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APPROPRIATE TECHNOLOGY FOR THE MANUFACTURE OF PULP AND PAPER PRODUCTS

LIME BURNING AND ALKALINE PULPING.

Background Paper,

LIME BURNING AND ALKALINE PULPING

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Contents

1. INTRODUCTION

This paper consists of two parts.

1.1 The first one describes the considerations taken in a particular case to chose an appropriate installation for lime burning in a developing country in connection with an alkaline sulphate pulp mill based on bamboo.

The mill site is situated in a rural area of the country, which is intended to be industrialized.

1.2 The second part gives some cost estimates, consumption and efficiency figures covering lime kilns in general.

1.3 As the prerequisites in this case study mainly differ from the situation if wood is the fibre raw material, if the infrastructure and technical experience have been well established for long time, etc, the choice of lime burning concept cannot be conventional.

Such a choice could jeopardize the total production of bleached pulp and converted paper products.

1.4 The paper is based on own experience and information and advice which the author has got from textbooks, other technical reports and brochures and also valuable discussions with lime kiln manufacturers, lime producers and pulp producers.

1.5 The choice of concept in the described particular case was finally easy to make since all other alternatives could be successively eliminated for different reasons.

PART 1

2. GENERAL TECHNICAL BACKGROUND

2.1 The alkaline pulping process

The cooking liquor when pulping wood or other fibre resources as bagasse, straw, esparto etc. according to the soda or sulphate (kraft) pulping process consists of sodium hydroxide and in the latter case also sodium sulphide.

During the cooking approx. 50% of the wood is dissolved by the cooking liquor and transformed together with the chemicals to a spent liquor, named black liquor.

This black liquor is washed away from the fibres and then concentrated by evaporation and finally burnt in a recovery boiler.

The concentration of dry solids in the black liquor from the washing is about 15% and has to be increased to about 60% before burning.

The evaporation has to be done with consideration to the successively changing properties of the liquor during its increasing consistency, where big differences are known between black liquors depending on fibre raw materials, cooking liquors, cooking yields etc.

A choice of evaporation principle and machinery must be done to minimize scaling deposits, foaming and in the meantime optimize investment, operation and maintenance costs with due consideration to the intended necessary heat value of the finally evaporated black liquor as fuel for the recovery boiler.

An appropriate evaporation will be made by the proper choice and combination of falling and/or climbing film indirect evaporators with or without by pumps forced circulation in tubes or plates. Also direct evaporators have in certain cases to be considered in the later stages.

The recovery boiler operates like an oil fired steam boiler.

The organic compounds are converted to carbon dioxide and water and give in the meantime a considerable amount of heat as steam.

The inorganic sodium components are recovered as a smelt of mainly sodium carbonate which is dissolved in a water solution, called weak liquor, thus forming green liquor.

The design features of the boiler and its operation has also to be adopted to the black liquor properties in order to get an adequate operation, mainly to prohibite inside salt cake ash deposits and thus guarantee the steady operation efficiency.

The proper design of evaporators and boilers is most pronounced in case of high silica content or high viscosity resins in the black liquor.

The green liquor has to be transformed to active cooking alkali - sodium hydroxide - which is performed by adding burnt lime to it, using the recausticizing reaction:

$$Na_2CO_3 + CaO + H_2O \rightarrow 2\ NaOH + CaCO_3$$

This reaction is necessary for closing the recovery circle and demands 200-250 kg burnt lime (CaO) per ton of produced pulp.

It is necessary for the alkaline pulping process not only from economic point of view, with regard to the high value of the chemicals, but also because a black liquor disposal to the effluent should create severe pollution problems as a result of poisonous components and high biological oxygen demand (BOD).

Waste of black liquor is only acceptable in case of small scale pulp mills in combination with big effluent water recipients.

2.2 The lime burning process

Until about 25 years ago the demand of burnt lime for the alkaline pulping recausticizing departments was normally satisfied by purchase from local lime kilns within the area or by own production at the pulp mill site.

This production was based on limestone shipped to and unloaded at the pulp mill harbour, as these older mills normally are situated at the sea or a river, which facilitates the import of different chemicals and fuels, floating and sea storage of pulp wood and finally export of the pulp and paper products and by-products as turpentine and tall-oil. The limestone was burnt in vertical shaft kilns masoned by bricks and fired with coal, wood or oil.

The lime burning reaction is: $CaCO_3 + \text{heat} \longrightarrow CaO + CO_2$.

The by-product from the recausticizing process - lime sludge ($CaCO_3$) - was separated as a deposit from the reaction tanks, washed clean from residual chemicals and then wasted.

The deposition of the lime sludge was arranged in different ways according to the local situation and surrounding; in piles, old sand quarries left from the construction of the mill or delimited areas of bays.

As a result of the increasing volumes of disposed lime sludge after tens of years of operation of the pulp mills, increasing size of the mills and consequently of the amount of lime sludge from the production and also increasing costs of unskilled labour and cheaper petroleum fuel the limestone shaft kilns in most developed countries have successively been replaced by rotary kilns for drying and reburning the lime sludge, chemically the same as limestone ($CaCO_3$).

The first installation in the world and experience of lime sludge reburning in rotary kilns was in Skutskär, Sweden, and has been described in detail (Ref. 2). In this article an interesting case study is given with motives for introduction, operation and later on shut down, which indicates that lime sludge reburning, already invented in the beginning of this century, has had to face many technical and economic difficulties until it finally during the last decades has found its proper function in alkaline pulp mill as an normally more appropriate method of burnt lime production than shaft kilns in this industry. This method, though, has still considerable drawbacks in certain applications as will be exemplified below.

The main world production of burnt lime based on limestone is found within other industries, where lime sludge is not available as in the alkaline pulping and is now alternatively well established not only with shaft kilns but also with rotary kilns.

The choice of kiln type in these applications is dependent on many facts and demands, as capacity, investment, operation and maintenance costs, quality of raw materials and final products etc., which has to be evaluated from industry to industry and case to case.

The description of such appropriate choices is outside the scope of this paper as far as other industries is concerned but in certain special situations also limestone burning in rotary kilns could be an alternative to shaft kilns in the alkaline pulping.

One example is if the kiln infrastructually shall deliver burnt lime not only to the pulp mill but also to other industries within the area and must have a much higher capacity than the pulp mill demand and therefore the total economic evaluation may prefer a rotary kiln.

Another example is an alkaline pulp mill which will be started up with limestone burning but later on within reasonable time intended to be changed to lime sludge reburning. In this case a rotary lime kiln will be mainly designed for reburning from the beginning and special arrangements made to permit small size limestone burning during the first period until the lime sludge reburning starts up.

Even with lime sludge reburning there is a certain need of extra fresh limestone or burnt lime, primary for substitution of normal losses, 5 to 10 percent, but also for further "opening ups" of the system by different reasons necessary to keep up the quality of the burnt lime from process point of view and avoid disturbances in the pulp mill coming from the lime sludge, as silica.

3. THE ACTUAL CASE STUDY: THE BAI BANG SULPHATE PULP MILL IN VIETNAM

3.1 General description

This mill, a mutual Vietnamese-Swedish investment, will start up in the early 80's and produce about 50.000 tons per year of bleached and converted paper products according to the alkaline kraft process. The demand of burnt lime is 50-75 daily tons.

The mill site is situated in the Viet Tri province of Vietnam, which will undergo a widespread industrialization process in the future.

Transport connections with the mill will be arranged with railway, roads and river harbour.

The fibre raw material will be mainly bamboo in the beginning but also tropical hardwoods.

The bamboo will be floated to the local harbour and later chipped in the mill, including washing operations of the bamboo stems and chips as clean as possible from river mud.

The pulp mill will be conventional with due respect to the local situation and consists of:

- batch digesters
- filter washers
- rotary screens
- filter bleaching plant
- climbing film evaporators with black liquor oxidation
- recovery boiler with cascade evaporators
- tank recausticizing plant.

There will also be a chlorine-alkali plant, power plant, in-take and effluent water treatment, paper mill (two machines), paper converting plant etc.

3.2 The choice of production method for lime burning

As the lime burning process is a very periferal activity of the total operation ot the mill it was originally decided in the project that the burnt lime should be delivered to the mill from outside suppliers as with other raw materials and chemicals.

The consultant during that stage of the project also advised to avoid reburning of lime sludge and also from process point of view recommended fresh burnt lime from limestone, which is frequent in the country. The main reason was the high content of silica in the bamboo - compared with common western woods as pine - and also the possible difficulties even with all precautions to wash the bamboo clean from all river mud, which also contains silica.

The silica, chemically bound in the bamboo itself, or as mud, will react with the burnt lime during the recausticizing reaction and calcium silicate ($CaSiO_3$) will precipitate together in the lime sludge.

Reburning of such a lime sludge will create severe operation problems in the rotary kiln and the recausticizing process, thus jeopardizing the preparation of the cooking chemicals and the total operation of the pulp and paper mill and must by all means be avoided.

Experimental work is going on in laboratories and pilot plants to find reliable methods to desilicate the liquor systems in other ways but can not yet be deemed fully proved and safe for continuous operation.

Another reason, mentioned earlier, is the higher investment, maintenance, and fuel cost of a rotary kiln compared with a shaft kiln and also the higher complexity and demand of skilled labour.

A comparison indicates in the case of Bai Bang about 30% more expensive investment but also following operation and maintenance costs. (This will be more exact and in detail discussed in the following Part 2 of this paper.)

Finally the rotary kiln gives a big amount of dust from the outlet end - the shaft kiln being almost dustfree. This dust has to be taken care of with expensive and complicated dust collectors.

Those are the reasons why it has been mutually decided to choose fresh limestone burning in shaft kiln for Bai Bang Pulp Mill and to arrange areas in the surroundings available for lime sludge disposal.

For the future, though, when the bamboo in 10-15 years has been substituted by pine from plantations, space has been reserved in the mill lay-out for installation of a rotary kiln for lime sludge reburning in case such an investment may be decided.

This future decision will depend on current investment calculations, also considering the general demand of both burnt lime and possibly also lime sludge in the Province of Viet Tri.

As earlier discussed a rotary kiln installation could occasionally be considered also in connection with a pulp mill where burning of limestone later on will be substituted by lime sludge reburning.

As the time span until this is deemed possible could be 10-15 years in the case of Bai Bang there is no reason to further complicate the operation of the mill and increase the different costs by such an installation already from the beginning of the mill start up.

3.3 Further motives for the decided choice of installation

Burning of limestone and use of burnt lime has been practised since many thousands of years and has all the time increased in value and dependence for many sectors of life, both in pure rural, semi-urban and highly industrialized areas.

Limestone can be found and mines are in operation in most countries and areas of the world and is used in quantities only exceeded by water, air, sand and gravel.

Burnt lime is used, often in parallel with the dissociated carbon dioxide(CO_2), for a great number of purposes, e.g. steel industry, cement industry and other building industries, sugar industry, soda industry, soil preparation etc.

Limestone and burnt lime are the cheapest and most available raw materials for production of alkalies, as is sulphur for acids.

Shaft kilns are well known and operated all over the world.

The production capacities, investment costs, fuel, power and labour demands can always be chosen at an appropriate level according to the local situation. There is a big number of more or less advanced kiln designs. The simplest possible ones can be constructed from local resources.

A shaft kiln installation in the Bai Bang Pulp Mill in Vietnam or similar plant in another developing country or area with the main reason to supply a kraft pulp mill will now and then also have the possibility to satisfy other needs of burnt lime outside the pulp mill when the mill demand or the capacity of the kiln so permits.

The kiln can also be operated independently of the pulp mill demand in question and always at the same load if there are other customers, which normally exist. This facilitates an effective operation.

Finally the lime sludge, not being recovered, may on the other hand be very valuable for soil preparation on acidic grounds.

3.4 The specific prerequisites

As there are many available suppliers of shaft lime kilns in many countries a number of different alternatives are to be studied in this case. Considerations must be taken to many factors, as:

1) Restrictions on chemical and physical properties of the limestone.
2) Kind of fuel and method of firing.
3) Manpower demand, quantity and quality.
4) Investment and operation costs.
5) Demand of utilities as power, steam etc. and there costs.
6) Degree of instrumentation.
7) Quality and quality flexibility of the produced product.
8) Possible demand of parallel produced carbon dioxide.
9) Local industrial infra-structure
10) Local experience.

PART 2

4. COST AND CONSUMPTION ESTIMATES FOR DIFFERENT SHAFT AND ROTARY KILNS

4.1 Investment costs

The total investment cost for installation of a lime kiln naturally varies much depending on many factors, as country of manufacture and erection, transports, complexity of design (admitting savings in operation costs) etc.

Based on current figures from the engineering department of one of the biggest shaft and rotary kiln manufacturers and users in the world, Onoda Cement Co., Ltd, Japan, the following installation costs are presented and found reliable. The figures were given in Japanese yen and are presented in US $ with the exchange rate 1 $ = 190 yen.

Tabel 1. Installation cost per daily ton. US $

Capacity, t/d	75	150	250	400	600	800 <
Shaft kiln	28,900	22,400	18,800	19,500 x)	16,800 x)	-
Rotary kiln	-	26,400	21,900	18,400	15,800	14,500

x) Two kilns

Table 2. Total installation costs. 1.000 US $

Capacity, t/d	75	150	250	400	600	800 <
Shaft kiln	2,170	3,350	4,710	7,810 x)	10,100 x)	-
Rotary kiln	-	3,950	5,470	7,370	9,470	11,580

x) Two kilns

4.2 Heat consumption as fuel

The following figures have also been given by Onoda and are based on Japanese experience which has been checked and coincides with other information.

Table 3. Heat consumption, kcal/kg.

Capacity t/d	75	150	250	400	600	800 <
Shaft kiln	1.100	1.000	950	975	925	-
Rotary kiln	1.700	1.600	1.500	1.400	1.350	1.300

(In case of lime sludge reburning the heat consumption is 2.000 kcal/kg or more)

The heat is consumed for decomposition of the limestone and lost as exhaust heat, radiation heat and with the product according to the following examples:

Table 4. Heat balance, shaft kiln

Heat	Kcal/kg	% of total
Decomposition	750	75
Exhaust	140	14
Radiation	100	10
In product	10	1
Total	1.000	100

Table 5. Heat balance. Rotary kiln (with preheater)

Heat	Kcal/kg	% of total
Decomposition	750	54
Exhaust	410	29
Radiation	225	16
In product	15	1
Total	1.400	100

The above tables show that rotary kilns are much more heat consuming than shaft kilns.

4.3 Power consumption

The consumption of electricity is the following:

Table 6. Power consumption

	kWh/t
Shaft kiln	40-45
Rotary kiln	35-40

These figures do not include any crushing and screening of limestone or burnt lime.

4.4 Steam consumption

The consumption of steam for heavy fuel oil heating and atomizing is 50 - 100 kg/ton.

4.5 Maintenance costs

These costs may vary depending on operation conditions etc.

As a rough average estimation the repair costs are 15-20% higher for rotary kilns. The difference comes mainly from the refractory costs.

Onoda gives following figures:

Table 7. Maintenance costs, US $/t.

	Shaft	Rotary
Refractory	0.34	0.47
Others	0.54	0.56
Total	0.88	1.03

As a total average in both cases 1 US $/ton could be used. It has to be pointed out that the shut down period for repair of a shaft kiln refractory takes several weeks, including 3-7 days starting time but max. 1 week for a rotary kiln. This has to be considered when deciding the storage capacity of burnt lime if no alternative supplier is available during the shut down periods and the demand is normal to the pulp mill or consumer in question.

4.6 Labour costs

The number of operators required for operation of both types of kilns is almost the same but could be much higher for a shaft kiln if this is designed to be operated with a minimum of transport facilities.

4.7 Plant Space

A rotary kiln plant needs about two times more space than a shaft kiln.

5. SUMMARY

5.1 The alkaline soda or sulphate (kraft) pulping process normally includes recovery of the spent sodium cooking liquor by fibre washing, liquor evaporation and burning, ash smelt dissolving and recausticizing with burnt lime to new cooking liquor and lime sludge as by-product.

Even if limestone and burnt lime belong to the cheapest and most common raw materials and chemicals different factors though have today normally changed the supply from burnt lime based on limestone burning to lime sludge reburning.

5.2 Under special circumstances, as described in this paper, limestone burning is still advisable for different reasons, as:

Fibre raw material (high silica content).
Different costs, considering lime kiln design and capacity.
Complexity and safe runability.
Alternative demand of burnt lime.
Usefulness of lime sludge.

5.3 Such a special case is the Bai Bang Pulp Mill in Vietnam:

The raw material is mainly bamboo with high silica content.
The pulp capacity is only 50.000 tons per year and the daily demand of burnt lime 50-75 tons.
The installation should be easy to erect, operate and maintain.
Alternative demand of burnt lime for other purposes may occur.
Lime sludge may be very valuable as soil preparation on acidic grounds.

5.4 In the latter part of the paper costs and consumption figures indicate, that the shaft kiln, when burning lime stone, is competitive with the rotary kiln up to at least a daily capacity of 350 tons, being the maximum capacity of one shaft kiln considering a uniform burning and product.

5.5 In the case of Bai Bang Pulp Mill and similar installations the supply of burnt lime shall be based on limestone.

If the lime burning will be done at the mill site a shaft kiln should be chosen.

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