible steam pressure or temperature. Therefore, machines with drying rates plotted toward the upper left area of the drying rate chart in **Figure 3-1** are the best performing machines.

To calculate drying rate, Valmet uses the number of effective dryers, rather than total dryers. Calculating the number of effective dryers accounts for the efficiency of top and bottom UnoRun dryers, and dryers that are cold (i.e. flooded) or out of service.

Knowing the total number of effective dryers provides a better indication of present dryer performance. It allows better comparisons to other machines and more accurate estimates of future operating conditions.

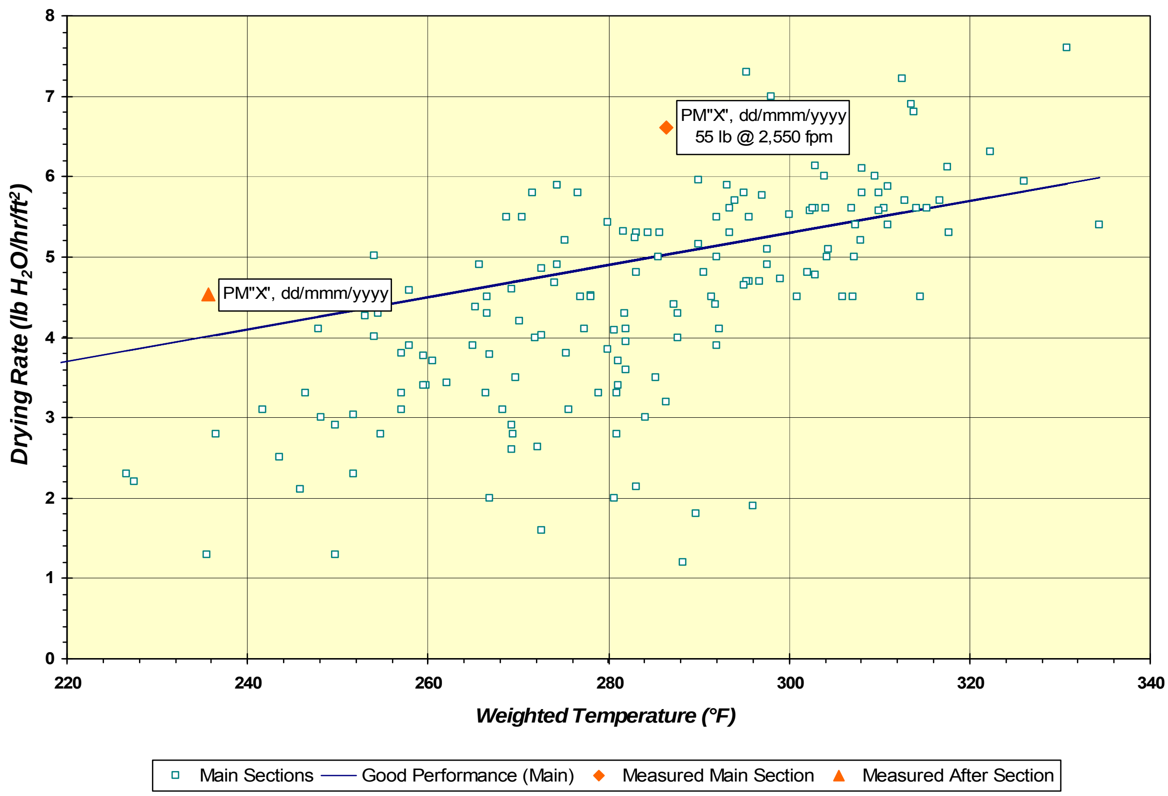

Figure 3-1. Drying Rate – Wood Free Fine

Figure 3-1 shows the calculated effective drying rate for 55 lb/3,300 ft^2. The chart includes the drying rates of other similar machines that were measured by Valmet. Complete drying rate calculations are included in the Appendix. The good performance line is based on paper machines with efficient dryer drainage, effective pocket ventilation and full width dryer bars. Paper machines without dryer bars will typically have drying rates somewhat below this line.

The drying rate on PM "X" is excellent for a machine with poor pocket ventilation and only some dryer bars. There are some contributing factors to the good drying rate. The product has some recycle content, which is easier to dry. Having dryers shut off allows the sheet to cool a bit more before the next dryer, this dryer will then work a little harder adding to the improved drying rate. Paper Machine "X" had five dryers in the main steam shut off during our study. Improvements to the pocket ventilation and the addition of dryer bars will help improve the drying rate further.

The accuracy of drying rate calculations depends on input data. We collected data from the scanners before the size press and the reel and the indicators on the DCS. For the press moisture, we used 59.2%, based on information provided to us by mill personnel. It is important to get a reliable press moisture value for calculating drying rate. A change of one percent moisture out of the press section affects the evaporation load in the dryer section by about four percent.

3.2 Dryer Surface Temperatures

Measuring dryer surface temperatures is a reliable method of determining heat transfer efficiency. The difference between the dryer surface and saturated steam temperature can indicate how effectively condensate drains from the dryers. A dryer that is not draining properly will have a thick condensate layer inside, which inhibits heat transfer and produces a high steam to surface temperature difference.

There are other factors to consider when assessing heat transfer and dryer drainage. Low temperature differences can also indicate poor contact with the sheet and show which dryers are in the falling rate zone, as condensing loads decrease toward the dry end.

Surface temperatures were measured with a proprietary surface temperature device. Readings with this sensor are not affected by changes in dryer surface emissivity (due to rust, scale, or other imperfections) which can happen with infrared temperature measurement technology.

Point readings were taken at the edge and 5 ft in from the tending side edge of the paper. Measurements were omitted at dryers 30, 32, 34, 36 and 38 in the main section and dryer 44 in the after section because they were shut off. Dryers 28, 42 and 43 were also shut off during the time of the study. **Figure 3-2** shows the surface temperature measurements and saturated steam temperatures from the pressures used during our study. The complete set of measurements is in the Appendix.

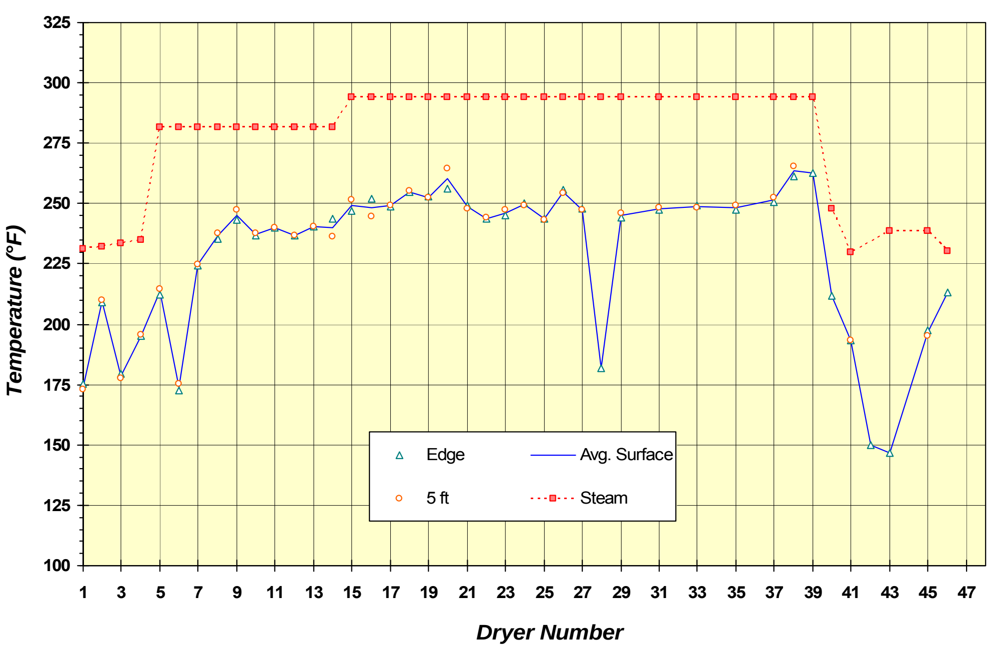

Figure 3-2. Dryer Surface Temperatures (55 lb, 2550 fpm)

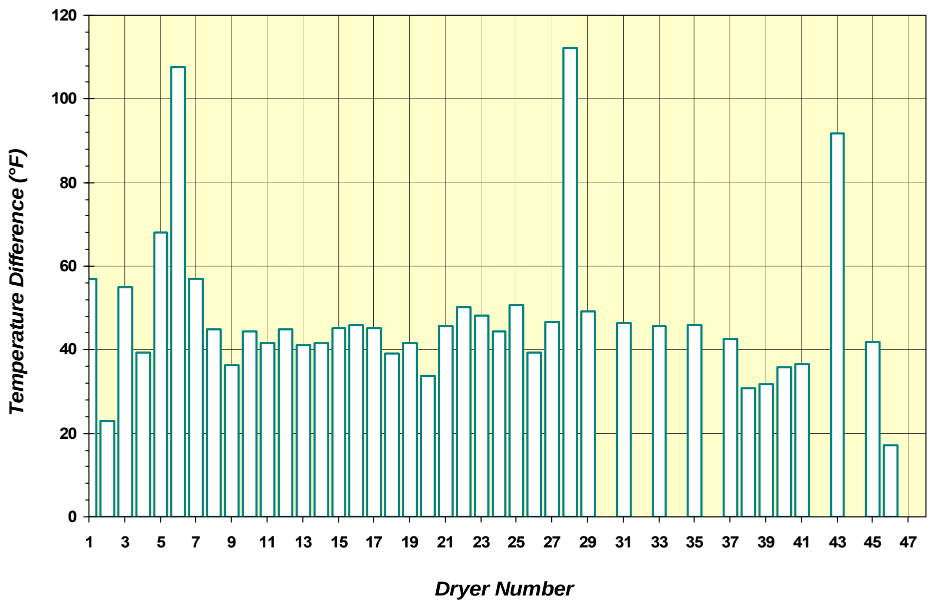

Figure 3-3. Steam to Dryer Surface Temperature Difference (55 lb, 2550 fpm)

The temperatures show a zigzag pattern in the first four wet end dryers. The bottom dryers do not come into contact with the web, therefore, the condensing loads are low in the bottom dryers and the surface temperatures are higher. Dryer 6, a bottom UnoRun dryer, does not follow this pattern. This dryer may be shut off or have an orifice plate in the condensate line, but that could not be confirmed. The rest of the dryers have fairly consistent temperatures. Surface temperatures start to rise after dryer 37; these dryers are in the falling rate zone where the condensing load reduces as the sheet gets dryer.

Steam Group	Dryers	Average ΔT
1 (Pre-dryer)	1 & 3	56.0
2 (Intermediate)	5 to 14	46.7
3 (Main)	15 to 39	43.5
4	40 & 41	36.0
5 (Bottom)	46 (42 & 44 Off)	17.0
6 (Top)	45 (43 & 47 Off)	42.0

Table 3-2. Average Temperature Difference (°F)

To evaluate heat transfer, we look at the differences between measured surface temperatures and saturated steam temperatures. The bar chart in **Figure 3-3** shows the temperature difference for each dryer. **Table 3-2** shows the average steam to dryer surface temperature difference in each steam group. Dryers that are off and bottom UnoRun dryers are not included in the table. The bottom UnoRun dryers have very low condensing loads and do not have as great an impact on drying the sheet.

For Paper Machine "X" we would expect an average temperature difference of 45 to 50°F for good heat transfer. The overall average temperature difference measured during the time of testing was 43.8°F. The average is slightly better because there are bars in some dryers and expected average is based on a machine with no bars. For a machine with full bars in all dryers temperature differences would be in the 35 to 40°F range. The average on this machine indicates the dryers are draining properly and explains the good drying rate.

Valmet recommends full width dryer bars in all active dryers. They generate turbulence in the condensate layer across the entire shell. This improves heat transfer to the sheet and provides a more uniform surface temperature. Dryers also require adequate drainage to minimize condensate layer thickness and ensure uniform heat transfer. In addition, turbulence created by dryer bars increase drying capacity. Steam pressures are reduced for the same production rate.

3.2.1 Surface Temperature Variation

Table 3-3 shows the average surface temperatures measured at each position on the dryers in each steam group. A good cross-machine surface temperature variation would be 5°F or less.

Steam Group	Dryers	Edge	5 ft
1 (Pre-dryer)	1 & 3	177.0	175.5
2 (Intermediate)	5 to 14	235.0	235.1
3 (Main)	15 to 39	250.5	250.5
4	40 & 41	202.5	NA
5 (Bottom)	46 (42 & 44 Off)	213.0	NA
6 (Top)	45 (43 & 47 Off)	198.0	195.0

Table 3-3. Average Surface Temperatures (°F)

The average temperature variation is 2.0°F which is good. There is no consistent pattern in the temperature variation, at some dryers the edge reading is hotter and at others it is cooler and other dryers have fairly even temperatures. This is to be expected with the random full width and partial dryer bars in the intermediate and main steam groups.

3.3 Sheet Temperature

Measuring sheet temperature is useful in determining where evaporation occurs and whether there is sufficient heat transfer from the dryer to the sheet. Sheet temperature provides the driving force for evaporation. The vapor pressure of water in the sheet is directly related to sheet temperature. The difference between the vapor pressure of water in the sheet and the partial vapor pressure of water in the surrounding air defines the amount of evaporation.

Sheet temperatures were taken with an infrared sensor after the last press and after each dryer cylinder. Infrared technology is useful in this application because the emissivity of paper is constant and well established. The sheet temperatures are plotted on **Figure 3-4**.

The difference between the sheet temperature leaving the press (109°F) and the surface temperature of the first dryer (174°F) is 65°F, this is too high. Typically the difference should be no more than 30°F. We observed dust is the area indicating sheet picking was occurring. Sheet warm-up strategy needs to be revised. Sheet temperature through the UnoRun drive groups shows up as a zigzag pattern. The top dryers heat the sheet and the bottom UnoRun dryers allow it to cool down. From dryers 1 to 9 the sheet goes through the warm-up zone. This is where it is heated up to evaporation temperature.

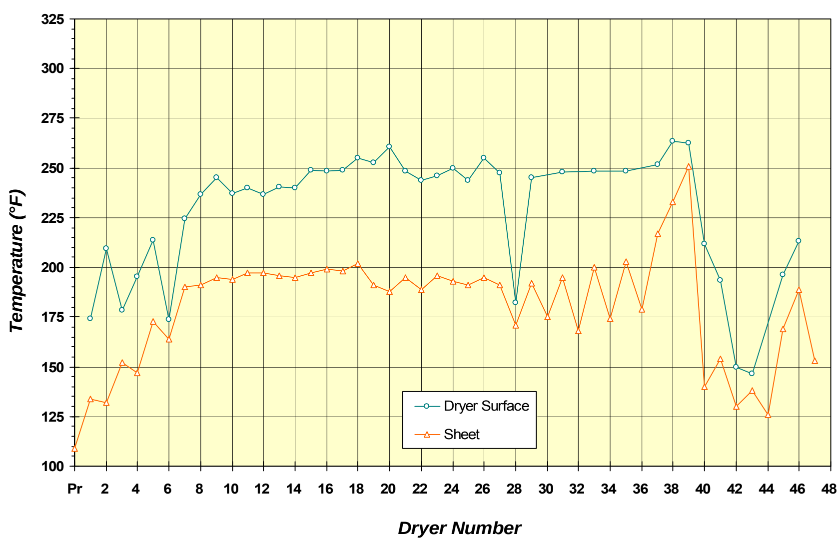

Figure 3-4. Sheet Temperature (55 lb, 2550 fpm)

Through the intermediate and main steam groups the sheet temperature is fairly constant at around 180 to 200°F. This is the prime or constant drying rate zone where the evaporation rate is at its peak. Again, we see a zigzag pattern starting at dryer 28. The bottom dryers 28 to 36 were shut off at the time the measurements were taken. Sheet temperatures rise continuously after dryer 33. This is the falling rate zone where the sheet moisture content is low and the evaporation rate decreases after each dryer.

3.4 Pocket Humidities

Evaporation efficiency is determined by measuring pocket humidities. To obtain optimum drying capacity, pocket humidities should be low and uniform. For a machine producing fine paper at 2,600 ft/min an average pocket humidity of 0.20 to 0.25 lb water vapor per lb dry air would be considered good.

Point readings were taken at the edge and 5 ft in from the tending side edge of the paper. Only single point readings were taken under the top UnoRun dryers and at the drive section splits because no pockets are formed in these locations. **Figure 3-5** shows the measurement results. **Table 3-4** shows the average pocket humidity for each drive section. The complete set of measurements is in the Appendix.

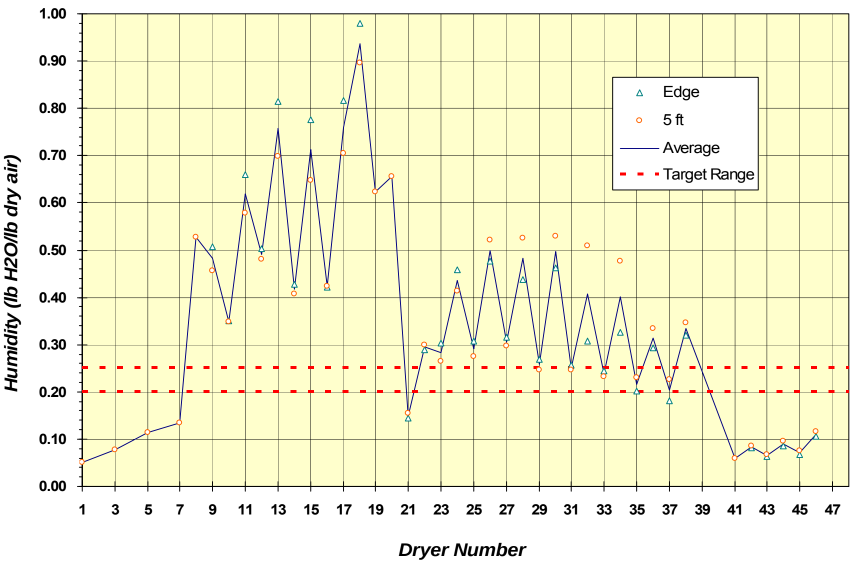

Figure 3-5. Pocket Humidities

Measurements were taken during the production of a 55 lb sheet with both the No. 1 and No. 2 pocket ventilation systems running. The No. 3 pocket ventilation system was not running and operators told us that it is never run. The overall average humidity for the double felted pocket locations is 0.38 lb water vapor per lb dry air.

The humidities in the 2nd drive group are very high and there is a prominent zigzag pattern with the bottom pockets having higher humidities than the top. In the 3rd drive group the humidities are too high as well and the zigzag pattern is also evident. In this group the top pocket have higher humidities than the bottom. The average humidity for these two drive groups is 0.43 lb water vapor per lb dry air. This is the prime drying zone and the high pocket humidities are impeding drying. The pocket ventilators at 13, 18, 25 and 34 have been removed and the humidities measured at these locations are still similar to the pockets that have ventilators. This is a good indication that the pocket ventilation system is ineffective. It should be noted that the existing pocket ventilation fans are capable of supplying the required air volume for the number of pocket ventilators, but we were only able to confirm the performance of the No. 1 P.V. system. Pocket Ventilation Supply No. 1 was providing 39,500 cfm, which is more than enough for the number of ventilators on this system yet the humidities were still high. We recommend upgrading the pocket ventilation, maintaining humidities within the good performance range has the potential to improve drying by up to 3%.

Drive Section	Pockets	Average Humidity
1	UnoRun 1, 3, 5 & 7	0.10
2	Bottom 9 to 17 Top 10 to 18	0.67 0.52
3	Bottom 21 to 37 Top 22 to 38	0.24 0.41
4	Bottom 43 & 45 Top 42 to 46	0.07 0.10

Table 3-4. Average Pocket Humidity per Section (lb H_2O/lb d.a.)

The zigzag patterns are typically a result of differences in fabric permeability, fabric cleanliness or an imbalance of the supply air. If the dryer fabrics within a drive are of the same permeability, one could still be dirtier and less permeable allowing less air through to ventilate the pocket. In regards to the air balance, because top ventilator and bottom ventilator are fed from separate headers within the system unequal amounts between headers will result in the zigzag pattern.

3.4.1 Pocket Humidity Variation

Table 3-5 shows the average pocket humidity measured at each position on the dryers in each drive section. The humidity variation across the machine in each pocket should be no more than 0.05 lb water vapor per lb dry air for good performance.

The overall average humidity variation on PM "X" is 0.05 lb water vapor per lb dry air, which is within the good performance level.

Drive Section	Pockets	Edge	5 ft
1	UnoRun 1, 3, 5 & 7	NA	0.10
2	Bottom 9 to 17 Top 10 to 18	0.72 0.54	0.62 0.51
3	Bottom 21 to 37 Top 22 to 38	0.25 0.37	0.24 0.44
4	Bottom 43 & 45 Top 42 to 46	0.06 0.09	0.07 0.10

Table 3-5. Average Pocket Humidities (lb H_2O/lb d.a.)

3.5 Hood Exhaust Humidity

Comparing exhaust humidity to the good performance value verifies whether there is optimum exhaust flow from the hood. Exhaust humidity that is higher than the good performance value increases the risk of condensation and deterioration within the hood. Dripping condensation at the hood openings can affect sheet quality and cause sheet breaks. Hood exhaust humidity that is lower than recommended reduces heat recovery capacity.

Measurements were taken during the production of a 44 lb sheet at 2,550 fpm. The average main hood exhaust humidity for No. "X" Paper Machine is 1,223 grains water vapor /lb dry air. The peak exhaust humidity was 1,254 grains water vapor /lb dry air. The after-hood exhaust humidity was 302 grains water vapor /lb dry air. For the existing hoods the recommended level is 600 to 700 grains water vapor /lb dry air. The hood exhaust calculation is included in the Appendix.

The measured main hood humidity level is way beyond the acceptable limit and would be even higher if the hood was containing all the water evaporated by the main dryer section. During the production of the 44 lb sheet with the No. 2 P.V. system off an estimated 3,000 lb water vapor/hour escapes into the machine room. For the production of the 55 lb sheet with both main section P.V. systems running this increases to an estimated 10,000 lb water vapor/hour. To correct this additional hood exhaust and a new hood are needed.

Given the poor condition of the existing main hood we recommend a grain loading of 600 to 700. This would require a total main hood exhaust volume of approximately 250,000 cfm for the current production values. The existing measured main hood exhaust volume is 111,000 cfm. Considering production increases the exhaust volume would need to be as high as 280,000 cfm. Also it should be noted that any additional hood exhaust would need to be offset with an equal amount of building make-up air on a machine room that is already grossly under supplied with make-up air.

A new hood can handle grain loading in the 900 to 1,200 range depending on the construction. For a medium humidity hood with a grain loading target of 950 the required exhaust volume would be 160,000 cfm for current production and for a high performance hood with a grain loading of 1,200 the exhaust volume would only need to be 120,000 cfm.

3.6 Dryer Energy Consumption

The dryer section consumes energy by:

- heating fiber and water to evaporation temperature
- evaporating water from the sheet
- heating pocket ventilation air
- heating infiltration air to exhaust temperature

Energy is lost when venting flash and blowthrough steam, instead of reusing it in the drying process. Using heat recovered from hood exhaust reduces energy consumption in the dryer section. **Table 3-6** shows an estimation of where energy is consumed on this paper machine.

Energy Use	PM "X"	Good Performance
Sheet heating	53	50
Water heating and evaporation	1050	1050
Hood supply air heating	100	62
Radiation and infiltration	28	44
Blowthrough steam from wet end dryers*	20	0
Steam venting	0	0
TOTAL	**1251**	**1206**

* Estimated amount, based on syphon performance and pressure drop

Table 3-6. Estimated Dryer Section Energy Consumption (BTU/lb water evaporated)

Energy consumption for a good performing paper machine with an insulated enclosed hood is 1,200 BTU/lb of water evaporated, including heat recovery for pre-heating hood supply air. The estimated dryer energy consumption for Paper Machine "X" is 1,251 BTU/lb of water evaporated. We based our calculation on having both main section pocket ventilation systems running. The energy consumption on PM "X" is high, areas for improvement include an increase in the temperature of the sheet leaving the press, utilizing air to air heat recovery and disconnecting the steam from the bottom UnoRun dryers.

The sheet heating good performance value is base on an entering sheet temperature of 120°F we measured 109°F on PM "X". Higher wet end sheet temperature can also have the benefit of improved pressing, installing a steam box is one option and they have profiling capability as well.

There are air to air heat exchangers on the existing heat recovery towers, but they have been removed from service. Originally outside air was preheated by these air to air heat exchangers and used for roof and pocket ventilation supply. We recommend using indoor air for these types of systems. Building make-up should be supplied to operator areas where it would have the most benefit to personnel. The air to air heat recovery should be reactivated.

If possible, the bottom UnoRun dryers should be taken out of service. This will eliminate excess blowthrough steam to the condenser and reduce energy consumption by $48,000 per 350 operating day year, based on an assumed energy cost of $7.00 per 1,000 lb of steam.

The radiation and infiltration value increases for good performance because the current measured hood balance is too high. A properly balanced hood would increase the amount of infiltration.

3.7 Dryer Runnability

Sheet stability is a very important factor for production speeds approaching 3,000 ft/min. The areas of concern are:

- transfer from the last press to first dryer
- UnoRun drive section(s)
- transfer from the UnoRun to the doubled felted drive section

Sheet draw and air movement influence runnability in the dryer section. The sheet needs to be completely supported and stabilized from the press to dryer transfer, through the UnoRun, and to the transfer between UnoRun and the double felted dryer sections.

The sheet is weak leaving the press and entering the dryer section. At higher speeds, higher draws are required to maintain sheet stability. The edges of the sheet often stretch more than the middle, which result in floppy edges down the paper machine. Higher draws will also increase the rate of sheet breaks and limit machine speed. The transfer from the press to dryer will require modification and a Valmet Press Run Blow Box should be installed to support the sheet completely.

The UnoRun fabric carries a boundary layer of air that is large enough to affect sheet stability. This air pumps through the fabric at the closing nips, and pushes the sheet away from the fabric. The sheet then loses support, and wrinkling can occur as it enters the closing nip to the top dryers. UnoRun Blow Boxes are required to stabilize the sheet and prevent wrinkling in the UnoRun section.

Boundary layer air also causes sheet flutter at the transfers between drive sections. They are the most troublesome areas for runnability and sheet breaks. The moving fabrics pump air into the area between drive sections. This causes sheet flutter at the open draw. This is complicated by the fact that there is effectively no draw between the first and second drive groups on Paper Machine "X". The two drive groups share a common rope run and therefore need to run at the same speed. We recommend dividing the rope run, relocating the felt rolls to reduce the open draw at the transfer and installing a GroupTransfer Blow Box to improve stability at the drive transfer.

3.8 Fabric Permeabilities

Sheet stability is the major limitation to higher speeds in many paper machines. Fabric permeability is a factor that needs to be considered as machine speeds increase. Dryer fabrics must allow the pockets to be ventilated but should not allow excessive airflow, which can cause sheet flutter.

Maintaining clean fabrics is also important. Depending on furnish and other machine operating variables, they can quickly become plugged. Many high-speed machines are using cleaning devices on dryer fabrics to keep them open. **Table 3-7** lists the drive section and the recommended fabric permeability for that section. The current fabric permeabilities used on PM "X" were not made available to us as a comparison.

Drive Section	Nominal	Recommended
1st UnoRun	Not provided	75 to 110
2nd Top	Not provided	150 to 185
2nd Bottom	Not provided	150 to 185
3rd Top	Not provided	185 to 300
3rd Bottom	Not provided	185 to 300
4th Top	Not provided	150 to 185
4th Bottom	Not provided	150 to 185

Table 3-7. Fabric Permeabilities (cfm/ft²)

Summary

Maintaining even stability and keeping the process at an optimum level require regular analyses and the right actions. As your drying partner, the purpose of the reports generated in all air systems studies performed by Valmet experts is to pinpoint immediate solutions to your existing drying problems, while simultaneously assessing feasibility and defining future projects. The recommendations are based on the best-known industry practices and our experience with similar machines making comparable grades. The method of implementing the recommended projects and variables associated with paper machines will obviously affect the final results obtained.

This white paper combines technical information obtained from Valmet personnel and published Valmet articles and papers.

Valmet provides competitive technologies and services to the pulp, energy and paper industries. Valmet's pulp, paper and power professionals specialize in processes, machinery, equipment, services, paper machine clothing and filter fabrics. Our offering and experience cover the entire process life cycle including new production lines, rebuilds and services.

We are committed to moving our customers' performance forward.