Optimizing the Vacuum Systems in a Paper Machine

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Existing Trends:

- No standard available information on section wise energy requirements for a particular department of paper mill.
- In many cases, mills using same amount of vacuum applied for different raw materials, machine speeds, basis weights etc. on the same machine.
- Available norms (CPPRI) consider paper machine as a whole, and it is often difficult for the mill to decide how to reduce power consumption for paper machine.

Barriers:

- Quality produced
- Raw Material used
- Machine configuration
- Runnability issues
- Possible effect on subsequent stages (pressing, drying etc.)
- Lack of availability of suitable information

Mill Practices (Vacuum):

Section	**PM-1**	**PM-2**	**PM-3**	**PM-4**	**PM-5**	**PM-6**
Wire Part	30	39	22	**72**	20	17
Suction Couch	**70**	36	61	--	--	-
Felt Cleaning	32	63	99	**164**	100	**39**
Press Section & Pickup Roll	35	60	65	**163**	--	-
TOTAL	167	198	247	**399**	120	56

•PM-1,2,3 & 4 relate to one mill, and PM-5 and PM-6 are other mills. The
•capacity, quality and basis weight of PM-5 is same to PM-4, but with different
•raw material. PM-6 is an agro based kraft paper mill.

Mill Practices:

Machine	**PM-1**	**PM-2**	**PM-3**	**PM-4**	**PM-5**	**PM-6**
SPC for Vacuum	167	198	247	**399**	120	56

It is interesting to know that many mills (of course, waste paper based) are using less than 300kWH/Ton for the whole plant, including boiler, utility and lighting.

This shows the potential available for energy conservation in this section.

Excuses for High Vacuum:

Machine	**PM-1**	**PM-2**	**PM-3**	**PM-4**	**PM-5**	**PM-6**
SPC for Vacuum	167	198	247	**399**	120	56

- Machine configuration is different.
- Raw Material is different.
- The other mill might be using more steam in dryers.

Optimization Points:

- The Process Itself
- Wire Part
- Press Part

Process:

- Reducing solids content can be a good strategy many a times.
- Typical Example:

	Wire Vacuum, kW	Wire Solids	Press Solids	Increase in steam Consumption
Initial	80kW	22%	42%	Base
Optimized	30kW	20%	41.5%	50kg/Hr
	Rs.250			Rs.100

Process:

- Instead of emphasizing too much only on reduction of steam consumption, or on increasing solids, the approach should be to minimize the sum of the values of-
  - Power Applied to Vacuum Pumps
  - Power Applied to Drive the Machine
  - Steam Used to Dry the Paper

Wire Part:

- Vacuum should be in increasing order.
- Airflow calculations
- Use of “Low-Vac” Boxes
- Back water quantities
- Use of drop legs
- Pipe sizes

Wire Part Airflow Calculations:

- Difficult due to variations in resistance to air flow
- Depends on stock properties
- In a box, airflow is proportional to square root of gauge vacuum applied.
- Airflow is proportional to open area of the box.
- Airflow is proportional to the web consistency in a cosine hyperbolic function.

Low Vac Boxes:

- Extremely useful for low vacuum levels.
- Efficient and uniform water removal
- Problem: Slime
- Solution: Frequent cleaning

Drop Leg:

- It has been observed that the drop leg is a good means to avoid unnecessary vacuum.
- It is quite easy to adjust the level of seal pit overflow to control the vacuum level in a particular suction box.
- Problem: Slime
- Solution: Use seal pits as small as possible, ensure thorough cleaning.

Pipe Sizing:

- Normally, air/vacuum piping are designed at a velocity level of 22-28m/s
- Undersized pipes result in vacuum drop.

Vacuum in Increasing Order

- Increasing Vacuum! Which one?
  - A: 1.0 2.0 3.0 4.0 5.0 6.0
  - B: 0.5 1.0 1.5 2.0 4.0 6.0
  - C: 3.5 4.0 4.5 5.0 5.5 6.0
  - D: 0.2 0.3 0.5 1.0 3.0 6.0
- How to maintain vacuum properly?

Vacuum & Solids:

- Sheet Solids% = **b** + **m** [tanh { **c**(dwell) }]
- ‘b’, ‘m’ and ‘c’ are constants.

- Typical values of constants-

Vacuum Level	b	m	c
3” Hg	6	8.18	50
6” Hg	6	11.20	65
12” Hg	6	13.25	125

- Ref: John A. Neun, Tappi, 77(9): 133 (Sept. 1994)

Vacuum Optimization:

- At higher vacuum, the consistency curve is steep.
- As ‘c’ increases with increase in vacuum, reducing the open area in high vacuum boxes is a good approach to get satisfactory results even with low airflow.
- Example: bagalley box → very low open area, excellent water removal.

Key Fundamentals:

- The consistency increase after a suction box decreases with
  - Increase in vacuum
  - Increase in inlet consistency
  - Decrease in box width
- On most machines, the applied vacuum airflow is limited.

Wire Part Airflow Calculations:

- Airflow = constant . $(\text{Vacuum})^{1/2}$
- Airflow increases rapidly with increase in vacuum.
- Airflow increases with increase in solids as air permeability increases.

- A dwell time of 0.02s is normally sufficient per box.

Wire Part Airflow Adjustments:

- Airflow in the initial boxes is low, and increases with the box number.
- In most of the cases, final solids (consistency) is a strong function of vacuum level in the last box.
- Furthermore, the vacuum in the last box increases with decrease in total airflow.
- So, for best results-
  - A: 1.0 2.0 3.0 4.0 5.0 6.0
  - B: 0.5 1.0 1.5 2.0 4.0 6.0
  - C: 3.5 4.0 4.5 5.0 5.5 6.0
  - **D: 0.2 0.3 0.5 1.0 3.0 6.0**

How to achieve(1):

- In many mills, operators find it difficult to maintain vacuum in increasing order.
- To begin with, open the last box fully, and close valves of all other boxes .
- Now, open vacuum in the first box slightly.
- Then, open vacuum in second, third and subsequent boxes gradually maintaining gradual increase in vacuum.

How to achieve(2):

- Use of anemometer to check airflow at vacuum exhaust is advantage.
- The target should be to have minimum airflow at desired couch consistency.
- Use of differential vacuum gauges between two consequent boxes can also be very useful.

Excess Airflow:

- While the increase in wire part vacuum results in increased dryness of the web, the gains decrease with every increase in vacuum. (Gauge vacuum & airflow)
- After a particular level, increased vacuum results in reduced web temperature, hence in reduced press efficiency and also steam consumption in dryers may not decrease to estimated levels.

Typical Temperature Profile:

- A typical temperature profile at the wire part is given as under-

- At Head Box : 37.2
- At Dry Line : 36.9
- At first Suction Box : 36.7
- At 2nd Suction Box : 37.0
- After Last Suction Box : 35.3
- After Bagalley Box : 34.4

(Temperature and humidity play significant roles, so data may change over time.)

Results Achieved:

- Capacity: 35 TPD
- Quality: Poster Paper, 34-80gsm
- Vacuum pump rating: 29 m^3/min.
- Action: Wire vacuum pump rpm reduced from 630 to 460.
- Saving: kW reduction from 55 to 22
- Speed: No change
- Steam Consumption: No change
- Investment: Rs.10,000/- only (Pulley Change)

Vacuum Source at Wire Part:

- Typically, wire part requires low gauge vacuum. This means, a water ring vacuum is not very much required.
- Application of roots blower (Twin Lobe) has been tried for the same successfully.
- In some cases, centrifugal blowers have also been used.

Installation of Centrifugal Blower:

- Installed for agro based kraft paper mill.
- Wire part load reduced from 23kWH/Ton to only 17kWH/Ton.
- Machine runnability improved.
- Wire part drag load reduced from 34kWH/T to 28kWH/Ton.
- Payback period: **One Month**

Roots Blower Installation:

- Initially, roots blower was installed at ground floor, but sometimes, water carryover from separator created problems.
  - Abnormal sound
  - Fluctuation in load
  - Bearing jammed
  - Shaft broken
- Finally, roots blower was installed at a higher elevation, where it is running successfully.

Roots Blower- Advantages:

- Decrease in wire part drag load≈15kW
- Better runnability
- Reduced load of vacuum pump (10kW)
- Reduced Maximum Demand (MD)
- Increase in wire life ≈15%

Typical Problems:

- Slack draw after wire part, on line shaft machine. (Couch diameter reduced)
- Web breaks after wire part, particularly at back side. (MD GSM study)
- Pulsating dry line along machine direction. (Suction box alignment)
- Fluctuations in vacuum level. (Tri lobe, Improved piping)

S/L or D/L Wire?

- We may consider wire and web as two resistances in series.

WEB	R_1
Wire	R_2

Net Resistance, $R = [R_1 + R_2]$

Here, wire resistance is very small compared to web, hence, vacuum requirement should not change significantly while changing from S/L to D/L.

Furthermore, after dry line R_1 reduces significantly, and Net Resistance, R reduces. That is why mills producing different gsm find it difficult to maintain vacuum profile in the wire part.

Press Part:

- Uhle box sizing
- Airflow calculations
- Back water quantities
- Use of drop legs
- Pipe sizes

Press Part Uhle Box:

- Uhle Box Slot Width Calculation:
- Residence Time: 2-4 ms per felt
- Limits:
  - Minimum width 9-10mm
  - Maximum width 25mm
  - Use two boxes for more width

Press Part Uhle Box:

- Airflow Calculation:
- As per TAPPI TIS:0502-01
- Airflow = 660 m^3/m^2/min of open area
- Uhle Box diameter:

Uhle Box Capacity	Diameter
20 m^3/min	150mm
34 m^3/min	200mm
54 m^3/min	250mm

- Ref.: Douglas F. Sweet, TAPPI, 80(7): 103 (July 1997)

Press Part Blow Box:

- Blow boxes are installed just to remove excess air entrained with the felt-paper combination and they do not serve as a dewatering element.
- Applying to high a vacuum in these result in poor felt life, increased drag load with no major increase in web dryness.
- Typically, a vacuum level of 150-200mmHg is sufficient.

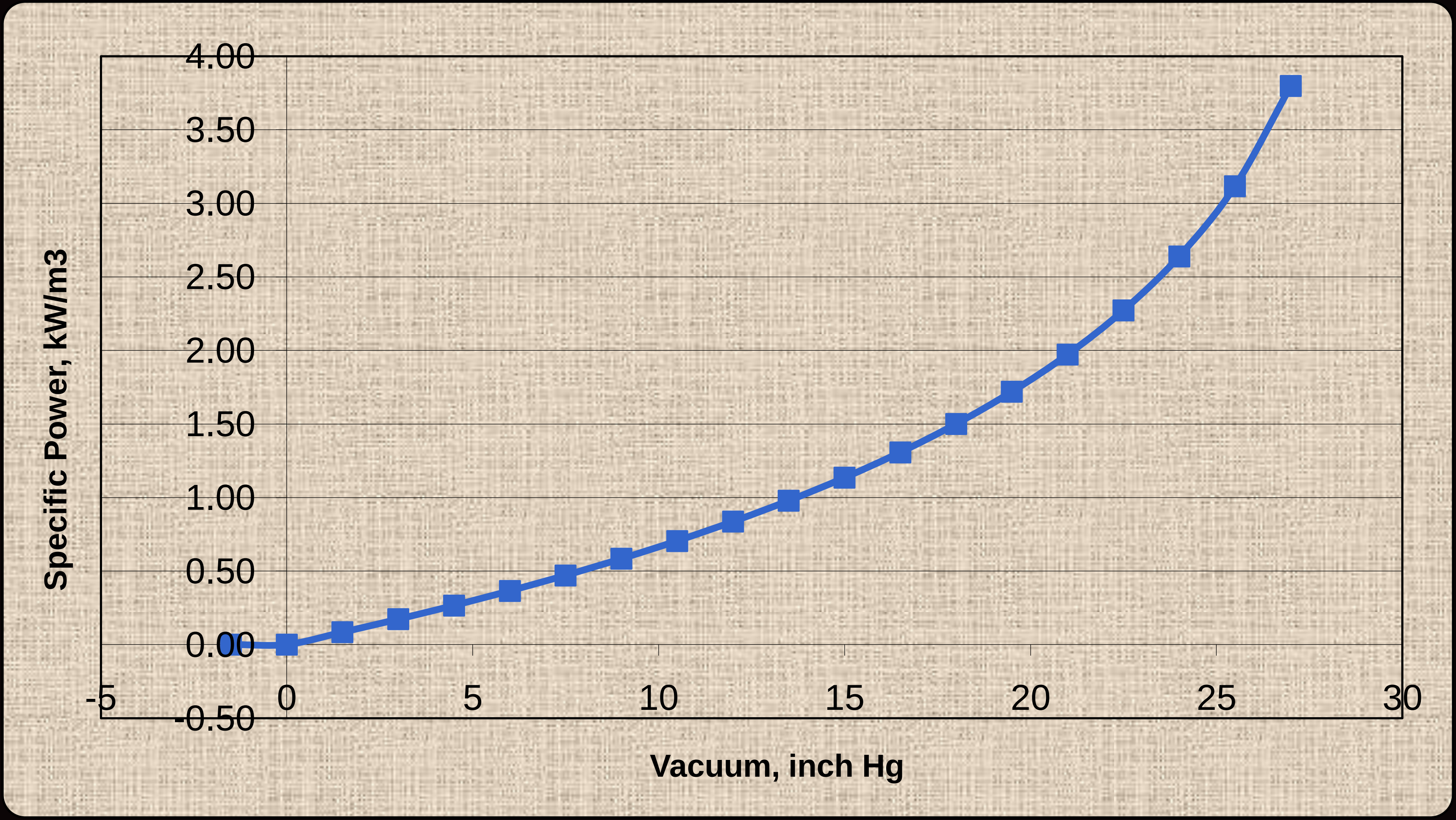
Press Part Back Water:

- Normally, the back water quantities are relatively much lower than the wire part.
- Having a higher capacity extraction pump tends to increase in problem of air locking, and hence vacuum leakage.

Effect of Pipe Sizing:

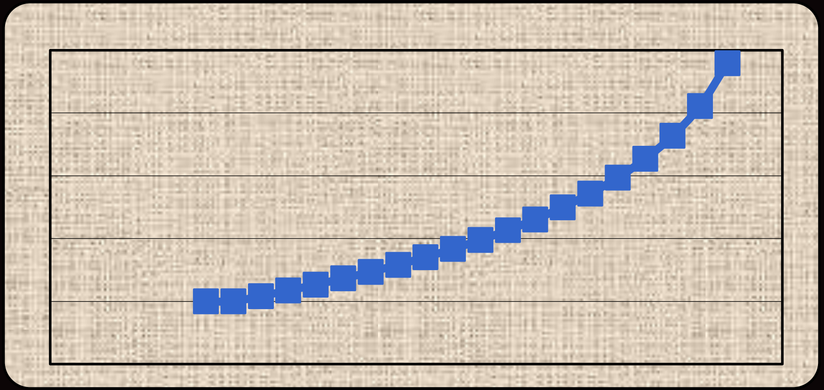
- Undersized lines result in pressure drop.
- If you require 12” vacuum at any box, and the vacuum pump is indicating 15” at its inlet, this means a **35%** excess power is being used.
- It is strongly recommended to analyze the pipeline, and reduce vacuum pump rpm.
- Use of VFD may also be considered in such cases.

Power Vs Vacuum Level:



Power Vs Vacuum Level:

- For every increase in gauge vacuum, power increases exponentially.



Excess Vacuum:

- A high vacuum in press part also plays a role similar to that in wire part.
- Web cooling results in increased steam consumption to increase temperature of the web.

Effect of Web Temperature:

- Consider a 5ºC drop in web temperature.
- Also consider web solid = 40%
- Heat required per ton of paper:

  For fiber heating: 1000X0.5X5=2500kCal

  For water heating:1500X1.0X5=7500kCal
- Total = 10,000 kCal ≈ **19kg steam**

Effect of Web Solids:

- Consider web solids =40%.
- Water per ton of fiber: 1.500kg/kg

- Consider web solids reduction by 0.3%.
- Water per ton of fiber: 1.519kg/kg

- Extra water to be evaporated: **19kg/T**

Web Temperature:

- This indicates that a 5ºC drop in web temperature is equivalent to 0.3% reduction in web solids.
- If process indicates a drop in web temperature after the press section, a reduction in vacuum levels must be considered.
- For yankee machines, felt comes in contact with yankee cylinder (indirectly).
- Felt gsm (say 1200 plus 600 as moisture) is very high.

Strategies for Vacuum Optimization:

- Reduce vacuum by throttling valves
- Monitor steam consumption during trial period
- Consider the possibility of vacuum pump speed reduction by changing pulleys or using VFDs
- If possible consider shutting off a vacuum pump
- Evaluate situations by increasing vacuum also.

Typical Results Achieved:

- One 29m^3/min. vacuum pump switched off.
- Decrease in press part drag load≈10kW
- Increase in machine speed by 5% *
- Better runnability
- Reduced load of vacuum pump (55kW)
- Reduced Maximum Demand (MD)
- Reduced seal water consumption for vacuum pump

To Policy Makers:

- Instead of benchmarking SPC for paper machine, a split of parameters would be advantageous.
- Typical sections for paper machines could be-
  - Approach Flow
  - Vacuum Pumps (whole → Section-wise)
  - Machine Drive

Norms for Paper machine Vacuum:

- The new norms should consist only two parameters. Fiber type (raw material) and basis weight. Typical norms could look like-
- Specific Vacuum Power, kWH/Ton

Furnish	16-32 gsm	30-50 gsm	50-100 gsm	100-300 gsm
Hardwood	180	150	120	100
Bagasse	200	160	140	120
Waste Paper, ONP	150	125	110	--
Waste Paper, Kraft	180	140	100	90

- Figures may be different than shown above.

Thank You.