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PINCH ANALYSIS – AN ESSENTIAL TOOL FOR ENERGY OPTIMIZATION OF PULP AND PAPER MILLS

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ABSTRACT

Process integration is a proven powerful tool for the improvement of the overall energy efficiency and the optimization of the water usage in pulp and paper mills. The application of thermal Pinch analysis, combined with practical mill experience, has resulted in very important energy, operating and capital cost savings for many mills. American Process Inc. (API) has applied Process integration in more than 200 pulp and paper mills for energy optimization and the minimization of the water usage and the effluent flow. API has also developed the O-Pinch™, a complimentary methodology to the pinch analysis that focus on operational projects with low or no capital cost. This paper will provide the theory and practice of Pinch technology, as well as examples of its application in different mills.

Keywords: cogeneration, heat recovery, operational review, Pinch technology, process integration, pulp and paper.

INTRODUCTION

Process integration is the science of examining any problem or project in the context of the overall site and improving efficiency by exploiting synergies between the various components. Process integration has long been established as an accurate and powerful tool for site wide analysis of energy saving opportunities. Process integration tools include simulation modeling, thermal and water Pinch technology, optimizers, and financial analysis.

Until now, evaluation of a site's energy performance has been based on comparison with another similar site or with a previous year's performance. However, very few sites are 'similar'. Even if the process or final product is the same, the age, technology used and ambient conditions can radically affect the energy profile. Striving continuously to reduce energy consumption without knowledge of the minimum possible target is like fighting in the dark. It can be expensive and fruitless.

ACTUAL = The thermal energy used at present at this site
(Derived from historical mill data)

TARGET = The minimum thermal energy required to run this site
(Derived from Pinch Analysis)

SCOPE = ACTUAL - TARGET

PROJECTS = What must be done to bring the actual closer to the target

Figure 1. The scope for thermal energy saving

If the target for the site, i.e. the minimum possible thermal energy consumption for that process, were known, then the present consumption could be compared with the target and the performance gauged from the proximity of the actual consumption to the target. In effect, this would compare the energy performance of the site against the best performance ever possible, assuming no changes to the process itself. This comparison would form a valid basis for long-term plans and future goals.

Pinch analysis does exactly as per **Figure 1** for a site. Applying Pinch technology determines unequivocally the minimum thermal energy required in order to operate the site without changing the process. We therefore have the target.

Over the last decade, Pinch technology has become accepted as a quick and objective tool for analyzing the energy profile of a site and clearly identifying opportunities for practical and financially attractive projects.

American Process Inc. is using the tools of Process integration, within a structured approach, for the improvement of the overall

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efficiency in pulp and paper mills. The main tool used is Pinch analysis supported by simulation and economic analysis. Pinch studies have been proven to be a powerful and efficient tool for pulp and paper mills for several cases:

- undergoing expansion in an existing mill;
- on a green field site;
- implementing projects for environmental compliance;
- considering process changes;
- short supply of steam;
- benchmarking – What should be the site's energy consumption be?;
- high fuel costs;
- investing in new process equipments, i.e., stripper, evaporator, etc.;
- changing process equipment type, i.e., batch cooking to modified batch or continuous, or adding deink to TMP, etc.

In all these cases a Pinch study can help minimize both thermal energy (operating costs) and capital cost.

The success of Pinch technology is based on being able to clearly identify the opportunities for savings and the actions required to achieve them. Process integration and Pinch technology are based on the following concepts:

– Side wide analysis: in a complex operation, as in a pulp and paper mill, it is often easy to identify and solve departmental problems and define local opportunities for energy savings, without clearly identifying their site-wide impact. The application of process integration avoids such pitfalls. Since it is based on an integrated approach, the analysis considers all interactions of the process, thermal and power generating systems, and ensures that no opportunities are missed.
– Minimization of driving forces: the degradation of temperature, which is the driving force for thermal efficiency and maximum power generation, is avoided. Process integration is based on using the minimum possible grade of heat to perform a specific duty, thereby increasing the energy efficiency.

PINCH TECHNOLOGY

METHODOLOGY

Process Integration and Pinch technology are very efficient tools, especially when they are used within a structured approach [1].

American Process Inc. is using this systematic and structured approach, which, combined with practical engineering experience, has revealed very important operating and capital cost savings for over 200 pulp and paper mills in North and South America and Europe.

The first step of a Pinch study is to establish a baseline that accurately determines the present configuration and performance of a site. Process flow diagrams representing the mill operations, actual mill data and reconciled mill-wide simulation models provide a credible baseline for the energy study.

Using the process flow diagrams and the model, the intrinsic heating requirements and cooling duties of a process are identified. The "hot" and "cold" streams of the process are quantified. This action is termed "Data Extraction" and is a highly specialized activity that uses the concepts of Pinch methodology, but also requires practical experience. Like with any optimization analysis, some constraints are required to be built in the problem definitions. In Pinch analysis, some of these constraints must be considered at the "Data Extraction" stage, in order to yield realistic results.

The "hot" and "cold" streams are plotted continuously using common temperature and enthalpy axes to generate the composite curves. The composite curves essentially represent the site heating and cooling duties as a multi-segment heat exchanger, revealing the maximum possible heat recovery and the minimum external heating and cooling requirements of the process ("targets"). The target-heating requirement of the site is compared with the actual hot utility consumption, and their difference determines the maximum theoretical scope for savings at the specific site. A sample composite curve is shown in **Figure 2**.

Another important concept of Pinch technology is the Pinch temperature, which defines the heat distribution in a site. Above the Pinch, there is a shortage of heat and below the Pinch there is excess of heat. Therefore, transferring heat across the Pinch, using external heating below the Pinch and external cooling above the Pinch, reduces the amount of heat that can be recovered and thereby increases the external heating and cooling requirements. The above heat transfer occurrences are termed "Cross-Pinch" heat transfer, and are the reasons for the actual steam consumption of a plant to be higher than the target.

From the above, it becomes obvious that the Pinch methodology does not only reveal the minimum possible hot utility demand of a site - or, in other words, the maximum heat recovery that can be achieved -, but also provides the engineer with clear guidelines on how to minimize the steam demand and maximize the savings.

In a Greenfield design case the optimum heat recovery network design is achieved by following the Pinch rules. In a retrofit study, the

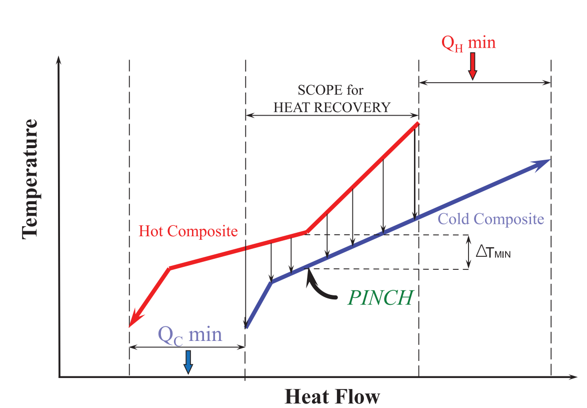

Figure 2. Typical composite curves

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"Cross-Pinch" occurrences are identified and are corrected in order to save steam.

The new or retrofitted heat recovery network design is the most crucial step in a Pinch study. Apart of following the Pinch rules, the engineer must use his practical engineering experience in order to set constraints in the design, such as the layout, difficulty to handle fluids, fluid contact restrictions, operability, and safety. All the above factors together with mill personnel preferences are taken into account in order to yield a practical design.

Apart of the design of heat recovery networks, the Pinch methodology is also used for the integration of new process equipment into pulp and paper mills, as well as for cogeneration analysis. The main tool for identifying the best integration of new processes and for defining the cogeneration opportunities is the Grand Composite Curve. The Grand Composite Curve is a graphical representation of all the heating and cooling requirements of a process, assuming the maximum level of heat recovery, so as to reveal the remaining heat demands and availability. A typical Grand Composite Curve is shown in **Figure 3**.

By defining the process temperature profile, Pinch shows what type of cogeneration system best matches the inherent thermodynamic opportunities of the process or the site.

Heat recovery should be optimized by Pinch analysis before specifying cogeneration systems. Excessive investment and operating costs are prevented by avoiding oversized plant supplying heat that could economically have been recovered.

By definition, Pinch theory shows that in true cogeneration the heat must not be rejected by an engine (turbine) across the Pinch. Many sites are now considering cogeneration possibilities; this is likely to be an increasing practice. Cogeneration is traditionally achieved with boilers burning black liquor and bark and using steam turbines. Today, gas turbines, fired on natural gas or light fuel oil, are increasingly being considered. Combined cycle operation yields a twofold benefit by producing power both from gas turbines and steam turbines driven by steam generated from heat in the gas turbine exhaust. Pinch is a powerful tool in revealing all the possibilities for cogeneration. **Figure 4** shows a graphical representation of the target cogeneration analysis methodology.

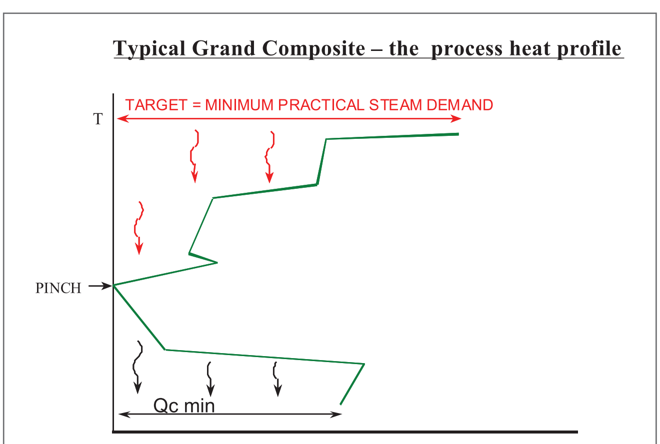

Figure 3. Typical Grand Composite Curve

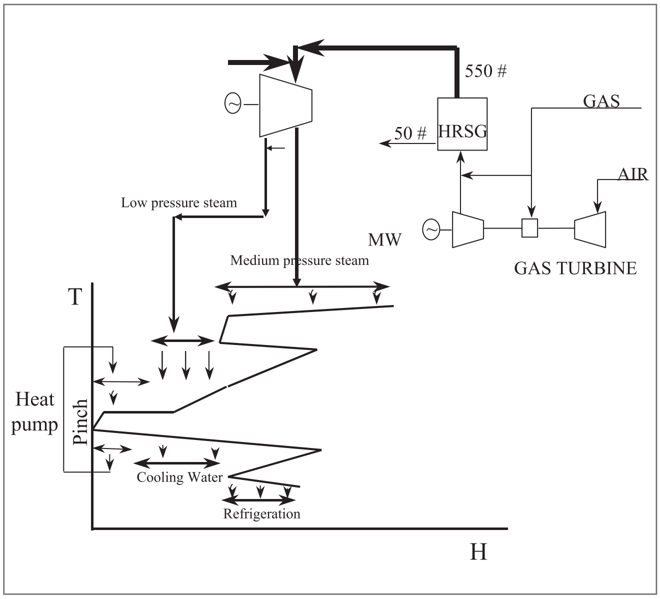

Figure 4. The use of the Grand Composite Curve for examining heat pumps applications and cogeneration potential

Pinch also provides great insight into the placement of heat pumps. Heat pumps upgrade heat by adding mechanical work. By examining the Pinch curves it becomes obvious that a heat pump is properly integrated when it is taking heat from below the Pinch (where there is an excess) and upgrading it above the Pinch, (where there is a demand). Placed this way, the heat pump produces real savings. A heat pump inappropriately placed, i.e., not across the Pinch, will have the same effect as putting the mechanical energy directly into the process. A correct heat pump placement is shown in Figure 4.

Economic analysis and monetary savings

In a realistic competitive environment, projects are implemented based upon their economic incentives. Therefore, one of the most important steps in an energy study is to examine the heat recovery projects from an economic point of view. The capital cost of the proposed projects is estimated and the potential monetary savings are calculated. Based on the cost benefit analysis results, some of the projects could be changed; sacrificing savings for capital, i.e., an optimization of savings *vs.* capital is performed. At the final stage of a study, the mill has a clear understanding of the opportunities for energy and capital savings, their financial benefit, and the actions required to achieve them.

There are several options as how to use the steam savings identified. Choice between the options depends on the economic analysis and other mill plans. The reduction of process steam demand can:

- lead to reduced purchased fuel consumption;
- be used to generate more power;
- facilitate increased production without a net increase in steam usage.

American Process analyses the option for the steam savings

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Table 1. Summary results of some Pinch studies performed by American Process Inc.

	Target	Actual	Scope	Practical Savings	
Mill Type	GJ/h	GJ/h	GJ/h	GJ/h	€MM/y
Semi-Sulfite/OCC Linerboard Mill	313	440	126	47-84	1.0-2.1
Kraft/NSSC/OCC Linerboard Mill	990	1318	328	187	1.0
Continuous Bleached Kraft	NA	NA	187	134	2.4
Bleached Kraft Mill	451	583	132	90	2.4
Bleached Kraft Mill	772	866	141	84	0.7
Newsprint Kraft Mill	544	913	424	169	1.2
Bleached Kraft Mill	308	466	158	105	2.2
Continuous Bleached Kraft HWD	NA	NA	148	124	1.8
Bleached Kraft/TMP/Groundwood Mill	835	1216	382	316	~2.9
Bleached Kraft Mill	871	1155	285	169	~1.5
Bleached Kraft Mill	1333	2007	674	248	2.1
Bleached Semi-sulfite Mill	248	331	83	39	1.0
Evaporator Integration in Kraft Mill	NA	NA	84	84	NA
Bleached Kraft/TMP Mill	659	1017	358	310	1.5
Bleached Kraft & NSSC Mill	526	725	199	105	1.5

realization, the resulting economic benefits and provides the mills with clearly defined pathways for the reduction of operating and/or capital cost.

In order to calculate the true monetary savings resulting from the heat recovery projects, it is important to identify the origin and the true cost of the steam savings.

The true value of marginal steam is derived from calculating the cost of fuel needed to generate this steam and subtracting from it applicable credits for desuperheating and power generation. The calculation also takes into account the utility system needs and costs, i.e., demineralized water, deaerator steam, blowdown, etc. Furthermore, the cost of steam differs depending on whether the steam is used indirectly (condensate is returned), or injected (condensate is not returned) and it also depends on which fuel is used to generate the steam.

The marginal cost of steam, which must be used for project justification, does not include the standard costs of maintenance, capital repayment, labour, etc., since using less steam will not significantly reduce these.

A detailed explanation of application of Pinch technology in the pulp and paper industry, and also the Pinch principle, can be found in the literature [2], [3], [4], [5], 6], [7].

Table 1 presents summary results of some Pinch studies performed by American Process Inc.

CONCLUSIONS

Pinch analysis is an essentially practical tool based on a conceptual methodology for looking at process plant heat flows. Pinch analysis can be used to develop benchmarking targets, and enables a mill to compare its actual energy performance to its own best possible energy performance.

In depth application experience has led to excellent results on a growing number of pulp and paper mills. The main benefits for mills include:

- meaningful energy targets;
- feasible projects with real savings;
- essential strategic insights

In times of increasing competition, tightening environmental requirements and with many new technologies to assess, Pinch has become a state of the art practical tool that no mill can afford to ignore. ■

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