Clean Technologies for the Pulp and Paper Industry

REPORT ON

CLEAN TECHNOLOGIES
FOR
THE PULP AND PAPER INDUSTRY, THE TEXTILE INDUSTRY, AND METAL COATING AND FINISHING IN THAILAND

Submitted to

UNITED NATIONS ENVIRONMENT PROGRAMME
(UNEP)

February 1986

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ACKNOWLEDGEMENTS

This study was funded by the United Nations Environment Programme (UNEP), Industry and Environment Office (IEO), Paris, as part of its global effort to promote the application of clean technologies for the prevention of pollution. The support of the Director and staff of IEO is gratefully acknowledged.

Research of this nature cannot be accomplished unless it draws upon the contributions of professionals from both government and industry. Foremost on our list, we are thankful to Professor Sanga Sabhasri, Permanent Secretary of the Ministry of Science, Technology and Energy, for his comments regarding the policy of the government on clean technology. Also on policy matters we would like to acknowledge the contributions of Dr. Yenchai Laohavanich, Deputy Governor of TISTR, Mr. Sangob Pandokmai, former Deputy Director of the Department of Industrial Works, Dr. Chokchai Aksaranan, Secretary-General of the Association of Thai Industries, and Mr. Ahram Kotikula, Executive Director of the Association of Thai Industries.

On technical matters, aside from the evaluation by members of the research team, comments of other local experts were also incorporated into the report. In this connection, we are grateful to Mr. Uthen Phisuthiphorn, Managing Director, Mr. Kaneung Indratanee, Mr. Vinij Ongnegnun, Mr. Chalermsak Sirikul and Mr. Soraphol Siripopankul of Siam Kraft Company who offered their voluntary collaboration with TDRI in analyzing the proposed wastewater-free paper production process.

Mr. Visid Wongboonchuoichai, Manager of Thaworn Trading, provided valuable insights on the market for low-pollutant dry-cleaning in Thailand. On metal coating and finishing, the contributions of Mr. Chaiyuth Klinsukont and Dr. Sumath Chavadej were invaluable to our evaluation.

Dr. Satian Niltawach, Asst. Prof. Suree Khaodhian and Asst. Prof. Kemchai Hemachandra from Chulalongkorn University provided useful comments on the local research work of the subjects under study.

Finally, the research team would like to thank Ms. Lana Larsen for her contribution in editing the manuscript, Ms. Chuchitt Sombunthawong and Ms. Sunee Yingpaiboonwong for typing the manuscript.

SUMMARY

The principle of clean technology is to introduce preventive measures to reduce wastes or to recover by-products rather than to rely on corrective end-of-pipe treatment of pollutants. This study evaluated the adaptability to Thailand of 13 processes in pulp and paper production, textile production, and metal finishing and coating.

The results verify that Thailand is ready to accept five of the proposed technologies. The Siam Kraft Company, a local producer of paper using wastepaper, is ready to emulate the wastewater-free closed-circuit system of its counterpart in the Federal Republic of Germany (FRG). Thailand Institute of Scientific and Technological Research (TISTR) is willing to initiate a cooperative pilot project on desilication of bagasse with the FRG. Concurrently, pulp bleaching by hydrogen peroxide and paint recovery are two processes which can be readily propagated locally, while the cost of chromium recovery in zinc-electroplating shops was found to be within the means of the local platers.

Market availability has proved to be the decisive factor which inhibits the present use of five other processes, namely low-pollution dry-cleaning, thermoprinting of polyester, cadmium electroplating, electrodeposition of aluminium, and wasteless salt bath for steel hardening. The remaining three processes are very much at the research stage in the FRG; hence their adaptability can not be determined.

The introduction of clean technology is easier in the pulp and paper industry. This is due to the universal manufacturing processes employed in different parts of the world and also to the fairly large size of the local pulp mills. In the case of textile production, the present slump in the market for synthetic fibers has arrested any chance for investment in new processes. In the metal coating and finishing arena, technologies which are applicable to the prevailing small shops must be simple and must not entail excessive investment or intensive training of the operators.

It is encouraging to reconfirm that technologies which abate pollution are also cost-effective. This clarifies why Thailand is ready to accept five proposed technologies even though there is no pollution charge which is the case in the FRG. The study also confirms the dominating role of market demand which may preempt the introduction of a clean technology. For example, cadmium electroplating is not practiced in Thailand; hence there is no market to substitute cadmium with the electrodeposition of aluminium.

Unfortunately, the study also highlights the paucity of local R & D capability, hence government should take full advantage of the research works already done elsewhere.

In summary, the time has not yet come for a wholesale promotion of clean technology. The approach should be selective, identifying the few local industries which are ready to benefit from the research and development already tested in the donor countries. The overruling factors are cost-effectiveness and product marketability. In the mean time, government should promote bilateral cooperative research and play the lead role concentrating in propagating information on the details of those technologies which can be adapted now.

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CHAPTER I

INTRODUCTION

1.1 CONCEPT OF CLEAN TECHNOLOGY

Industrial pollution is regarded as an accepted phenomenon in Thailand. There are about 90,000 registered industrial establishments in the country, one-third of which are located in the Bangkok Metropolitan area.

Among the pollutants generated from industries, those originating from metal-plating are among the most severe. To rectify this situation, effluent standards are imposed on the limit of heavy metals and cyanide. As for biological oxygen demands, major sources of industrial pollution include pulp and paper mills, textile mills, distilleries and tanneries.

In Thailand, end-of-pipe treatment to conform to effluent standards is the norm. Such practice, however, cannot reduce the volume of wastewater, only control its degree of pollution. Furthermore, the present standards do not consider the spatial factor nor the assimilative capacity of the surrounding environment of each particular locality.

The clean technologies under study in this report offer a new approach to pollution control. "Clean technologies" refer to technologies designed specifically to prevent waste emissions at the source of generation, as opposed to treating them at the end of the production process. Thus, clean technologies are designed to generate less pollution and waste than conventional technologies while saving raw materials and conserving energy whenever possible. Clean technologies include recycling, process and product reformulation, substitution with less hazardous feedstocks, and installation of more efficient equipment.

1.2 TERMS OF REFERENCE

The terms of reference (TOR) for this study are as follows:

a) To evaluate the adaptability of the following thirteen processes in Thailand:

1) Pulp and paper

Clean Tech # 1 Wastewater-free paper production technology on used paper.
Clean Tech # 2 Pulp production from domestic wood and annual plants with organic solvents as lignin extracting agents.
Clean Tech # 3 Bleaching of pulp.

Clean Tech # 4	Desilication of pulp waste liquors.

2) Textile

Clean Tech # 5	Low-pollutant cleaning process with minimum fresh water pollution by simultaneous or successive use of solvent and water in one machinery assembly.
Clean Tech # 6	Low-pollutant thermoprinting of textiles.
Clean Tech # 7	Reduction of waste water pollution caused by size.

3) Metal finishing and coating

Clean Tech # 8	Low-waste electroplating process for zinc.
Clean Tech # 9	Low-waste electroplating process for cadmium.
Clean Tech #10	Low-pollution galvanizing technology for printed circuit board production.
Clean Tech #11	Low-emission technology for electrodeposition of aluminium coatings on base materials of technical importance.
Clean Tech #12	Wasteless salt bath processes.
Clean Tech #13	Reduction and utilization of lacquer sludges.

b) To study the practical approach for inducing private industry to invest in clean technologies, to assess the research and development needed in the country, and to study the role of governmental organizations in promoting these technologies.

The thirteen processes referred to in (a) above were presented at the International Symposium on Clean Technologies, from October 7 to October 18, 1985, in Karlsruhe, Federal Republic of Germany. The descriptions of the thirteen processes were contained in the monographs compiled as the main background document of the Symposium and were used as the bases for this study.

1.3 ORGANIZATION OF THIS REPORT

Chapter II, III and IV present the analyses of the proposed technologies by local experts from both governmental research institutes and private industries. Chapter II presents the analysis for the pulp and paper industries, Chapter III for the textile industry, and Chapter IV for the metal finishing and coating industry. Each chapter will begin with a profile of the industry under investigation so that the conditions specific to Thailand can be reviewed before considering each particular clean technology. Chapter V serves as the concluding chapter with an evaluation of the feasibility of adapting the proposed technologies to Thailand, and of the role of both the government and industry in initiating such an effort.

CHAPTER II

CLEAN TECHNOLOGIES FOR THE PULP AND PAPER INDUSTRY

This chapter evaluates the adaptability of four proposed processes, namely:

Clean Tech # 1 : Wastewater-free paper production technology on used paper.

Clean Tech # 2 : Pulp production from domestic wood and annual plants with organic solvents as lignin extracting agents.

Clean Tech # 3 : Bleaching of pulp.

Clean Tech # 4 : Desilication of pulp waste liquors.

Among these four, only Clean Tech # 1: "Wastewater-free Paper Production" has been in commercial use since November 1980, whereas the other three processes are still at the research stage.

It was thus decided to evaluate Clean Tech # 1 on its actual adaptability to a local company. Siam Kraft Company, which is the foremost pulp and paper producer in the country, was selected for this purpose. The production lines of the company include those which use 100% wastepaper and were the bases for comparing both the technical and economic viability of adapting the proposed wastewater-free system.

As for the remaining three processes, the analyses emphasized their future potential to the local market in Thailand.

Before turning to specific evaluations of each proposed technology, the general profile on pulp and paper production in Thailand will be given.

2.1 PROFILE OF THE PULP AND PAPER INDUSTRY

2.1.1 Pulp and Paper Production

At present Thailand has only three pulp mills in operation viz., the government-owned Bang Pa-In Paper Mill which produces bleached pulp from rice straw wastepaper, Burma grass and imported long fibers; the Siam Pulp and Paper Company which produces bleached pulp and unbleached pulp using bagasse, and the Phoenix Pulp and Paper Company which produces bleached pulp from kenaf and bamboo. The combined production of these three pulp mills is 103,000 tons/year.

The local pulp demand is always over the supply since the annual pulp production has not increased as targeted. Table 2.1 shows the fluctuation in the demand and supply of pulp between 1977 and 1983.

The supply condition has improved in the last few years. In 1985, the Phoenix Pulp and Paper Company came into operation with an annual capacity of 70,000 tons. At present, the Siam Pulp and Paper Company is expected to expand its capacity to 50,000 tons/year. Table 2.2 provides more basic data on pulp production in Thailand. It should be noted that wastepaper is used as a raw material in both the Bang Pa-In Paper Mill and the Siam Pulp and Paper Company, and that the latter produces pulp to supply its mother company, the Siam Kraft Company.

Table 2.1 Demand and Supply of Pulp in Thailand (1977-1983)

Unit : ton

Year	Production	Import	Demand	Ratio of Production:Import
1977	30,131	86,516	116,647	26 : 74
1978	26,376	105,149	131,525	20 : 80
1979	33,056	128,526	161,582	20 : 80
1980	22,230	80,737	102,967	22 : 78
1981	21,599	113,637	135,236	16 : 84
1982	40,836	90,509	131,040	31 : 69
1983	63,334	122,340	184,760	34 : 66

Source : Industrial Economic and Planning Division, Ministry of Industry (1984), "Report on Economic Situation of Pulp and Paper Industry", Bangkok.

Table 2.2 Basic Data of Pulp Mills in Thailand

Description	Bang Pa-In Paper Mill	Siam Pulp and Paper Co.	Phoenix Pulp and Paper Co.
Location	Phra Nakorn Sri Ayuthaya on Chao Phraya River	Rachaburi, on Mae Klong River	Khon Kaen, on Nam Pong River
Type of mill	Integrated	Integrated	Pulp mill only
Products	Bleached sulfite pulp	Unbleached soda pulp Bleached soda pulp	Bleached sulfate pulp
Capacity, t/y	9,000 (pulp)	24,000 (unbleached and bleached pulp)	70,000
Raw materials			
pulp mill	Rice straw Burma grass	Bagasse	Kenaf Bamboo Fast growing trees
paper mill	Bleached rice straw and Burma grass pulp Imported long fiber pulp Wastepaper	Bleached bagasse pulp Imported long fiber pulp Wastepaper	
Pulping process	Monosulfite	Soda	Sulfate
Bleaching sequence	CEH	CEHH	CEHD
Chemical	None	Available	Available
Wastewater treatment	Sedimentation	Anaerobic and aerated lagoon	Aerated lagoon

In 1983 there were 35 pulp and paper mills in the country whose combined production capacity was 467,600 tons/year; but the actual production was only 77.65 percent of their total capacity, amounting to 363,095 tons. These paper mills manufacture various types of paper including printing/writing paper, industrial paper, sanitary paper and other special papers. The production amount is more than enough to serve the local demand, while some papers, such as industrial paper and sanitary paper, are also produced for export. Table 2.3 provides details on the production of paper in Thailand.

So far no newsprint has been produced domestically; thus the whole supply has to be imported. The local demand for newsprint is about 100,000 tons per year at the cost of over 1,000 million baht.

Table 2.3 Production of Paper in 1983

Type of paper	Number of mills 1/	Potential production (ton)	Actual production (ton)	Actual production as percentage of potential production(%)
1. Printing and writing paper	9	81,800	53,353	65.22
2. Industrial paper	20	349,300	285,396	81.71
3. Sanitary paper	6	25,200	15,440	61.27
4. Others	7	11,300	8,906	78.65
Total		467,600	363,095	77.65

1/ a particular mill may produce more than one type of paper.

Source : Industrial Economic and Planning Division, Ministry of Industry "Report on Economic Situation of Pulp and Paper Industry, 1984".

2.1.2 Wastewater Treatment

From the questionnaire survey conducted by the National Environment Board in 1984 addressed to major pulp and paper mills in the country, the general effluent treatment practices employed can be summarized as follows:

a) Screening to remove coarse materials.
b) Sedimentation.
c) Chemical coagulation, in which alum, sodium hydroxide or lime are used as flocculents.
d) Biological treatment, such as anaerobic or aerated lagoons.

Table 2.4 shows the amount and characteristics of effluents, from five selected mills.

Table 2.4 Effluent Volume and Characteristics

Name	Effluent volume (m/day)	Treated effluent characteristics COD	BOD	SS	Others
Bang Pa-In Pulp Paper Industry	25,000	787	205	390	Hg 0.002
Hiang-Seng Fiber Container	15,000	-	60	500	-
Phoenix Pulp and Paper	33,600	-	-	-	-
Siam Pulp and Paper	7,600	145	19	28	pH 7.6 DS 700 ppm
Thai Union Paper Mill	20,000	50-100	20-50	15-20	temp 35 c

Source : Questionnaire survey conducted by the National Environment Board, 1984.

2.1.3 Production Cost

Due to the high cost of production, domestic pulps are more expensive than imported ones. The price of imported pulps are approximately 11,500 baht/ton, compared to the price of domestic pulps at 11,750 to 12,500 baht/ton in 1984. As a result, both imported pulps and paper are more attractive than those which are domestically produced.

Table 2.5 shows the data on local production costs for pulp, Table 2.6 for printing paper and Table 2.7 for industrial paper.

Table 2.5 Estimation of Direct Production Cost of Bleached Pulp in Thailand

Particular	Bleached sulfite rice straw pulp 40 t/d	Bleached soda bagasse pulp 80 t/d	Bleached sulfate kenaf pulp 200 t/d
Raw materials			
wood or non-wood	7.0	14.0	16.0
chemicals	65.0	51.0	49.0
Labor cost	5.0	3.0	3.0
Operation cost			
energy	12.0	9.0	8.0
water	1.0	2.0	2.0
maintenance	3.0	2.0	2.0
depreciation	2.0	5.0	5.0
wastewater treatment	-	3.0	2.0
miscellaneous	5.0	11.0	13.0

Table 2.6 Disaggregated Cost of Production in 1983 for Printing Paper Industry.

Item	Per cent
Raw materials	
straw and Burma grass	5.93
fibers (long and short)	19.27
scrap papers	5.15
chemicals	15.02
Labor cost	13.71
Production expenses	
labor welfare fund	2.37
chemicals used in steaming process	0.37
electricity	13.78
fuel and lubricant	16.08
maintenance expenses	3.71
inventories	0.17
factory premium	0.26
depreciation cost	2.33
other costs	1.85
Total	100.00

Source : Industrial Economic & Planning Division, Ministry of Industry, 1983.

Table 2.7 Disaggregated Cost of Production in 1982 for Industrial Paper Industry

Item	Percent
Raw Materials	
1) Raw fibrous materials	
long fiber pulp	16.60
pulp produced from kenaf	1.29
pulp produced from bagasse	2.13
pulp produced from domestic wastepapers	20.26
pulp produced from imported wastepapers	14.76
2) Chemicals	3.63
Direct Labor Cost	2.38
Production Expenses	
indirect labor cost	4.65
electricity	14.31
fuel cost:-	
- bunker oil	4.39
- other oil	3.11
maintenance expenses	2.43
inventories	2.98
factory premium	0.21
depreciation cost :-	
- factory	0.73
- machinery	5.25
other cost	0.99
total	100.00

Source : Industrial Economic & Planning Div., Ministry of Industry, 1982.

2.2 CLEAN TECH # 1 : WASTEWATER-FREE PAPER PRODUCTION

This section attempts to evaluate the feasibility of adapting the wastewater-free paper production technology to Thailand.

It should be mentioned here that the proposed technology is applicable only to a production line which utilizes 100 percent wastepaper as the raw material. This closed-cycle system has been in operation in Julich, Federal Republic of Germany (FRG) since November 1980.

Since this is a well-established process in the FRG, the methodology employed in evaluating its adaptability to Thailand is to assess the economic feasibility if the process is applied to a leading local company, in this case the Siam Kraft Company. (The Siam Kraft Company and the Siam Pulp and Paper Company both belong to the same group of companies. The reason for their separation is mainly financial. In this report, their references are synonymous).

2.2.1 Conventional Technology

Siam Kraft Company is well known for its innovative approach in energy conservation and pollution control. It produces both pulp for internal consumption, and paper. It uses imported fibers, bagasse and wastepaper as the raw materials. The paper production capacity is 100,000 tons per annum.

There are five paper production lines in the plant, viz.:

1) Corrugated papers which are divided into corrugating medium and kraft liner board used in making paper boxes,
2) Multiwall sack kraft paper used in making cement, animal food, flour and chemical containing bags, including special quality paper called "Clupak",
3) Shopping bag paper,
4) Core paper, and
5) Ready-made bags.

The volume and characteristics of wastewater from major sources in the production process are shown in Table 2.8

Table 2.8 Wastewater volume and characteristics

Sources of wastewater	Production ton/day	PPM SS	PPM BOD	Flow M/day
Pulp mill	90	6000	2800	1900
Bleached plant	70	600	300	3200
Wastepaper plant	350	3000	1230	2800
Paper machine No.1 (P/M1)	200	900	380	9300
Paper machine No.2 (P/M2)	100	1200	400	3000
Printing & writing paper machine	50	200	150	2000

Note: PPM = Part Per Million
SS = Suspended Solids
BOD = Biochemical Oxygen Demand

The present wastewater treatment follows the conventional process using a combination of anaerobic ponds and aerated lagoons. This is typical of the process employed in Thailand taking advantage of the availability of land and the tropical climate which fosters natural degradation of biochemical pollutants. The treated wastewater from the aerated lagoons is also used successfully in irrigating the adjacent sugarcane plantations. The wastewater treatment system is shown diagrammatically in Figure 2.1.

The treated effluent characteristics before discharged into the river are as follows:

Volume not exceeding	30,000	m^3/day
DS (dissolved solids)	855	ppm
SS (suspended solids)	24	ppm
BOD	19.8	ppm

In 1985, the wastewater treatment expenses totalled 10,500,000 baht, 73% of which were energy costs.

The average treatment cost is approximately 1.25 baht per 1 m3 of wastewater.

2.2.2 Proposed Technology

The main improvement in adapting the proposed technology is to introduce the closed-water cycle. This is limited to wastepaper plants number 1 and 2 and paper machines number 1 and 2 (see Figure 2.1). It should be mentioned that in this case the engineers of the company are considering the modification of the existing production system. The planned closed-water cycle is intended to complement the existing system not to supersede it.

There were two components in the feasibility study. First, experiments were conducted on the effect of sludge recycling on the quality of paper. Second, the proposed system was tentatively designed to fit the existing conditions in the mill and an economic feasibility analysis was undertaken. For easy comparison, the flow diagram of the system in use in the FRG is attached as Appendix A.

Effect of sludge recycling on paper quality

The most important factor to be taken into consideration before deciding whether to apply the closed-water cycle system is the impact of such process on the quality of the paper to be produced.

In the experiments conducted by the company, sludge from Paper Machine # 2 was mixed with wastepaper pulp to produce corrugated medium (CM) by using an experimental paper machine at the following wastepaper pulp to sludge ratio of 100:0, 95:5, 90:10 and 80:20, respectively.

The results of the experiments can be summarized as follows:

a) The retention values which reflect the fiber contents of the produced paper were 93.0% at the sludge ratio of 5%, 92.2% at the sludge ratio of 10% and 83.4% at the sludge ratio of 20%. The results indicated that the fiber content in the produced paper will be reduced as the sludge ratio is increased.

b) The freeness value at the sludge ratio of 20% is 266 ml. CSF (Canadian Standard Freeness) compared with 368 ml. CSF at the sludge ratio of 0% (100% wastepaper pulp). The reduction in freeness value reflects the retardation in the rate of water drawing from the pulp which can finally slow down the speed of paper production.

c) The color of paper produced from sludge recycling was darker than that produced from wastepaper pulp alone.

d) Despite the three mentioned inferior characteristics of the paper resulting from the sludge recycling process, the overall paper quality index (QI) increased by 20% at the sludge ratio of 10% and 29% at the sludge ratio of 20%. The increase in the paper quality index was the result of recycling sludge from Paper Machine # 1 (which only produces high quality paper) as a raw material for Paper Machine # 2 (which produces inferior-quality paper).

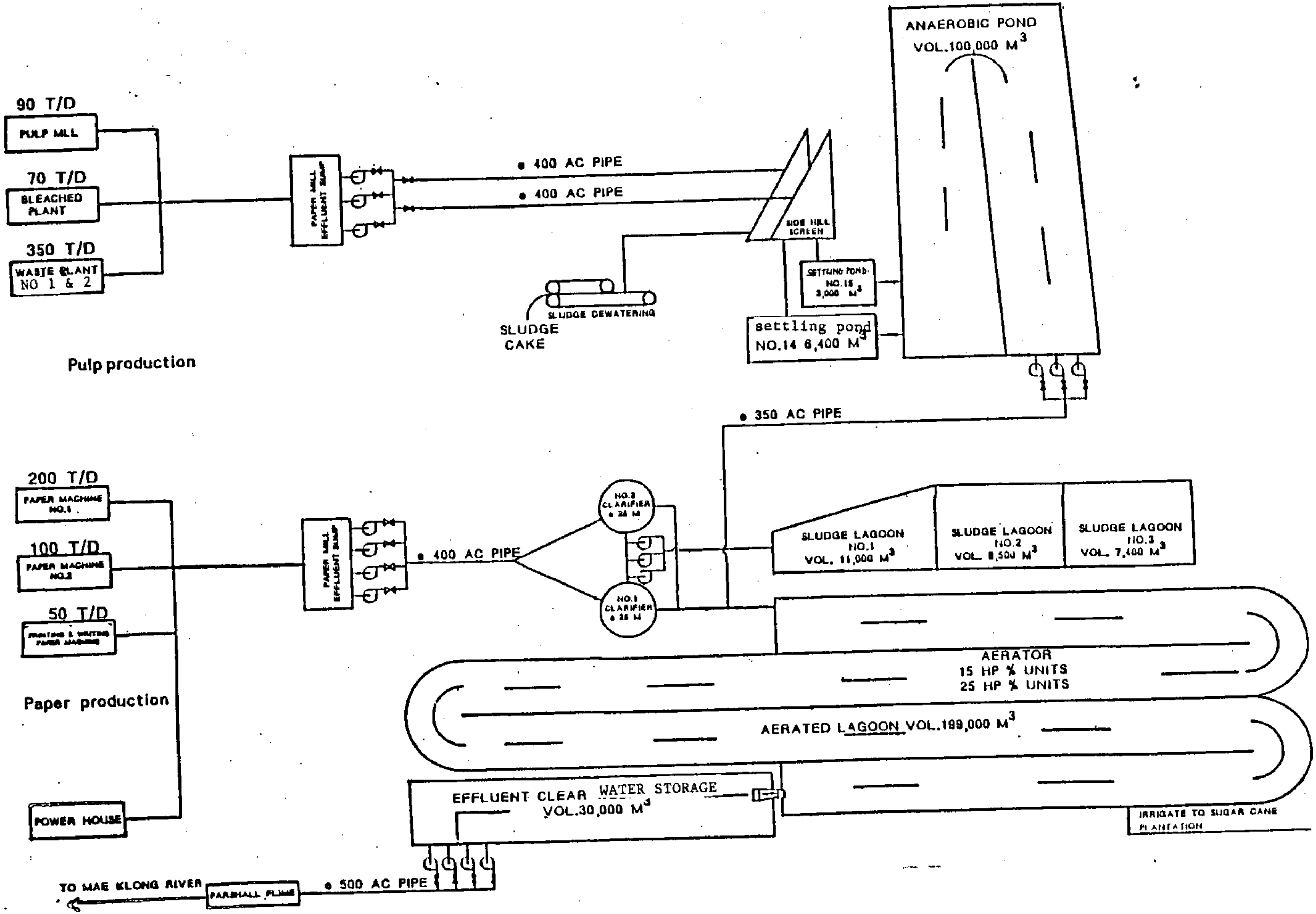


Figure 2.1 Wastewater Treatment System of Siam Kraft Company

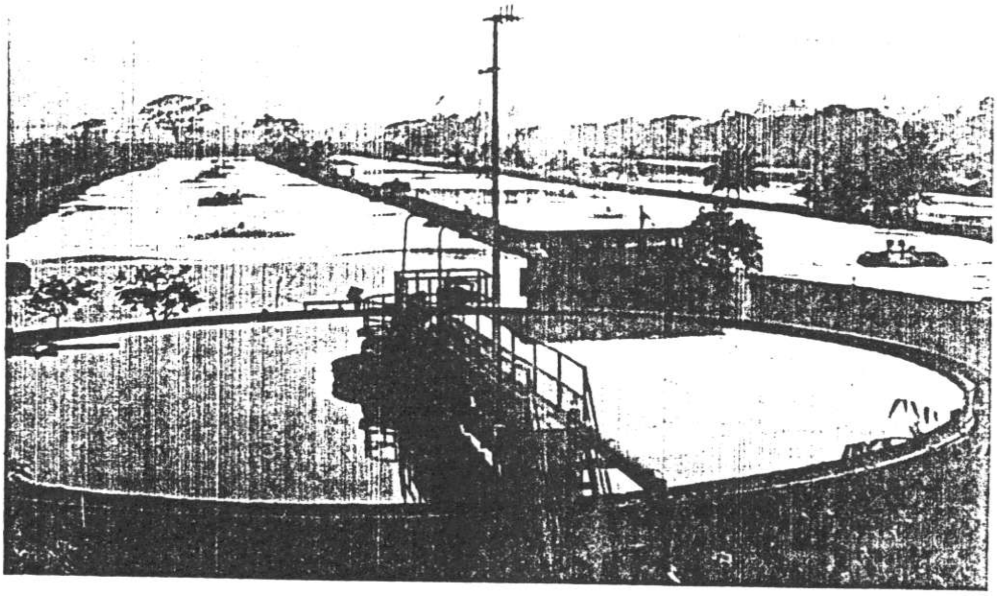


Figure 2.2 Wastewater Treatment at Siam Kraft Company

In conclusion, the overall paper quality can be increased as a result of sludge recycling. However, the sludge ratio should be limited to within 10 percent so that the retention and freeness value will not become too low.

Feasibility of the closed-water cycle

Since the wastewater from the pulp mill and the bleached plant are heavily colored, the closed-water cycle was designed to apply only to wastewater from the wastepaper plants and Paper Machines # 1 and # 2. The designed closed-water cycle system is shown in Figure 2.3.

Following the experience in the FRG by maintaining the suspended solids (SS) in the recycled water below 50 ppm., sedimentation cones were designed with a volume of 150 m and 800 m. After treatment at the sedimentation cones, the wastewater passes through fine filters before it reaches Paper Machines # 1 and # 2. Sludges from the two Paper Machines are then mixed at the appropriate ratio with wastepaper pulp for Paper Machine # 2 only. Sludge from the wastepaper plant is sent to the sludge dewatering press and will later be burned as fuel.

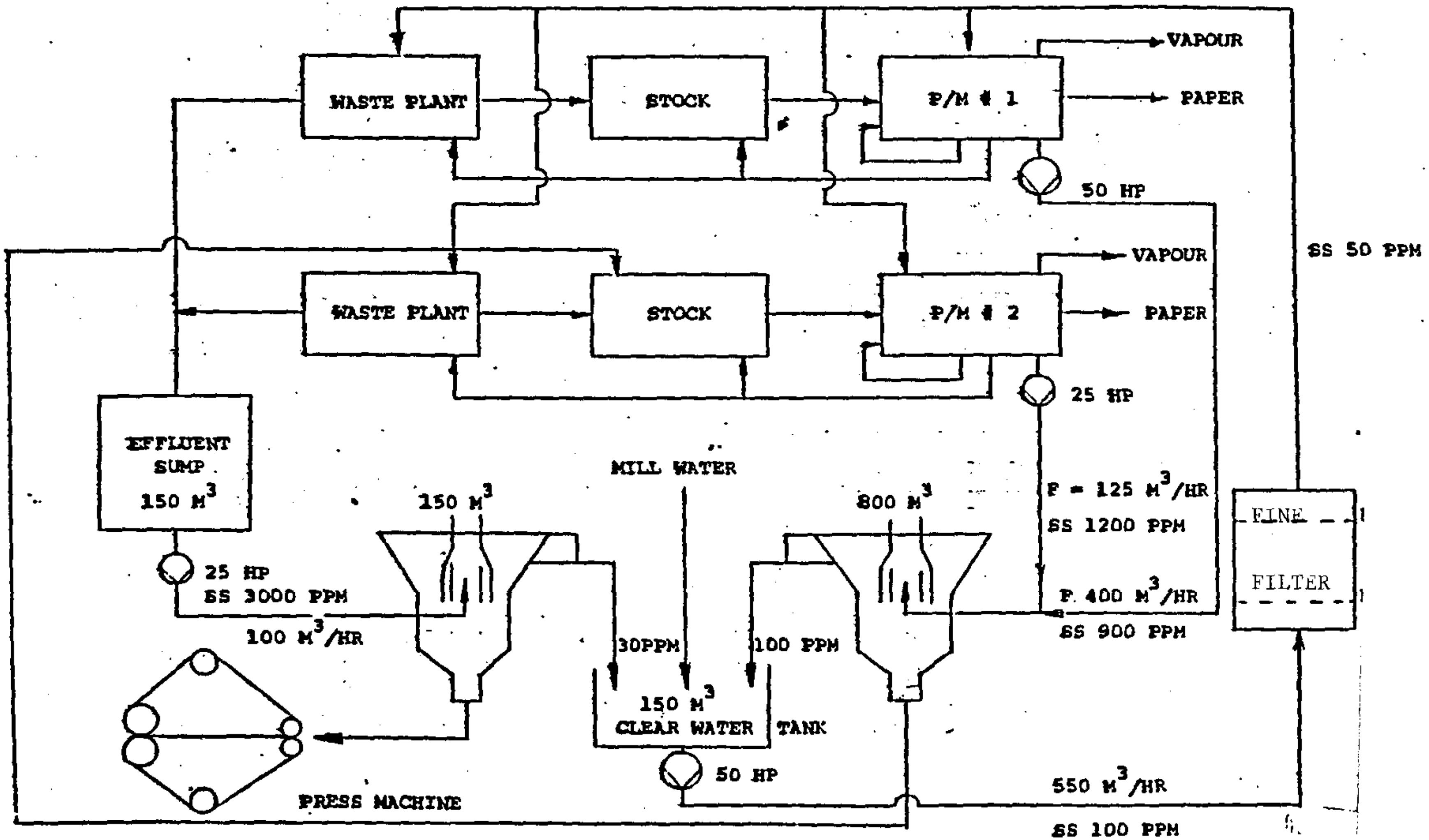


Figure 2.3 Proposed Closed-water Cycle at Siam Kraft Company

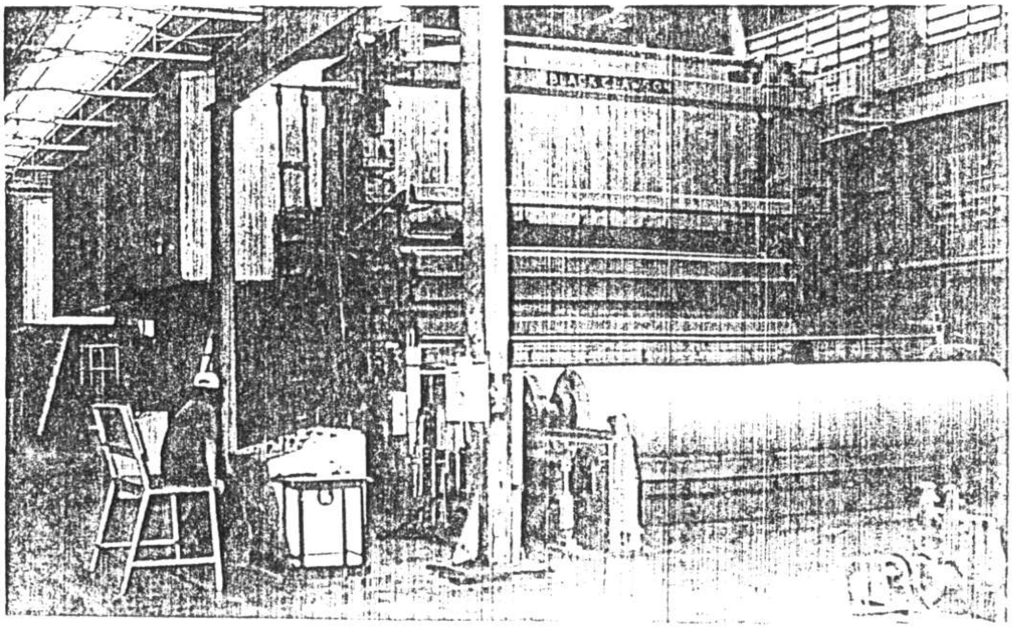


Figure 2.4 Paper Machine #1 at Siam Kraft Company

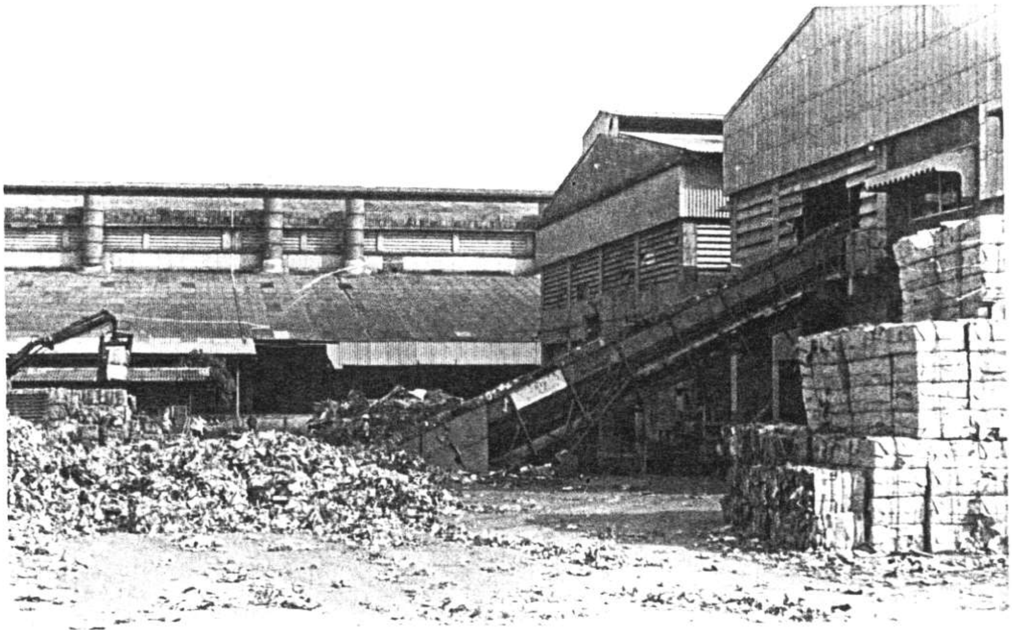


Figure 2.5 Wastepaper Serving as Raw Material at Siam Kraft Company

Financial analysis

This section provides a preliminary financial analysis to consider the feasibility of investing in the closed-water cycle system.

Investment Costs		Baht
Sedimentation cones	800 m	5,000,000
" "	150 m	2,000,000
Clear water tank	150 m	300,000
Effluent sump	150 m	300,000
Fine filter	2 units	2,000,000
Press machine	1 unit (20 kwhr)	5,000,000
Pump and piping	4 unit (150 kwhr)	2,000,000
	Total	16,600,000
	Contingencies 10%	1,660,000
	Grand total	18,260,000

Operating costs		Baht/year
Labor cost (3 men)		150,000
Maintenance		500,000
Power consumption (170 kwhr)		2,450,000
Chemicals		2,920,000
Contingencies 30%		1,806,000
	Total	7,826,000

Revenues generated		Baht/year
Fiber recovery 5 tons/day		3,832,500
Cost saving on wastewater treatment (15,000 m/day)		6,840,000
Cost saving on water intake (15,000 m/day)		3,550,000
	Total	14,222,500

Assuming an interest rate of 17.5 percent on an investment loan of 18,000,000 baht, and an annual revenue which will exceed operating costs by 6,396,500 baht, the investment can be totally recovered in 4 years. This project is financially sound.

2.2.3 Conclusion

In considering the adaptability of the proposed system, the local conditions must be the deciding factors.

a) Wastepapers used to prepare pulps in Thailand are dirtier than their counterparts in the developed countries. Sludge from the wastepaper plant is thus too polluted to be recycled as in the case of the FRG. It can be burned as fuel instead.

b) The engineers at Siam Kraft questioned the need for secondary treatment of wastewater after it is passed through the sedimentation cones. The maximum BOD allowance in the recycled system must be clarified in the final design. In any case the 10% contingencies provided in the calculation of the investment costs should be sufficient for the construction of a trickling filter, if it is necessary.

c) The mechanism to regulate the ratio of sludge and wastepaper pulp needs to be tested in the field.

d) In the plant under consideration, the closed-water system was designed in such a way that Paper Machine # 1 will be limited to only produce high quality paper while Paper Machine # 2 will concentrate on lower grade papers such as corrugated medium. This is feasible because the company already plans to add a new Paper Machine # 3 to respond to increasing demand.

2.2.4 Recommendation

In summary, the proposed closed-water system looks promising to the Siam Kraft Company. The next step is to acquire more detailed information for final financial analysis. Field trips to observe the system in progress in the FRG should also be encouraged.

2.3 CLEAN TECH # 2 : MD ORGANOSOLV PROCESS

Pulping processes in use universally are sulfate and sulfite processes, both of which must be treated by sulfur-containing chemicals to digest lignin. These sulfur-containing chemicals can not be easily recovered and are pollutants in themselves. Apart from this, the residuals, mostly lignin, are of restricted use and low in value.

Pulping with organic solvents (the Organosolv process) is thus a promising solution. It is particularly advantageous for the small production of pulp (less than 100 tons/day). However at present, this technology is still at the laboratory stage, with experiments of up to 20 kgs. of pine wood per run only.

2.3.1 Principles of the Organosolv Process

In the proposed process, water and alcohol (preferably methanol) are mixed with caustic soda. Alcohol is used to replace sulfur-containing chemicals for digestion by taking into account the solubility of lignin. The pulping temperature of 160° - 200° C is considered most appropriate and the process can be conducted in two steps.

First, approximately 20% of the lignin, and the principal proportion of hemicellulose and the extractive components are brought into solution with a mixture of methanol and water at a temperature of around 195° C. The second stage is pure delignification by adding caustic soda for better lignin solubility, with a treating temperature of 175°C.

It should be noted that a maximum digestion time of about 45 minutes is needed for the continuous sulfate process. Also, an attempt has been made to perform these two stages in one digester but separated from each other hydraulically.

Chemical recovery is simple and easily controlled by using a relatively plain combination of downstream evaporators and distillation columns. During the first stage, lignin will precipitate on evaporation of methanol and can be separated from the aqueous solution of hemicellulose and extractive substances by centrifugation.

At the second stage, lignin can be precipitated only by acidification of aqueous alkaline lignin solution. Study on the feasibility of electrochemical process in order to precipitate lignin and recover caustic soda by not having to add more chemicals to the system is also in progress.

There has been a comparison of the pulp qualities obtained from the sulfite and sulfate processes. The pulps produced are characterized by an extremely low resin content and contains a very high degree of absorbancy in addition to its quality of good strength.

Lignin derived from the Organosolv process has the property similar to that of the natural produce. When used as fuel, lignin contains no sulfur, and has a calorific value of about 25000 kj/kg in a dry state.

Unfortunately these trials are still at the laboratory scale. Data on materials, energy requirements and cost cannot yet be made available until a pilot plant has been built and put into operation.

2.3.2 Advantages of the Organosolv Process

The advantages of the Organosolv process are listed below.

1) In conventional sulfate and sulfite pulping processes, there are emissions of pollutant gases viz., SO_2 , H_2S and mercaptan. These pollutants release a strong odor. With the Organosolv process, these problem are solved since no sulfur will be required.

2) The Organosolv process uses methanol with water, of which boiling points are very different. Only evaporation and distillation are needed for recovery. Besides, the only chemical used is NaOH; thus recovery will be greatly facilitated.

3) Lignin as the by-product can be widely used:
- as surface active polymer,
- as raw material for the production of other chemicals,
- as hemicellulose for biotechnological use.

4) Emission can be treated easily since there is no sulfur.

5) The process may be adapted for other woods, particularly high-resin woods.

2.3.3 Comparison with the Existing Process

The comparison between the Organosolv and other conventional processes in use in Thailand is tabulated in Table 2.9.

Table 2.9 Comparison of the Organosolv Process and Conventional Pulping Processes

Description	Conventional pulping processes in Thailand			Organosolv process
	Sulfite	Soda	Sulfate	
Technical Aspects				
Process-pulping	batch sulfite	continuous soda	continuous sulfate	two stages cooking with alcohol and caustic soda by batch digestion
- temp, C	165	170	170	160-200
- time, min.	240	45	45	45
Input requirements				
- wood raw materials	rice straw, Burma grass	bagasse	kenaf, bamboo, Eucalyptus	pine
- energy/unit of pulp	<----------	less than Organosolv	---------->	more than conventional
- chemicals,%of oven-dried pulp				
- NaOH	3.5	15	17-19 (Na_2O)	exact amount not available
- Na_2SO_3	10	not used	not used	not used
- Na_2S	-	-	13-25(Sulphidity)	not used
- Methanol	not used	not used	not used	exact amount not available
Pulp quality				between sulfite and sulfate pulp
Economic Aspects:				
1. installation cost				Small increasing, additional digestion unit may be needed
2. economy of scale,t/d	40	80	200	50-100
3. by-products	none	none	none	lignin, hemicellulose, biogas and waste water sludge
Degree of Pollution	sulfur emissions	-	sulfur emissions	no sulfur emission

2.3.4 Recommendation

As mentioned earlier, there is a good prospect for the application of the Organosolv process. The only foreseen disadvantage is the energy requirement which is higher than the conventional processes.

The results of the research on this clean technology should thus be closely monitored and made available to interested developing countries such as Thailand.

2.4 CLEAN TECH # 3 :
LOW-POLLUTANT BLEACHING OF PULP

Pollution control in the pulp and paper industry has often been cited as a success story. In the last decade, the volume of water consumed in pulp and paper production has drastically decreased resulting in a significant reduction of the oxygen demand in the effluents. This development has enabled scientists to turn their attention to solving a more potent problem - the treatment of toxic chlorinated organic compounds.

2.4.1 Proposed Clean Technology

For the proposed clean technology, hydrogen peroxide is used as the pre-bleaching agent in lieu of chlorine or chlorine dioxide. By this substitution, the effluents will be free from the toxic chlorinated organic compounds.

The application of hydrogen peroxide is in practice in the FRG for several reasons:

1) To use H_2O_2 in the pre-bleaching stage as a lignin removing agent in place of the mechanical pulp bleaching process which has been in practice for decades, but which retains lignin.

2) To replace elemental chlorine with H_2O_2 as far as possible in the C/D (chlorination/chlorine dioxide) stage of pre-bleaching. The introduction of P (hydrogen peroxide) eliminates the formation of harmful organochlorine compounds and their release into the environment.

3) To optimally collect, evaporate and concentrate the alkaline bleaching process effluent from the P and P/E (peroxide/NaOH) stages so that it can be utilized or incinerated and hence reduce the emission of biologically undegradable bleaching processed wastewater.

4) To test whether the wastewater from the bleaching process without C/D in pre-bleaching would be biologically easier to degrade.

From the experience in the FRG, it has been found that the introduction of hydrogen peroxide bleaching led to the reduction of BOD, COD and DOC in a calcium sulfite pulp of as much as 40%.

2.4.2 Comparison with Chlorine Bleaching

As mentioned earlier, the conventional bleaching process by delignification with chlorine and/or chlorine dioxide generates organochlorine compounds in the effluent which is toxic.

In Thailand, the effluent standard for pulp and paper mills covers only BOD of not more than 100 mg/l. There is no control of organochlorine compounds.

In addition H_2O_2 could degrade the hemicellulose at the removal of lignin. Hemicellulose degradation causes low pulp yield and strength loss.

Table 2.10 compares the particulars between the conventional chlorine bleaching and the proposed hydrogen peroxide bleaching.

Economic comparison

The main difference in the proposed clean technology is the use of hydrogen peroxide as the bleaching agent. The use of this new bleaching chemical has been under experimentation in the FRG in the last ten years for sulfite pulping. The hindrance to its full scale commercial application is its cost. Whether this is also the case in Thailand, will now be discussed.

Comparison is made between chlorine bleaching and hydrogen peroxide bleaching of pulp with Kappa # 35 as shown below:

Chlorine bleaching

Chlorine (100%) requirment in the bleaching process	70 kg/ton of unbleached pulp
Price of Chlorine solution (containing only 6% Chlorine)	1,500 baht/ton
Chlorine solution (6%) required in the process (to yield 70 kg Chlorine)	1,166.67 kg/ton of unbleached pulp
Therefore, the cost of the Chlorine solution (6%) will be	1,750 baht/ton of unbleached pulp

Hydrogen peroxide bleaching

H_2O_2 (100%) requirement in the bleaching process	13 kg/ton of unbleached pulp
Price of H_2O_2 solution imported from Taiwan (containing only 25% H_2O_2)	950 baht/30 kg or 31.67 baht/kg
H_2O_2 solution (25%) required in the process (to yield 13 kg of H_2O_2)	52 kg/ton of unbleached pulp
Therefore, the cost of H_2O_2 solution (25%) will be	1,646.84 baht/ton of unbleached pulp

Both bleaching chemicals cost more or less the same; however since H_2O_2 vaporizes easily and is explosive, it requires additional handling and storage facilities. These factors should also be taken into consideration.

2.4.3 Recommendation

By using hydrogen peroxide as the bleaching agent, the generation of organochlorine compounds can be avoided. This process is ready to be promoted to the private sector.

Table 2.10 Comparison of P/E Pre-bleaching Stage of Beech and Spruce Sulfite Pulp and Rice Straw Sulfite Pulp Chlorination in Thailand. 1/

Description	Conventional process	Clean technology
Technical Aspects:		
Process		
- bleaching	C-E stage	C/D - P/E stage
- temp C	room (C) stage 70 (E) stage	70-75
- time, hrs	1	2
Input requirements		
- raw material	rice straw sulfite pulp	Beech and spruce sulfite pulp
- energy/t of ovendried pulp	not available	No significant increase from conventional process
chemicals,% of ovendried pulp C/D, Chorine	required amount depending on Kappa no.	10-20 of the originally required amount
- E, NaOH	2	-
- P/E, NaOH	not used	1.5-2.5
H_2O_2	not used	0.7-1.3
Pulp properties at 40-50 °SR		
- brightness(elrepho), %	85	94-96
- breaking length, m	5,000	3,900-7,000
- bursting strength, kp/cm	-	1.5-3.5
- tear resistance, cmg/cm	91	60-150
Economic Aspects:		
1. installation cost		small increasing of accessories to the process line
2. economy of scale, t/d	40	any size
3. by-products	none	none
Degree of Pollution		
Toxicity	contains toxic substances due to chlorides and chlorine compounds	less organochlorine compounds
Pollution load		45-50% COD reduction

1/ It should be added that the local consumption only requires 85^{0} brightness in the paper produced.

2.5 CLEAN TECH # 4 : DESILICATION OF BLACK LIQUOR FROM RICE STRAW PULPING

In using nonwood annual plants (rice straw, bagasse, kenaf, bamboo, etc.) as raw materials for pulping, the main disadvantage is their high silica contents. The presence of calcium silicate inhibits the recausticizing process, and thus entails higher costs. Furthermore, it lowers the efficiency of the equipment, particularly evaporators and boilers.

The proposed technology has been under research in a pilot plant in Egypt for the past 10 years and uses rice straw as the pulping material.

2.5.1 Proposed Clean Technology

The desilication step is usually added before the evaporation step. The proposed technology uses carbon dioxide from flue gas as the conditioner, thereafter the silica sediment can be separated. (Figure 2.6)

The desilication process began by freeing suspended solids from weak black liquor by a drum filter in order to avoid the scaling problem in the evaporator (for preconcentration). The filtered liquor is then reused in pulp washing until its total solid content is increased from 1.5-3.5% to 8-20%.

The preconcentrated black liquor is later passed through a precipitator (reaction tank) for reacting with carbon dioxide mixed in the flue gas from the boiler. With a one-hour retention time in the tank the pH of the black liquor is reduced from 11 to 9.5. The precipitated silica is then be discharged with the desilicated black liquor to a centrifugal separator to separate the silica-containing sludge.

The desilicated black liquor is then processed through the normal conventional treatment, while the sludge is burned in a vertical combustion chamber by the use of fuel oil. Lignin and other organic substances will be burned until only sludge with a high silica content is left, which can also serve as a raw material in the glass industry. The flue gas dust from the combustion chamber must be treated by water scrubbing before disposal.

2.5.2 Comparison with Conventional Technology

The main advantages in introducing desilication are:

a) To improve equipment efficiency by
   (1) Increasing the efficiency of the drum filter by reducing screen blocking.

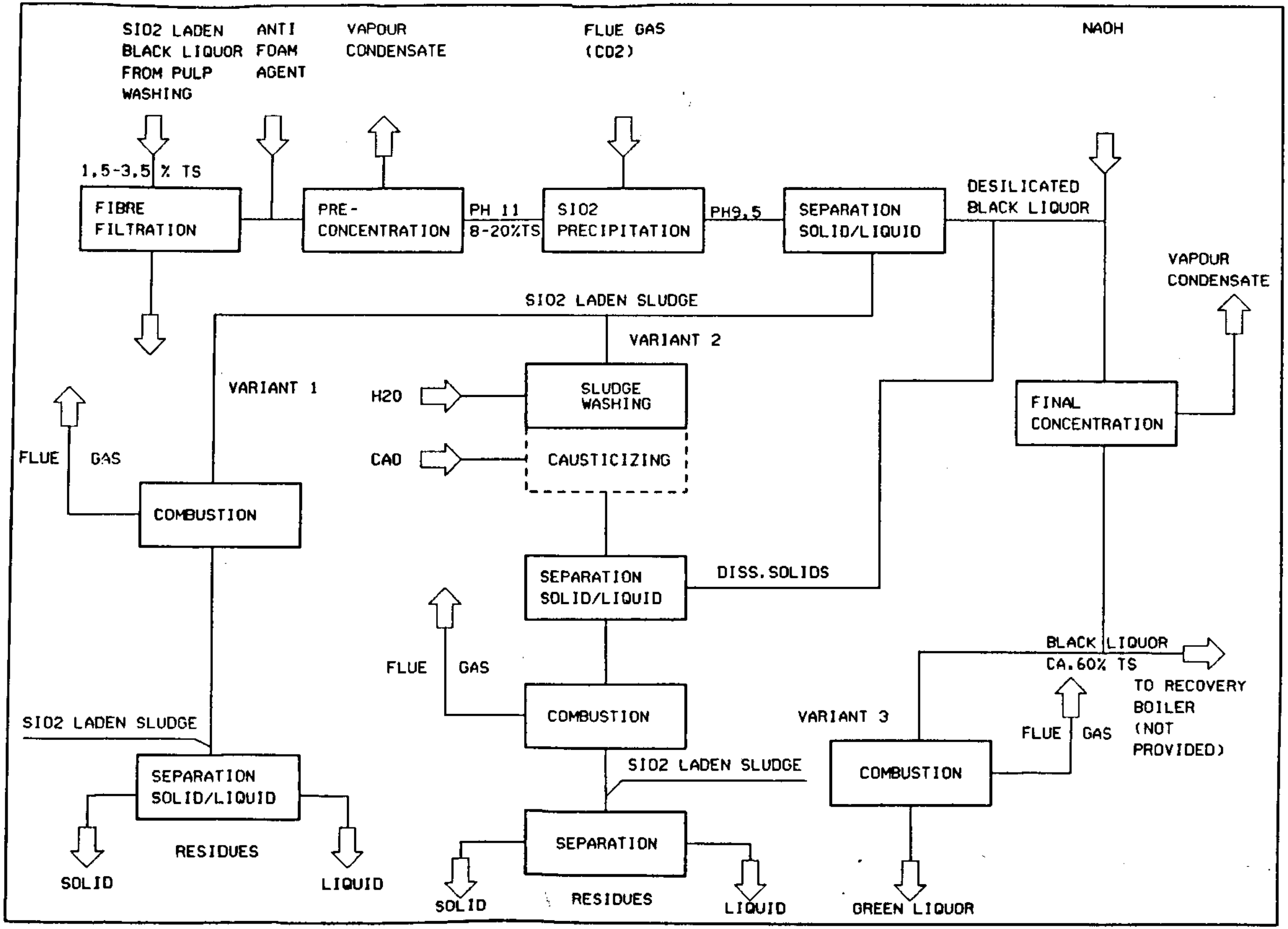


Figure 2.6 Desilication of Black Liquor

(2) Decreasing the depreciation and increasing the efficiency of the evaporator and the recovery boiler with less silica scaling needed.

b) To facilitate the recausticizing process for the recovery of caustic soda (sodium hydroxide). Through desilication, silica (SiO_2) will be eliminated, hence calcium silicate ($CaSiO_3$) will not be produced. In the recauticizing step, caustic soda can then be chemically recovered in greater quantity.

Futhermore, without calcium silicate in the lime mud, lime (CaO) can be recovered for reuse back in the recausticizing step.

Table 2.11 compares the salient characteristics between the proposed and the conventional processes.

2.5.3 Pilot Plant in Thailand

As shown in Table 2.2, all three pulp mills in Thailand use annual plants as raw materials, viz., rice straw, Burma grass, bagasse, kenaf and bamboo. The repercussion is that equipment damage from silica deposits has become a real problem. Due to its volume, bagasse containing between 0.3 to 3.5% by weight of silica, is the main concern. Both the Government and the pulp and paper industry are ready to support a pilot project similar to the one in Egypt.

Table 2.12 lists all seven agencies or companies which are active in various aspects of research on pulp and paper. Among these seven, the Thailand Institute of Scientific and Industrial Research (TISTR) is the most suitable to take the lead. As a government agency, the results of its pilot study can be widely propagated to all interested mills.

There are more than 10 professional staff with research experience in pulp and paper in the Chemical Industry Department of TISTR. Besides, this state enterprise has complete lab-scale equipments needed for all experiments on chemical pulping. Its laboratory on pulp and paper has been in operation for more than 20 years. Under contract, TISTR regularly provides lab services to all existing pulp mills in the country including quality testing of both pulp and paper.

2.5.4 Recommendation

The on-going research in Eqypt does not require complicated technology and is of interest to the local pulp mills. A parallel pilot plant should be initiated in Thailand emphasizing other annual plants such as bagasse. TISTR has expressed its willingness to cooperate with a foreign partner for such an endeavor.

Table 2.11 Comparison of Desilication Process and Conventional Chemical Recovery System in Thailand

Description	Conventional system in Thailand			Desilication process
Technical Aspects:				
Process				
- pulping	soda, kraft and sulfite 1/			soda
- chemical recovery	sulfite mill - none kraft and soda mills- only recausticizing, lime is not recovered			conventional process with desilication step added before evaporation
Input requirements				
- raw materials	rice straw2/, Burma grass, bagasse, kenaf, bamboo and Eucalyptus			rice straw 2/
- energy/unit of pulp production	less consumed			more consumed
- chemicals	more required of both caustic soda and lime			less required of both caustic soda and lime
Pulp properties	likely to be a little lower			higher 3/
Economic Aspects:	cannot yet be compared, due to the unavailability of economic data of the proposed process, while the production cost data of local mills are kept confidential.			
C. Degree of pollution	Sulfite mill	Soda mill	Sulfate mill	
wastewater volume, m3/t pulp	409	40	220	95% reduction in the degree of pollution
COD, mg/l	4,297	-	655	
BOD, mg/l	1,335	880-1,000	221	
SS, mg/l	1,098	1,500	280	
DS, mg/l	-	3,500	1,842	
pH	7.56	7.8	3.8	
Temp, C	33.6	40	-	
Others	Hg 0.038 ppm	-	-	

1/ Characteristics of weak black liquor under experiment in Egypt are similar to those of soda and kraft pulping processes.

2/ Rice straw is a raw material with most silica content (about 11%)

3/ Silica treatment will reduce accumulation of calcium silicate and lignin in recycled white liquor. Therefore the deposition of silica and silica compound on fibers can be decreased.

Table 2.12 Present status of R&D in pulp and paper industry in Thailand (1986)

No.	Name of organization	Type	Technical staff	Equipment for production research	Testing equipment	Field of research work	Note
1.	Thailand Institute of Scientific and Technological Research (TISTR), Ministry of science, Technology and Energy	Government	X 1/	X	X	- Raw materials - Processes - Testing	Contract services as well as technical co-operation
2.	Department of Science Service, Ministry of Science, Technology and Energy	Government	X	X	X	- Testing	Testing services
3.	Forest Products Research Division, Royal Forest Department, Ministry of Agriculture and Co-operatives	Government	X	X	X	- Wood raw materials	
4.	Faculty of Forestry, Kasetsart University, Office of State Universities	Government	X	X	X	- Academic	
5.	Bang Pa-In Paper mill, Ministry of Industry	Government	X	X	X	- Testing	In-plant quality contract only
6.	Siam Pulp and Paper Co.	Private	X	X	X	- Raw materials - Processes - Testing	Mill R&D and In-Plant quality control only
7.	Phoenix Pulp and Paper Co.,	Private	NA	NA	X	- Testing	In-plant quality control only

1/ shows the availability of specific activity.

CHAPTER III

CLEAN TECHNOLOGIES FOR THE TEXTILE INDUSTRY

The objective of this chapter is to evaluate the adaptability of the following processes in Thailand:

Clean Tech # 5 : Low-pollutant Cleaning Process.
Clean Tech # 6 : Low-pollutant Thermoprinting of Textiles.
Clean Tech # 7 : Reduction of Wastewater Pollution Caused by Size.

The profile of the existing status of Thailand's textile industry emphasizing synthetic fiber production and printing, due to their relevance to the proposed technologies, will be given. Subsequently, the proposed technologies will be evaluated with an analysis of both pros and cons, the R & D needed and recommendations for their future potential in Thailand.

3.1 PROFILE OF THE TEXTILE INDUSTRY

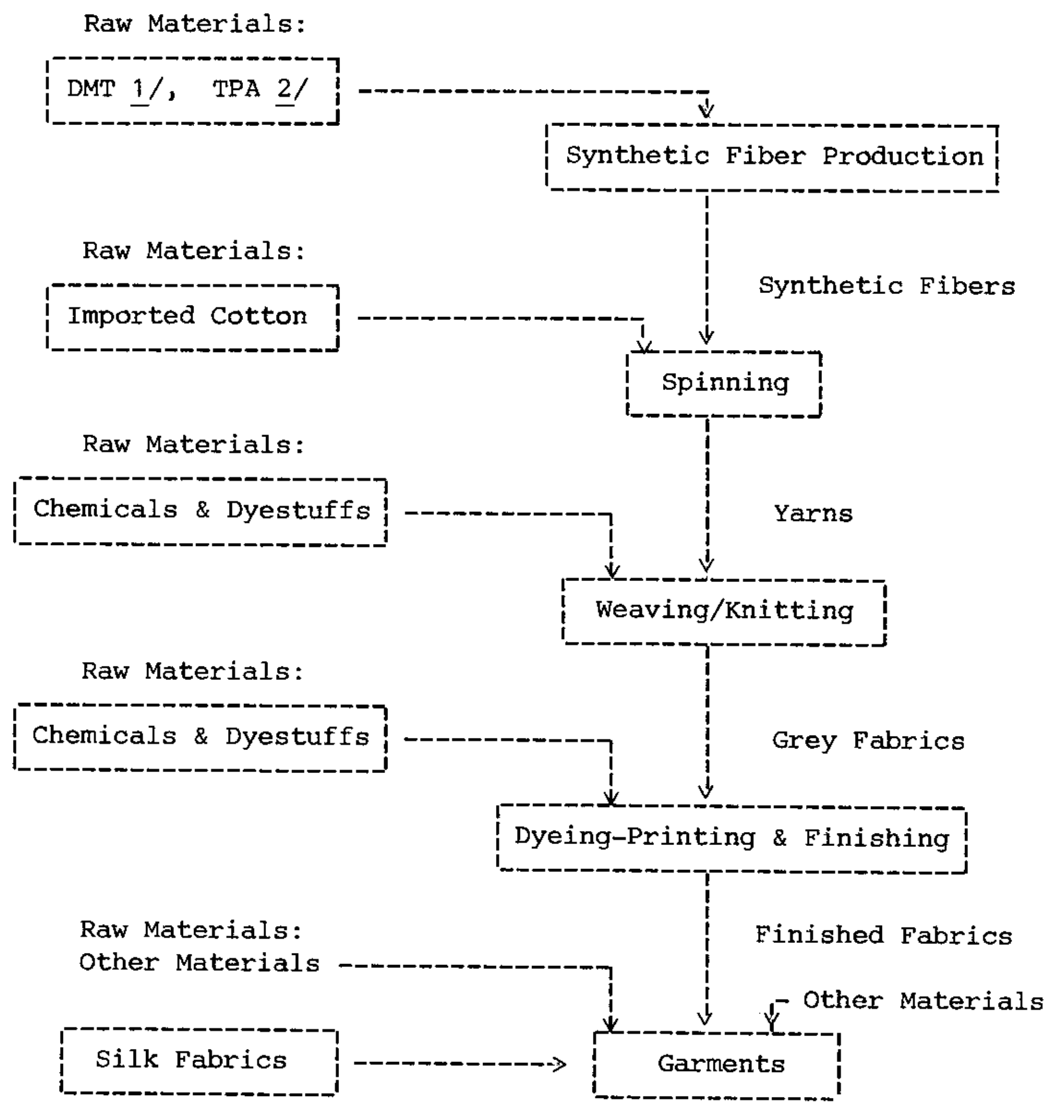
The textile industry is playing an important role in Thailand's economy. Its rapid growth over the last 20 years has catapulted the industry to the present position as the nation's largest manufacturing industry employing the largest number of Thai labor.

In 1983 Thailand manufactured 35,249 million baht worth of textile products, directly employing 541,879 workers. Thailand exports garments, yarns and fabrics of both cotton and synthetic fibers, in grey and finished form to its major markets in the USA, member countries of the European Economic Community (EEC), Middle East, Japan, Singapore and Hong Kong. Sales to the USA and EEC are restricted by quotas. In 1984 Thailand earned 18,500 million baht from the export of all textile products, second only to rice in the list of country's main exporting goods. In terms of production, in 1984 Thailand produced a total of 2,330 million square yards of fabrics, 10.8 per cent of which were synthetic.

The textile industry, according to its production processes, is composed of five main sectors namely, fiber production, spinning, weaving and knitting, dyeing-printing and finishing, and garment production. The industry may be characterized as a chain industry as each sector is related to the others in such a way that the product from one sector will be the raw material of the subsequent sector and so on, as shown in the schematic diagram of Figure 3.1.

3.1.1 Synthetic Fiber Production

The production of synthetic fibers for domestic consumption started in Thailand in 1969 and increased rapidly. In 1973 Thailand began to export these products. At the end of 1985, there were seven manufacturers, with a monthly combined capacity of 8,380 tons of polyester, 1,500 tons of nylon and 1,500 tons of rayon. The producers and their production capacity are shown in Table 3.1.



1/ Dimethylterephthalate
2/ Terephthalic acid

Figure 3.1 Structure of the Textile Industry

Table 3.1 Production Capacity for Synthetic Fibers

Unit : Ton/month

Producer's name	PE/SF	PE/FY	POY	Nylon/ FY	Rayon	Total
Asia Fibre Co.,Ltd. 1/	-	-	-	300	-	300
Hantex Corporation	-	-	-	400	-	400
Oriental Fibre Co.,Ltd.	-	-	240	-	-	240
Teijin Polyester 1/	3,800	1,200	-	-	-	5,000
Thai Melon Polyester 1/	1,800	600	-	-	-	2,400
Toray Nylon Thai	-	500	240	600	-	1,340
Thai Rayon Co.,Ltd. 1/	-	-	-	-	1,500	1,500
Total production capacity	5,600	2,300	480	1,300	1,500	11,380

PE/SF = Polyester Staple Fiber
PE/FY = Polyester Filament Yarn
POY = Pre-oriented Yarn
FY = Filament Yarn

1/ with polymerization unit

This sector of the textile industry employs about 4,400 workers of both unskilled and semi-skilled labor. The workers are better educated and trained than those working in spinning and weaving. Due to its recent history, relatively new and modern equipment and machineries are in use.

Production Processes and Technology

The production processes employed in Thailand may be classified, according to the nature of raw materials, into two types, viz.:

a) Those with a polymerization unit, employing monomer substances as raw materials to produce polymer chips, fibers and filaments. The raw materials used in this type are:

- Dimethylterephthalate (DMT), terephthalic acid (TPA) and ethylene glycol (EG) for polyester.
- Caprolactum for nylon.
- Wood pulp for rayon.

b) Those without a polymerization unit, relying on intermediate products i.e., polymer chips to produce only filaments in the form of pre-oriented yarns (POY).

The raw materials used in both cases are normally imported from Japan, U.K., USA, Canada and Mexico except that parts of polymer chips, especially polyester, may be supplied by local producers with a polymerization unit.

The processing technology used for producing polyester may be either batch or continuous process. Teijin Polyester Company was the first company (1970) who produced polyester chips, filaments (FOY) and staple fibers by batch process using TPA and EG as raw materials. The production processes are shown in Figure 3.2. Thai Melon Polyester employs a continuous process to produce polyester filament (POY) and staple fibers using DMT and EG as raw materials. The production processes are shown in Figure 3.3.

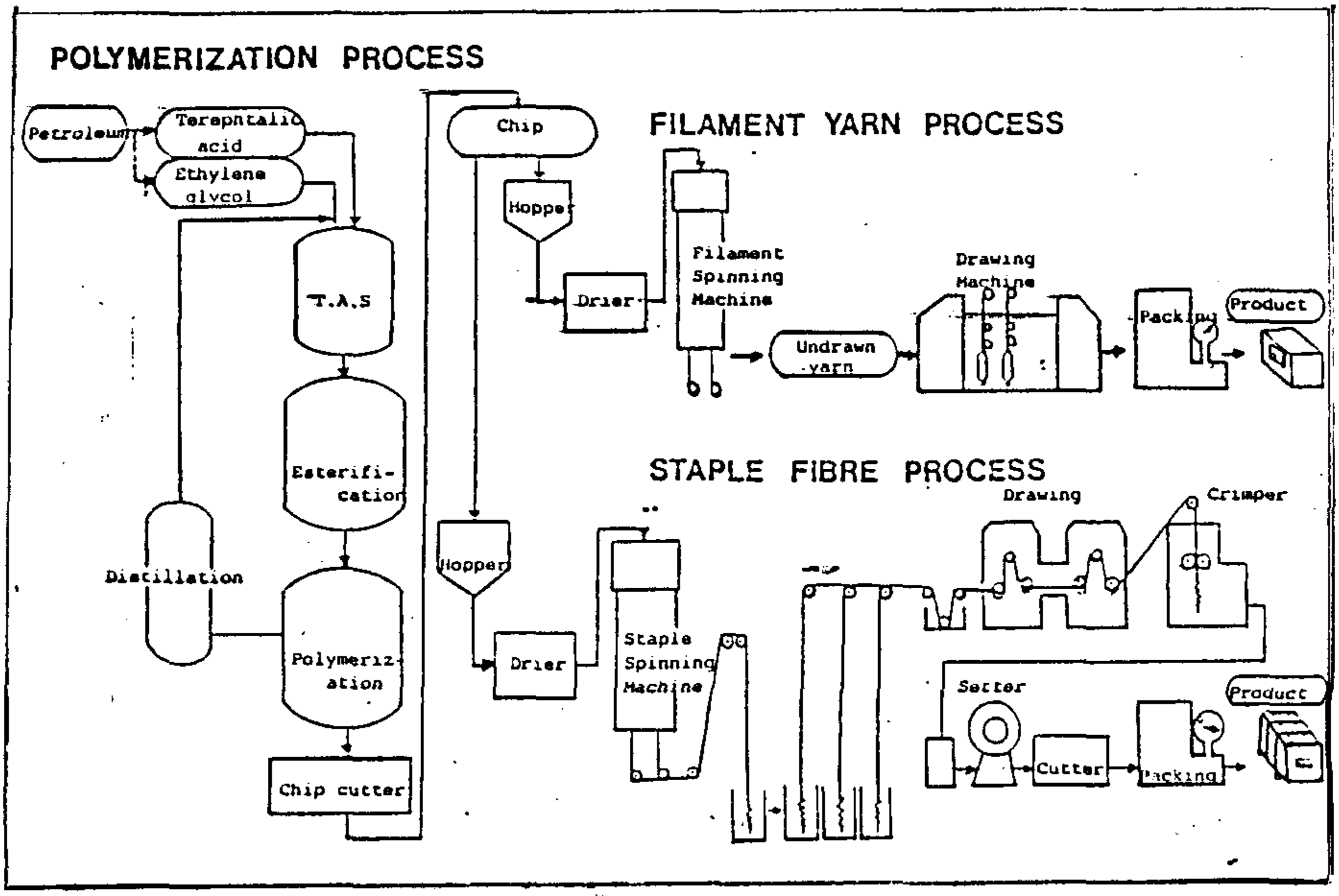
Economic Aspects

Since the raw materials used to produce synthetic fibers are imported and they are products of the petrochemical industry, their prices fluctuate with the international market. This significantly effects the costs of synthetic fibers. A cost evaluation from a synthetic fiber production mill (Thai Melon Polyester Company) shows the raw material cost as high as 72 percent of the total cost (Table 3.2).

Table 3.2 Cost Evaluation of Synthetic Fiber Production, 1986

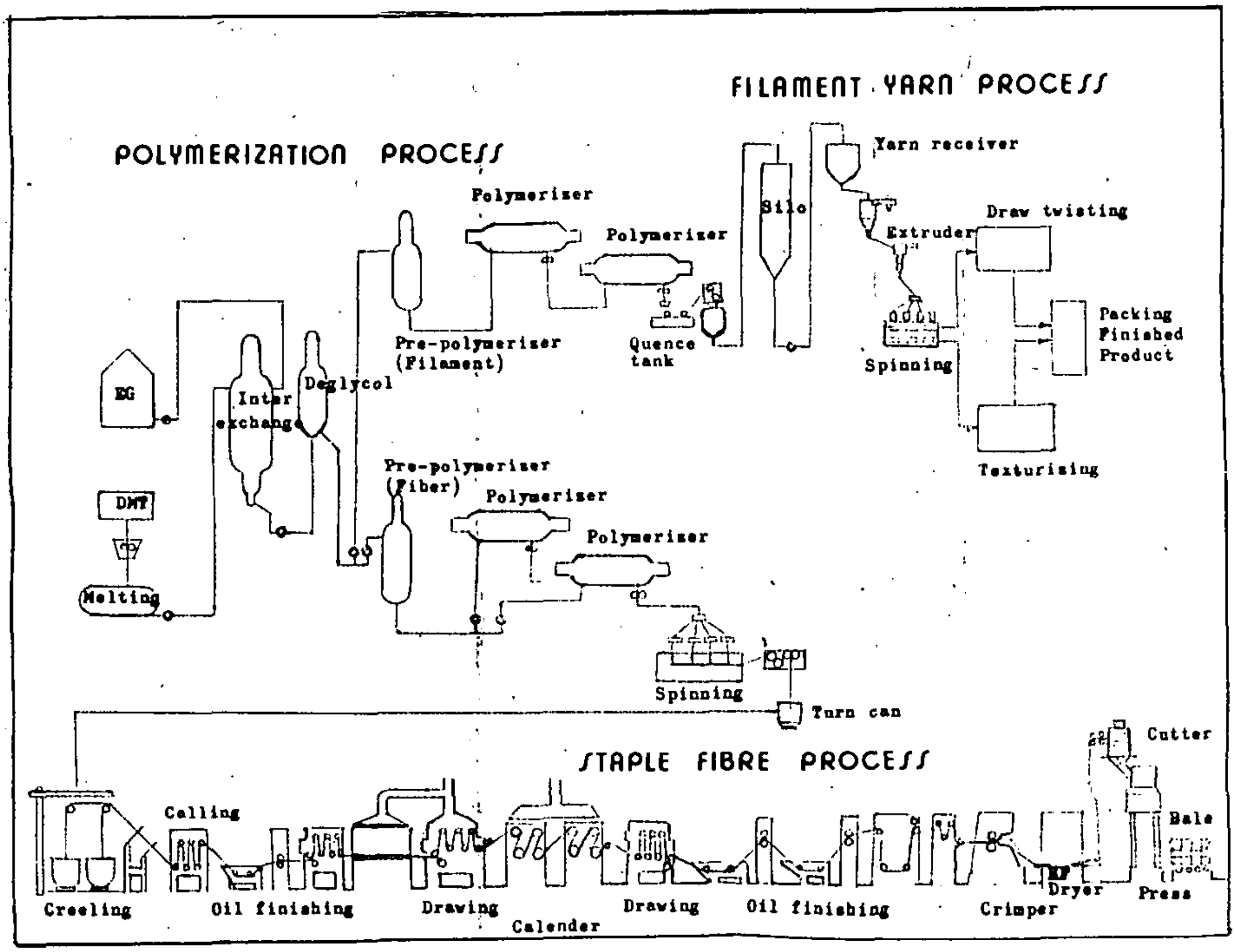
Item	Percent
Raw material	72.0
Labor	2.5
Energy consumption	10.8
Administration and others	14.7
Total	100.00

Source: Thai Melon Polyester Co.



Source : Teijin Polyester (Thailand) Ltd.

Figure 3.2 Batch Process for the Production of Polyester Filament Yarns and Staple Fibers



Source : Thai Melon Polyester Company

Figure 3.3 Continuous Process for the Production of Polyester Filaments and Staple Fibers

Marketing

The majority of the synthetic fibers produced in Thailand are used as raw materials for spinning and weaving. The remainder of only about 15% is exported.

In the past three years although the production of synthetic fibers (except nylon) has not decreased, the demand for 100% polyester in the form of yarns and grey fabrics has significantly decreased. This is due to its decrease in popularity among domestic consumers. It is also due to the closing of border markets where 100% polyester fabrics are of highest demand. However, the main consumption of polyester fibers is for blending with cotton and rayon to produce spun yarns which are the staple raw materials of regular requirements for weaving and knitting mills.

Before 1984 the Thai government imposed a 20% surcharge on imported synthetic fibers in order to protect the domestic textile industry. By that time, the surcharge period lasted only for one year. There was usually a period between the expiration and renewal of a new surcharge, in which exploitation was attempted by unscrupulous traders. Synthetic fibers would be imported without surcharge and sold to local spinning mills. Such incidents caused large losses to domestic synthetic fiber producers.

In 1984 the government gave up the surcharge and increased import tax from 20% to 30%. This brought more stability to the domestic market. At present, a normal tax of 10% is charged on totally imported raw materials for producing synthetic fibers.

From 1986 onwards, the Thai textile industry will be in a more difficult position due to the passage of the Textile and Apparel Trade Act of 1985 in the US Congress and the uncertainty of the extension of the International Trade in Multi-Fiber Textile (MFT) agreement which will expire in July this year. Thailand will face stiffer competition from other exporting Asian countries particularly Taiwan, the Republic of Korea and Hong Kong. Relatively, the cost of synthetic fiber production in Thailand is still higher than some other Asian countries due to the lesser amount of financial support provided by the Government.

Characteristics of Wastes and their Treatment

It is known that, among all textile operations, wastewater from the dyeing and printing mills is the most polluted. Next to it is the wastewater discharged from synthetic fiber production. The latter is composed of wastes from different sources, namely:

a) Wastes from the polymerization process

b) Wastes from the application of finishing oils in textile processing

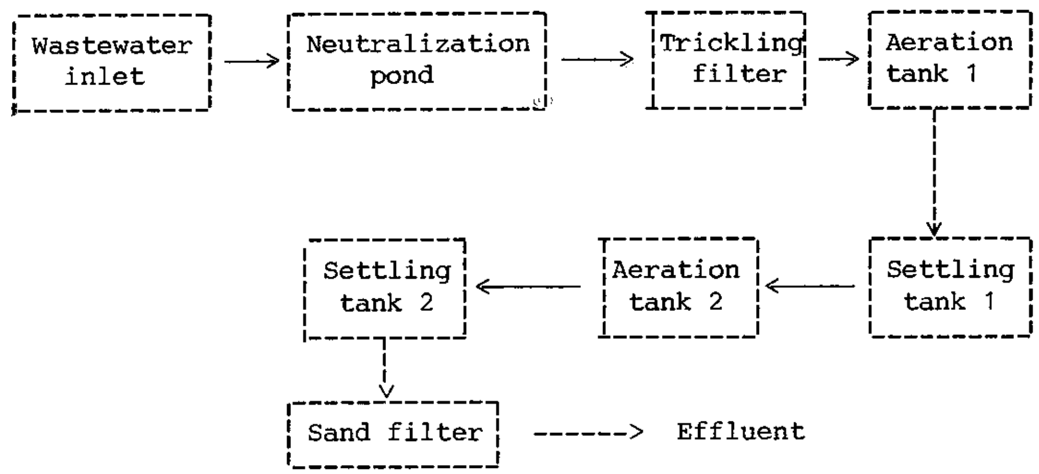
c) Wastes from the chemical laboratory

d) Wastes from auxiliary shops

The general characteristics of these combined wastes are:

- Suspended solids 30 ppm
- Ph 6
- COD 16,500 ppm
- BOD 4,200 ppm

The wastewater treatment system typically employed in the synthetic fiber production mills is the activated sludge system. A schematic diagram of the system is shown in Figure 3.4.



Source : Thai Melon Polyester Co., 1986

Figure 3.4 Typical Waste Treatment System for Synthetic Fiber Production

The effluent from the wastewater treatment process has the following characteristics

- Suspended solids 15 ppm.
- Ph 8
- COD 40 - 60 ppm.
- BOD 10 - 15 ppm.

3.1.2 Printing of Synthetic Fabrics

Status of the printing industry

The dyeing and printing industry in Thailand may be classified into three types according to the characteristics of textile mills, viz.:

a) The integrated mills which combine all textile processing in one place starting from spinning and weaving up to garment production. The dyeing and printing processes are only parts of the production line. Most of the mills of this type employ either dyeing or printing, only a few have both.

b) The dyeing or printing mills that start from fabric preparation, i.e., desizing, scouring and bleaching, through dyeing and printing up to finishing. Most of the medium and large mills belong to this type.

c) The dyeing or printing mills of incomplete processing that operate with or without fabric preparation process and with or without the finishing process. The mills belong to this type are small in size.

In Thailand, it is very difficult to precisely estimate the number of dyeing and printing mills since there are a large number of small plants of 10 to 30 employees operating illegally without proper registration. According to the industrial plant survey's report of the Ministy of Industry in 1984, there are 230 dyeing and printing mills divided into 118 mills for dyeing and finishing and 112 mills for printing. This does not count the small illegal plants referred to earlier. Most of the dyeing and printing mills are concentrated in and around Bangkok Metropolis.

The size of the dyeing and printing mills are classified as small, medium or large as follows:

a) Small-scale mills with 10 to 49 employees and with total machinery assets of up to 5 million baht.

b) Medium-scale mills with 50 to 199 employees and with total machinery assets of 5 to 20 million baht.

c) Large-scale mills with over 200 employees and with total machinery assets of over 20 million baht.

There are totally about 24,200 employees in the dyeing and printing mills, 5,740 for small-scale mills, 12,600 for medium-scale mills and 5,860 for large-scale mills. Within these numbers, 10,000 are employed in dyeing mills.

At present, the production of printed fabrics in Thailand is about 25 to 30 million yards per month. This figure as reported by the Ministry of Industry, is only from the registered medium and large-scale mills. The real figure should be much higher if small-scale industries were included. The printed fabrics include 100% polyester, polyester/cotton blends, cotton, rayon and silk. The main products are printed polyester/cotton and cotton fabrics.

The production pattern is dependent upon the market demand. White and dyed fabrics are considered as standard items which are required in all seasons. Printed fabrics in which design patterns vary according to fashion trends and specific consumer's demand, are produced only under commission from brokers. The printed silk fabrics are an exception, since they are produced only in small quantities with special retail outlets.

Production Pattern

In Thailand, there are a number of printing methods used for printing textile materials such as screen printing, hand-block printing, roller printing, rotary-screen printing as well as transfer printing. The screen printing method is the most widely used and may be operated by hand which is then called "hand-screen" printing or by automatic-screen printing machine which is called "flat-screen" printing. As mentioned earlier, it is difficult to estimate the exact number of dyeing and printing mills in Thailand. It is, therefore, even more difficult to estimate the total number of printing machines operating in those mills. However, in the survey of 80 printing mills conducted by the Ministry of Industry in 1984, printing machines could be classified as shown in Table 3.3.

Table 3.3 Number of Printing Machines in 80 Printing Mills

Printing method	Number of machines
Hand-screen printing	473
Hand-block printing	21
Automatic screen printing	22
Roller printing	10
Rotary-screen printing	2
Transfer printing	5 1/

1/ There are no more than 3 mills operating thermoprinting machines (1986).

Grey fabrics are normally used as raw materials for printing in medium and large-scale mills, and bleached fabrics are normally used in small-scale mills. The dyestuffs used in printing processes such as disperse, vat, reactive and direct dyes are produced locally but with limited shade variations and quality. A large amount of dyestuffs are still imported. In 1983 Thailand imported 5.38 million kg of dyestuffs worth 1 billion baht (C.I.F.).

Economic Aspects

The main costs of fabric printing are dyestuffs, chemicals and energy (oil, gas), which cover almost 85% of the total cost. The analysis of production costs of fabric printing classified according to processing steps in comparison between roller printing and screen printing is shown in Table 3.4.

The cost for roller printing is about 75 - 80% to that of screen printing. Table 3.4 shows the breakdown of the production costs for both types of printing.

Table 3.4 Analysis of Production Costs of Fabric Printing

		Roller Printing	Screen Printing			
			Cotton	T/C	T/C,B/O	100% Polyester
Preparation	Chemical	12.04%	9.06%	4.77%	4.72%	9.85%
	Labor	4.63%	3.48%	3.41%	3.37%	3.08%
	Energy	13.89%	10.45%	9.37%	9.27%	11.38%
Printing	Block	11.57%	-	-	-	-
	Chemical-Dyestuffs	23.15%	43.55%	51.11%	50.59%	46.15%
	Labor	1.62%	2.61%	2.56%	2.70%	2.31%
	Energy	3.47%	2.61%	2.56%	2.53%	2.31%
Finishing	Chemical	0.56%	4.18%	3.41%	2.53%	4.31%
	Labor	4.63%	3.48%	3.41%	3.37%	3.08%
	Energy	3.24%	3.14%	2.40%	2.36%	2.15%
Admin.		16.20%	17.43%	17.00%	16.86%	15.38%
		100%	100%	100%	100%	100%

Note: C = Cotton
T/C = Polyester/cotton blends
B/O = Burnt out

3.2 CLEAN TECH # 5: LOW-POLLUTANT CLEANING PROCESS

Thailand is a tropical country where the average temperature ranges between 75°- 100°F, hence a wearing coat or sweater is not the normal practice for most of the year. The dry cleaning industry in Thailand is therefore confined to men suits and luxurious clothes such as those made from silk. Moreover, the national uniform which is now in vogue normally is made of cotton and polyester and does not require dry cleaning. It has substituted for the western suit as the formal men's wear. The size of the dry cleaning industry in Thailand is thus very limited.

The dry cleaning industry comprises few large dry-cleaning shops, mainly those operating in hotels which use machines, and a larger number of small dry cleaning operations relying on hand washing, taking advantage of cheap labor. The demand for new dry cleaning machines is therefore stagnant.

3.2.1. Proposed Technology

The proposed technology is a commercially available dry cleaning machine produced by BOWE Company (Figure 3.5).

In the Federal Republic of Germany (FRG), an activated carbon filter is required in a dry cleaning machine to recover the solvent used which evaporates into the cleaning room.

Instead of a water-cooled heat exchanger, the proposed machine uses a refrigeration unit to cool down the drying air to the degree that only little amount of solvent (perchloethylene) remains at the end of the drying period. Hence the release of perchloethylene is kept to a minimum.

3.2.2 Feasibility in Introducing the Proposed Technology to Thailand

This section determines whether the BOWE machine which is commercially available in the local market is cost-effective. Comparison is made between the proposed machine and the conventional machine with an activated carbon filter assuming that both are imported.

The comparison between costs incurred by the two machines emphasizes the cost difference not the costs in absolute terms. Therefore, factors which cost the same in the two cases will be neglected because they do not reflect any cost difference. The calculations follow the comparison between the clean and conventional technologies presented at the International Symposium on Clean Technologies, Karlsruhe, October 1985 (Appendix B).

Figure 3.5 BOWE P 422 Front View

Local data and assumptions required to make the calculation reflect real costs in Bangkok (1986). The assumptions and local data used are listed as follows:

a) Operating costs are incurred for solvent (perchlorethylene), cleaning aid, filter aid, electricity, steam, cooling water and compressed air. The costs for cleaning aid, filter aid and compressed air remain unchanged when comparing between clean and conventional technologies. The costs of solvent, electricity, steam and cooling water will be different depending on the consumption level of these two machines. Unit price data are as follows:
   - solvent 22 baht/kg
   - electricity rate for dry cleaning enterprises ranges between 1.81 - 2.04 baht/kwhr
   - steam 0.20 baht/kg
   - cooking water 8 baht/m3

b) It is also assumed that labor cost will be the same for both machines.

c) For comparing fixed costs, it is assumed that the cost for space rental will be the same in both cases, since the difference in the floor space requirement is not regarded as significant in the local market. To calculate the fixed cost, the interest rate used was 9% (based on supplier's credit). The exchange rate used was 10.5 baht/DM.

The cost comparisons between the operating costs of a BOWE machine and a conventional machine are shown in Table 3.5. As can be seen, the operating cost of the BOWE machine is approximately 4 baht/load lower than that of the conventional machine.

Table 3.5 Comparison between the Operating Costs of a BOWE Machine and a Conventional Machine.

Working time: 8.5 h/day
cycle time: 30 min.
Loading weight 12 kg

		Consumption/load	Baht/load
solvent	A	240 gm	5.28
	B	480 gm	10.56
electricity	A	1.8 kwhr	2.74
	B	0.9 kwhr	1.37
steam	A	7 kg	1.4
	B	12 kg	2.4
cooling water	A	100 l	0.8
	B	160 l	1.28
cleaning aid, filter aid, compressed air	A, B	same between A and B	same between A and B
labor cost	A	same	same
	B	between A and B	between A and B

A = BOWE

B = Conventional machine with activated carbon filter

A: No.of loads
per day 14
per month (22 days) : 308
per year : 3696

B: No.of loads
per day 16
per month (22 days) : 352
per year : 4224

Table 3.6 shows the comparison between the fixed costs of a BOWE machine and a conventional machine. The fixed cost of the BOWE machine is 5.68 baht/load higher than that of the conventional machine. Taking into consideration the lower operating costs of the BOWE machine at 4 baht/load, the total cost of the BOWE machine is 1.68 baht/load higher than the conventional machine.

Table 3.6 Comparison between the fixed costs of a BOWE machine and a conventional machine

Machine price	A: 556,657.5 Baht B: 551,985 Baht	Fixed cost/load
Maintenance on machine (4% of machine price)	A B	0.57 0.50
Calculated depreciation (16% of machine price)	A B	2.29 1.99
Calculated interest (9% of machine price)	A B	2.51 2.18

A = BOWE machine
B = Conventioal machine with activated carbon filter

3.2.3 Environmental Aspects

Currently, there is no emission standard for perchlorethylene in Thailand. No study has been conducted to evaluate the pollution caused by dry cleaning, particularly the impact of perchlorethylene on the environment.

Perchlorethylene, the solvent used in the dry cleaning operation, is toxic if inhaled, or if exposed to prolonged or repeated contact, or if orally ingested. Due to the effect of perchorethylene upon the nervous system, acute intoxication may result.

In the FRG, the emission of this chemical is limited to 30 ppm as stipulated in the Federal Law on Environmental Protection.

In the case of Thailand, no evidence has been recorded on the hazardous effect of perchlorethylene on the environment which may be due to the limited use of this solvent. The need to restrict perchlorethylene has not been established. The benefit gained from reducing the emission of perchlorethylene is not evident.

3.2.4 Conclusion

The proposed technology, in this case, is already available commercially in the local market. It is employed in one of the 4-star hotels in Bangkok. Hence its technical feasibility has already been tested.

For the economic feasibility, the cost comparison undertaken in this study shows that the clean technology costs 1.68 baht/load or 6200 baht per year more than the conventional machine. When comparing the total costs of the two machines, the added cost is far from excessive. There is no clear comparative advantage in cost.

3.2.5 Recommendation

The decisive factor which so far hinders the promotion of the proposed technology is the limited size of the local market. Thailand, similar to other tropical countries, does not have a large market for dry cleaning.

3.3 CLEAN TECH #6 : LOW-POLLUTANT THERMOPRINTING OF TEXTILES

Transfer printing or transfertex printing is a process of thermoprinting of textiles. It is being advocated as a clean technology, since it does not use any water, hence no effluent and no pollution. The process however has been limited to polyester-printing ever since it was invented in the early 60's. The process is based on the principle of transferring dispersed dyes from pre-printed papers to polyester fabrics by means of pressure and dry heat without any wet after-treatment. (See related information in Section 3.1.2 : Printing of Synthetic Fabrics.)

3.3.1 Background

The technology of transfer printing came to Thailand in the early 70's. In 1978 there were more than 10 transfer printing mills in full operation with the total production of over one million yards of printed fabrics per day. But a few years afterwards, the entire textile industry was hit by a slump which has lasted up to now. At present, there are three printing mills of this kind left. The number of transfer printing machines in use depends more on the fabric order than the availability of machines, as few of the transfer printing machines are needed. The total production using transfer printing is now in the range of only 30,000 - 50,000 yards per day. The Middle East market is the only export market taking about 80 - 90% of the total production, and the remainder is sold to the local market mainly for suiting. The orders as well as the designs of the fabrics to be printed come through brokers on a case by case basis with no long-term guarantee. The total market share of transfer printing is not more than 4.2% of the total printed fabrics produced in Thailand.

3.3.2 The Future of Thermoprinting

The transfer printed fabric is limited to 100% polyester material which is not suitable to tropical countries like Thailand where cotton and polyester/cotton blends are standard materials.

Effort has been made to apply transfer-printing to other synthetic fibers such as acrylic or nylon, and to some man-made fibers such as cellulose acetate or tri-acetate. However, similar to the case of polyester, all the fibers named are inferior to cotton according to the local taste.

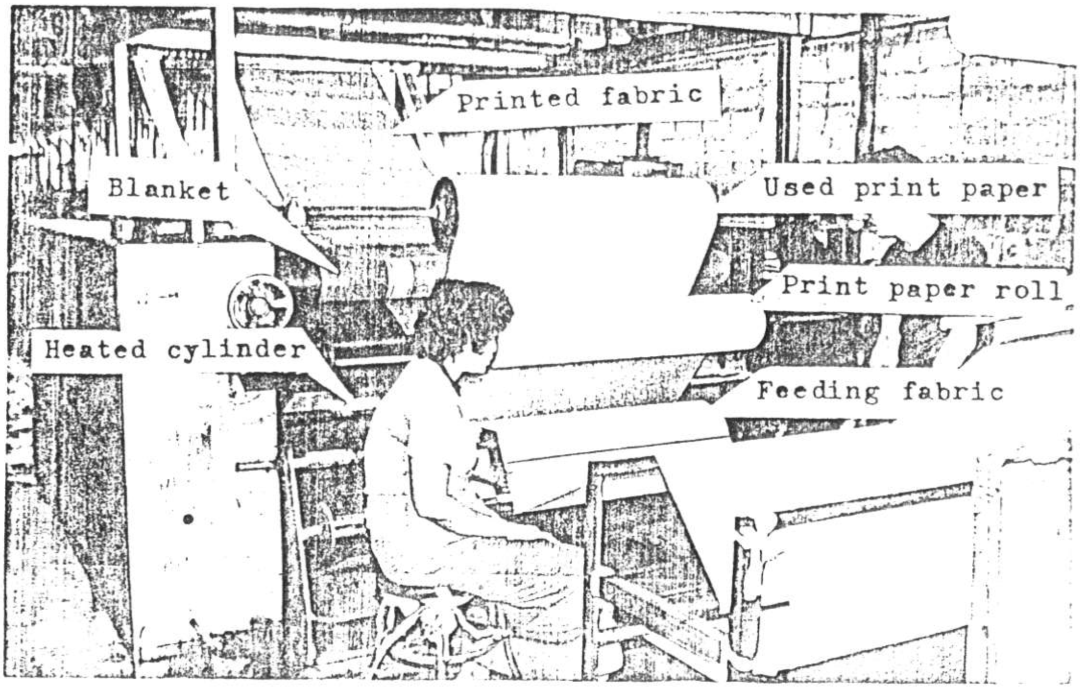


Figure 3.6 Thermoprinting machine, Bankok.

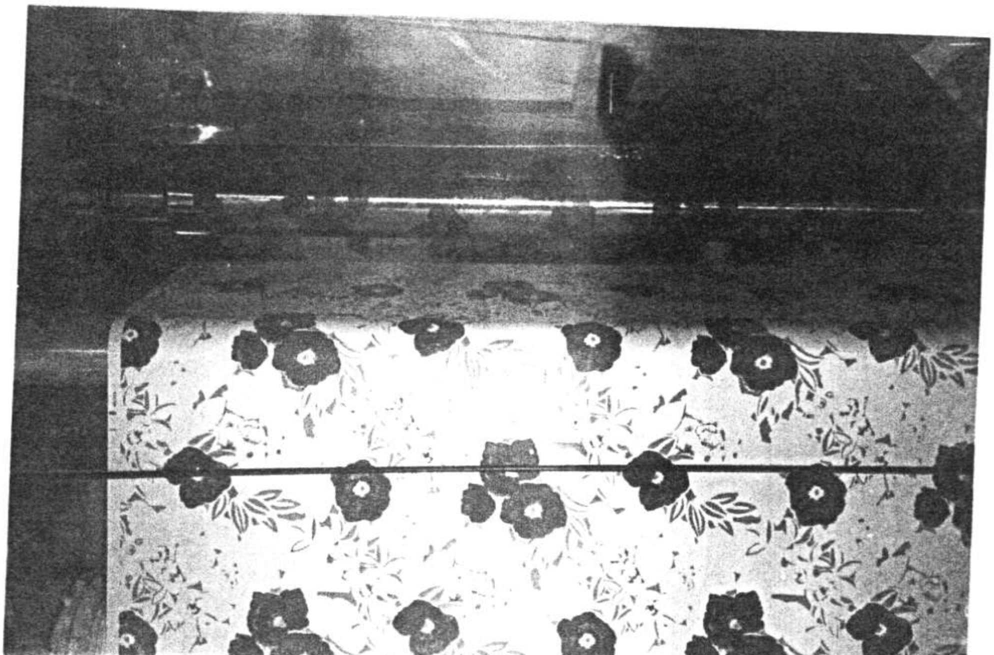


Figure 3.7 Gravure printing machine, Kleinostheim.

Hence the only demand in existence is for export. As reported earlier, the present situation is not promising since the entire textile market is in decline due to overseas competition and protective measures from other countries.

The prospect of promoting transfer printing lies with any future success in opening up new market for Thai textile products.

3.3.3 *Recommendation*

The Thai textile industry is already familiar with thermoprinting. However, the chance of promoting this technology now is nil due to the shrinking export market.

3.4 CLEAN TECHNOLOGY #7 : REDUCTION OF WASTEWATER POLLUTION CAUSED BY SIZE

Size is one of the materials that causes serious pollution in wastewater discharged from textile finishing plants. Size is applied to warp yarn prior to weaving in order to improve the efficiency of the weaving operation. When this is completed, the size has to be removed from the fabric. Failure to remove the size influences preparation, dyeing and finishing processes.

3.4.1 Characteristics of Size

There is a great variety of sizes used, viz.: native starches like maize, wheat, rice, sago, tapioca and potato starch; derivatives made from these starches; and petro-chemical products such as polyvinyl alcohol, poly-acrylates, sodium carboxy-methyl cellulose, and polyvinyl acetate.

Normally, one or more types of these sizing materials is used as the main ingredient in a size mix. It gives an adhesive power to stick all fibers or filaments of the warp yarn together resulting in an increased strength of the yarn.

In desizing, the native starches are not likely to dissolve well in water so they are extremely difficult to be removed from a fabric by normal washing. The starch derivatives have the advantage because their chemical modifications have higher water solubility which facilitates their removal from fabrics. As for the synthetic polymer sizes, they are readily soluble in water and can be easily removed from fabrics by normal washing.

A major additional ingredient in the size mix is the lubricant, for which materials used vary quite considerably in type and ease of removal. The range of materials includes tallow, spermaceti, mineral oils, soluble oils and emulsifying agents to further modify properties and facilitate removal.

For sizing applications, the size used has to be compatible with the textile material in order to achieve optimum performance of the warp during the weaving operation. In Thailand, the major sizing materials used are tapioca starch, polyvinyl alcohol (PVA) and acrylic size. Tapioca starch is applied mostly to cotton and polyester/cotton fiber blends. It is not compatible to use with 100% synthetic fibers which have low water absorption for it can not be easily attached to the fibers resulting in hairiness of the yarn. PVA and acrylic sizes are more compatible and are mainly used with synthetic fibers.

There are usually a large number of size formulas. Each weaving mill has a sizing recipe of its own for a certain type of textile material, and always keeps it a secret. Therefore, it is normal that different sizing recipes are applied to the same type of textile material, varying from mill to mill. Moreover, in the same mill, different sizing recipes are used with the same type of textile material but for different yarn counts, i.e., to increase weavability of the warp yarn.

In the case of sizing of 100% synthetic fibers, proper selection of the size depends upon the type of synthetic yarn. The size formulation will depend upon yarn count, warp density and fabric structure.

Sizing Process

The process of warp sizing can be divided into two operational steps, namely, preparation of the size solution and sizing of the warp on a sizing machine.

a) Preparation of the size solution

The preparation of the size solution or size mix comprises cooking of a sizing agent and mixing it with additional materials according to a given recipe. These processes are done in a mixing kettle. The cooking operation is employed only for the starch-based sizing agent. Complete cooking of the sizing agent is done by boiling the kettle until the required viscosity of the solution is obtained. The solution will then be transported to a storage tank ready for mixing. The mixing with other sizing agents and with additional materials is done in the same kettle just prior to using. The automatic system is normally employed in all the operations.

The cooking operation is not necessary in the case of synthetic sizing agents for they can be prepared in a solution by dissolving them in cold water.

The concentration and viscosity of the size solution after mixing have to be properly adjusted to meet a required application.

b) Sizing of the warp on a sizing machine

In general, a conventional sizing machine is composed of four sections:

- Beam creel section
- Sizing section
- Drying section
- Beaming section

Before starting the sizing operation, the warp yarns to be sized have to be wound on a warper beam. The operation is then started by setting up a number of warper beams on the beam creel and filling the size solution in a size box on the sizing machine. The warp ends coming from the creel are then sized and dried while maintaining a thread separation of about 1 mm between adjacent yarns. The yarns are finally wound on a large beam called a weaver's beam at the beaming section. Tension of every warp end has to be constantly controlled throughout the sizing operation.

The sizing of polyester spun yarns follows the above-mentioned procedure. But for the polyester filament yarns, there will be an additional waxing section after the drying section but before the beaming section.

Desizing Process

Desizing and sizing are always related to each other because a finisher is supposed to know what type of size is contained on the fabric he has to desize. In Thailand, tapioca starch is used mainly for sizing of cotton and polyester/cotton blends. Therefore, the desizing method is aimed at removing the starch. In the batchwise process of desizing, enzyme-batching is normally used following with the washing of the soluble starch from the fabrics. For the continuous process of desizing, the fabrics are chemically treated, steamed and finally washed off to remove the starch.

The desizing process for 100% polyester fabric is different from those for cotton and polyester/cotton fabrics since the finisher knows that synthetic size is mainly employed for sizing of the fiber and it is easier to be removed. This process is sometimes called the "relaxing" process for it has an additional purpose apart from removing the size. The purpose is to allow the fabric to shrink freely resulting in additional softness and good elasticity of the fabric. The process can be batchwise or continuous. Batchwise relaxing is a slow process using a batchwise finishing machine such as a circular machine or a winch. The grey fabric in rope form is treated in the machine with a desizing solution before it is washed off. This process is suitable for only a small quantity of fabric but consumes a much longer time than the continuous process. In continuous relaxing, the grey fabric is operated in an open-width form treated in a desizing solution for a few seconds and passed to lie freely in wet steam in a steam box at 100°C for 30 seconds. After this, the fabric is washed off in a series of washing tanks using large volume of hot water. By this process, a large volume of fabric can be operated at comparatively low cost although it consumes water. For eight hours operation with 15,000 yards of 100% polyester fabric, 225 cubic meters of water will be required.

Wastewater Generated

In Thailand, there is no specific treatment plant for wastewater caused by size. Since the desizing section is usually located in the dyeing or printing area, it is normal for a mill to discharge wastewater from the desizing process into a common drainage where wastewater from other processes such as scouring, bleaching, dyeing, printing and finishing are collected in a storage pond.

The starch waste discharged during the desizing process constitutes about 16% of the total volume of waste produced, 53% of the BOD, 36% of the total solids and 6% of the alkalinity. Caustic wastes (from NaOH) generated in scouring and mercerizing processes constitute about 19% of the total volume, 37% of the BOD, 43% of the total solids, and 60% of the total alkalinity. General wastes composed of wastes from all other processes (washing, bleaching, dyeing and finishing) constitute 65% of the total volume, 10% of the BOD, 21% of the total solids and 34% of the total alkalinity.

The general characteristics of textile effluents are: 356 mg/l suspended solids, 5700 mg/l BOD, 16,569 mg/l COD.

Textile wastes are composed of both organic impurities extracted from fibers and chemical substances such as dyes. The effluents are generally colored, highly alkaline, high in BOD and suspended solids. Wastes generated during the dyeing and printing processes, known as color-shop wastes are the most difficult to treat.

3.4.2 Proposed Clean Technology

Wastewater pollution caused by size may be minimized by two methods, firstly by a reduction of size pick-up on warp yarns, and secondly by introducing effective methods of removal of size in wastewater discharged from the desizing process. The proposed clean technology claimed that by using a new generation of size-compatible spin finishes for synthetic fibers, it could reduce the size pick-up level necessary for good performance on weaver's looms. Results of the research confirmed the reduction of 10 - 30% size and thus the corresponding reduction in water, wastewater and energy consumption. The advantage in applying such technology is the cost reduction in the sizing process.

The on-going research in the Federal Republic of Germany (FRG) includes the development of a new size - recycling method through ultrafiltration which will increase the amount of recycle size pick-up level up to 10% by weight for fiber yarns, but not applicable to filament yarns.

Since the proposed technology is only at the research stage, one can only agree with the potential improvement in principal, pending its introduction at the commercial level.

3.4.3 Prospect for the Future

Question may arise whether Thailand possesses the R & D capability to initiate similar research rather than relying on imported technology only.

At present, Thailand has a limited number of public institutions conducting research and development in the field of textile technology. The existing institutions are:

a) Textile Industry Division, Ministry of Industry
b) Faculty of Science, Chulalongkorn University
c) Department of Textile Engineering Chemistry, College of Technology and Vocational Education.

In the private sector, there are three associations viz., Thai Textile Manufacturing Association, Thai Synthetic Fiber Manufacturer's Association and Thai Weaving Manufacturing Association who may in principle, support research works which are beneficial to their members.

In practice, weaving technicians are regularly attempting to search for new sizing at lower cost but can simultaneously offer higher performance of warp yarns during weaving.

The present research effort in the country concentrates on searching for new sizes or spin finishes in order to lower size pick-up level while maintaining a good performance of the warp, and in modifying natural fibers and their blended fabrics to render them printable through heat transfer.

For more advanced research such as the development of new sizing and desizing processes, technical cooperation with a developed country is a prerequisite. This is due to both the lack of experience and the limited research fund available today.

The introduction of the proposed technology to Thailand in the future shall take the following considerations into account:

a) Thai weavers are known to be conservatives who regard their sizing formulae as trade secrets. It will require extra effort to convince them that a proposed technology will reduce size pick-up while giving equal or even better performance of the warps.

b) In Thailand, the weaving mill where sizing is operated and the dyeing or printing mill where desizing is done are always located separately though they may belong to the same group of companies. Sizing formulas will not be disclosed to the dyeing/printing mills. Moreover, most of the dyeing/printing mills operate under commission, receiving grey fabrics of different sizes from various weaving mills without knowing about the property of these sizes. It will be impractical for these mills to attempt size-recycling since all the sizes which can be recovered will be mixtures of unknown chemicals.

c) Skilled labor to operate the recovery system as proposed in the Clean Technology will be required.

3.4.5 Recommendation

New formulations of spin finishes which may reduce the consumption of sizes are of great interest to the local textile millers. The on-going research and development in the FRG should be closely monitored.

CHAPTER IV

CLEAN TECHNOLOGIES FOR METAL COATING AND FINISHING

This chapter evaluates the feasibility of the proposed clean technologies for metal coating and finishing, namely:

Clean Tech # 8 : Low-waste Electroplating Process for Zinc.

Clean Tech # 9 : Low-waste Electroplating Process for Cadmium.

Clean Tech #10 : Low-emission Technology for Electro-deposition of Aluminium.

Clean Tech #11 : Low-pollution Galvanizing Technology for Printed Circuit Board Production.

Clean Tech #12 : Wasteless Salt Bath Processes.

Clean Tech #13 : Reduction and Utilization of Paint Sludges.

The evaluation will emphasize the possibility of introducing such technologies to Thailand taking into consideration both the technical and the economical feasibility.

4.1 INDUSTRY PROFILE

According to a recent survey conducted in 1985 by the Department of Industrial Works, the total number of registered electroplating shops in Bangkok Metropolis is approximately 200 (Table 4.1) compared with 161 in 1984. Thirty-two workshops or 16% practice zinc electroplating together with other metals: eight workshops employ only zinc. Both aluminium and cadmium electroplating are not available in Thailand but aluminium anodizing has been widely used.

4.1.1 Conventional Zinc Electroplating Process

The alkaline-cyanide process is widely used in zinc electroplating in Thailand. Figure 4.1 illustrates the flow diagram of this conventional process. The process consists of three main steps, namely pretreatment, electrolysis and posttreatment. Table 4.2 shows the chemical requirements, costs and wastewater volume produced per 10 kg of zinc deposit.

Table 4.1 Profile of the Metal-coating Industry in Thailand (from MOI survey), 1985

Items	Number of workshops
Total registered plating workshops 1/	200
Cr, Ni, Cu and other metal electroplating	89
Ni electroplating only	11
Zn and other metal electroplating	32
Zn electroplating only	8
Ag and Au electroplating	8
Al anodizing and metal electroplating	13
Anodizing only	9
Sn hot-dip and metal electroplating	18
Sn and other metal electroplating	4
Unspecified electroplating practices	31

1/ It was estimated that there are 25% or 50% more workshops which could not be identified during the survey, hence the total number should be 250.

Source: MOI Survey.

Table 4.2 Material Requirements, Cost and Wastewater Volume Produced per 10 kg of Zinc Deposit in Conventional Process in Thailand.

ZnO	19.0	kg
NaOH	4.5	"
NaCN	3.2	"
HNO_3	3.0	"
H_2SO_4	1.6	"
Chromating	1.6	"
Degreasing agent	1.0	"
Total chemical cost	680	baht
Wastewater volume	180	l

Source : Tunk King Hang Factory, Bangkok, 1986.

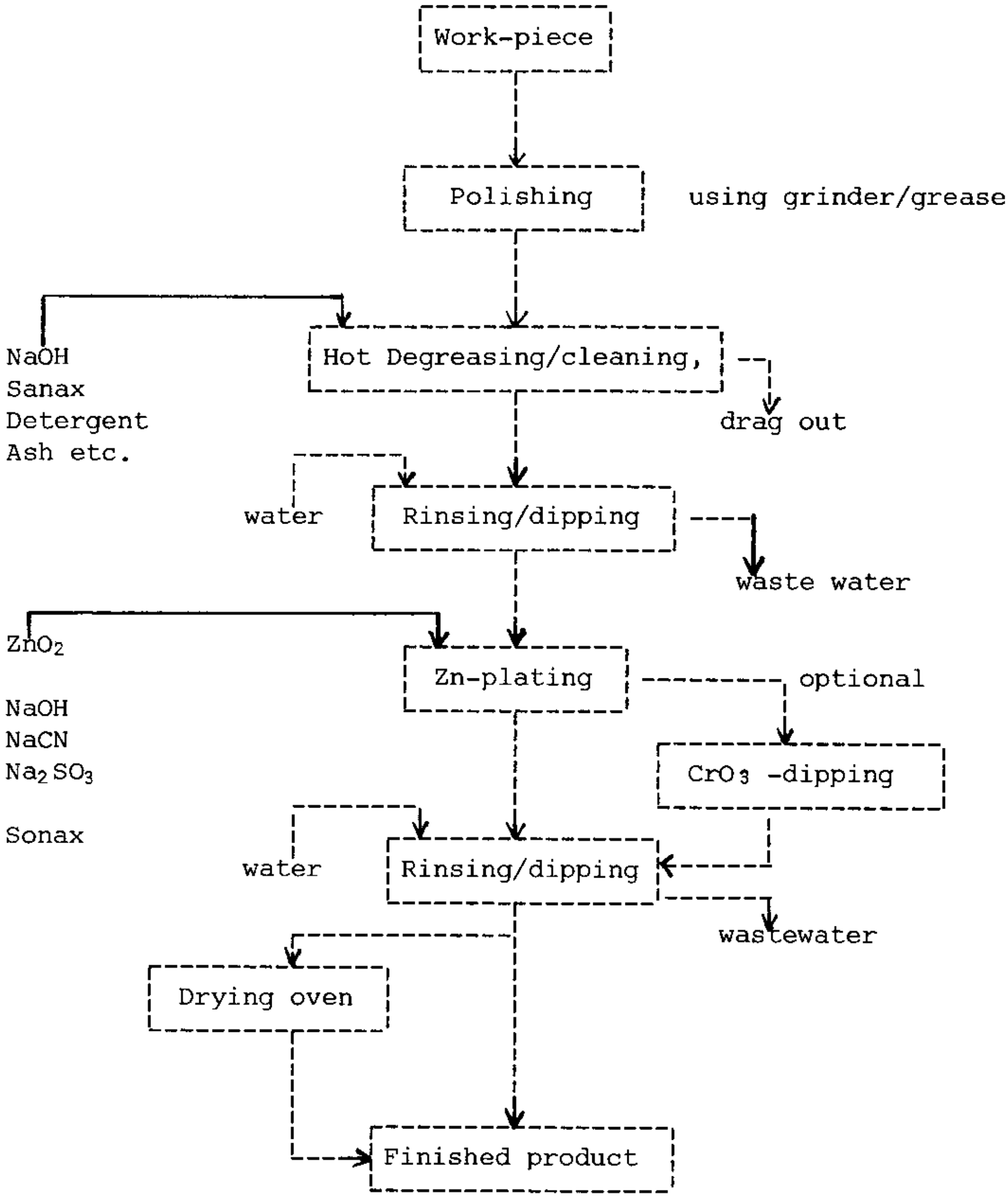


Figure 4.1 Flow Chart of the Zn Plating Process Employed in Plating Plants in Bangkok

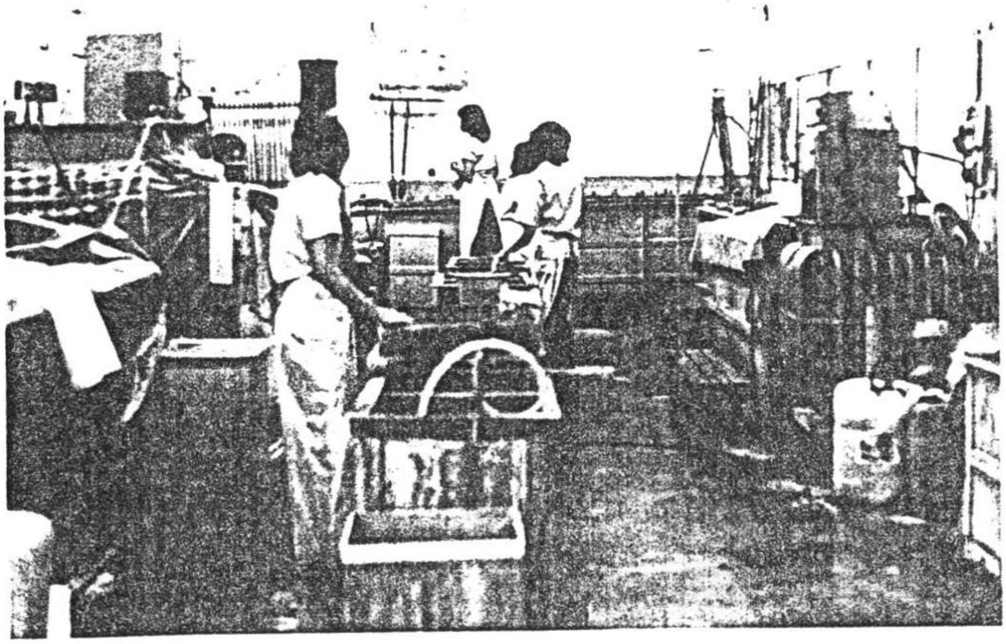


Figure 4.2 Interior of a Zinc Electroplating Shop in Bangkok

4.1.2 Cyanide Treatment

The electrolyte wastes discharged from the electrolytic baths, rinsing water and floor washing water flow into a single receiving tank. Since the waste is alkaline and contains cyanide, chemical treatment is employed as shown in Figure 4.3. Firstly, sodium hydroxide is added to the alkaline waste to adjust the pH to about 10 in order to precipitate zinc ion as hydroxide. Cyanide is then detoxified by chemical oxidation using sodium hypochlorite and then converted into harmless nitrogen gas. The complete reaction of cyanide oxidation can be achieved by controlling the pH to about 10. The series of cyanide oxidation is shown below:

$$CN^- + NaOCl + H_2O \longrightarrow CNCl + NaOH + OH^-$$

$$CNCl + NaOH + OH^- \longrightarrow CNO^- + NaCl + H_2O$$

$$2CNO^- + 3OCl^- + H_2O \longrightarrow N_2 + 2HCO_3^- + 3Cl^-$$

$$CNO^- + 3Cl_2 + 6NaOH \longrightarrow 2HCO_3^- + N_2 + 6NaCl + H_2O$$

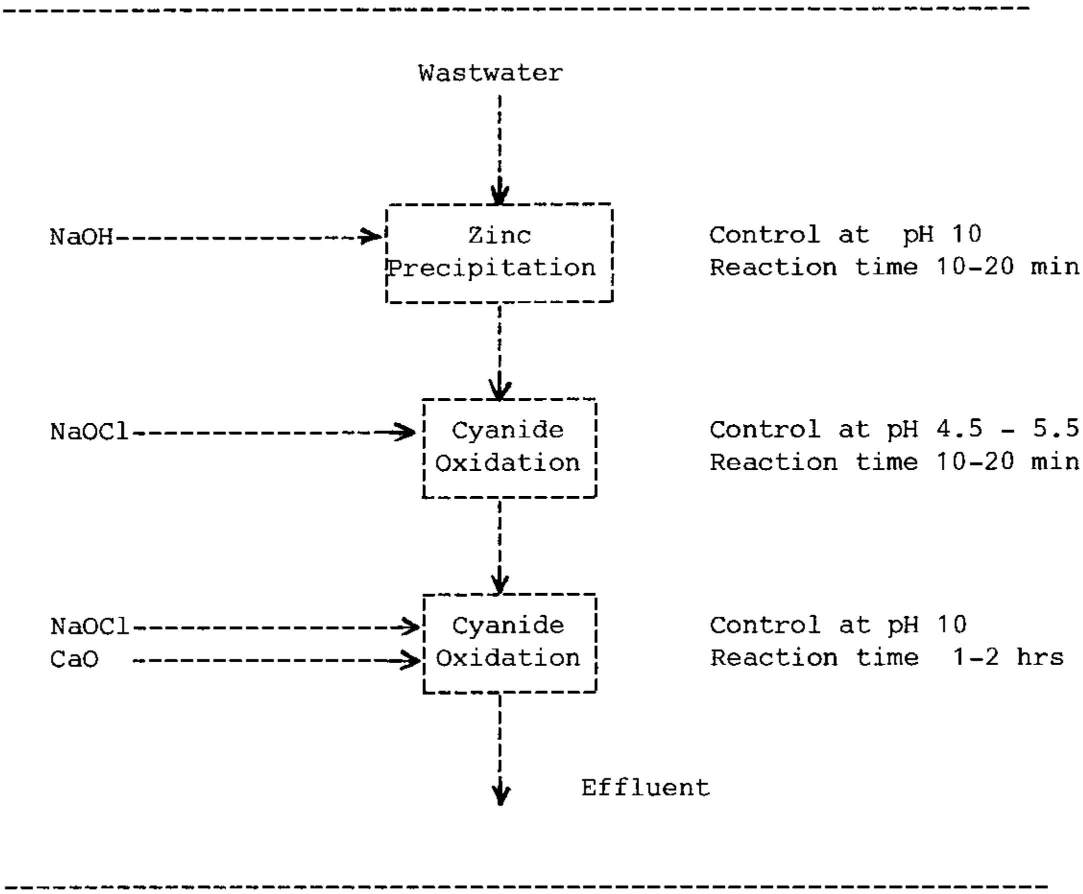


Figure 4.3 Cyanide Treatment Process of Zinc-electroplating Waste in Thailand

For 10 kg of zinc deposit, the chemical cost for waste treatment is about 45 baht and the total treatment cost is approximately 100 baht which is roughly 5-10% of the production cost. The sludge of zinc hydroxide is commonly disposed by dumping into a garbage bin.

4.1.3 Comparison of Different Electroplating Processes

Table 4.3 compares the different types of metal electroplating to be considered in this chapter, namely, zinc, cadmium and aluminium.

Table 4.3 Comparison of Different Types of Metal Electroplating

Items	Electroplating Processes		
	Zn	Cd	Al
Market demand	Yes	No	No
Metal price	very low	high	low
Availability of metal	Yes	import	import
Process status	commercial scale	pilot scale	pilot scale
Complication of process	moderate	high	high
Surface appearance	fair	good	moderate
Corrosion resistance	moderate	high	moderate
Toxicity	low	high	low
Investment	low	high	very high
Operating cost	low	high	high

Note: Zn = zinc
Al = aluminium
Cd = cadmium

Even though cadmium electroplating is superior to zinc plating in terms of corrosion resistance and solderability, cadmium electroplating is not practiced in Thailand. This is due mainly to its high cost when compared to zinc electroplating. Aluminium electroplating has not yet been introduced to Thailand because it is a very recent innovation. However aluminium anodizing is common for coating aluminium itself.

4.1.4 Wastetreatment Plant

TISTR (1979) reported that the treatment and recovery of individual metal or metal compounds from mixed liquid wastes might be achieved through fractional precipitation by controlling the pH. In 1984 this idea was tested at the laboratory level by TISTR under the commission of UNEP. The fractional precipitation solvent extraction and fractional dissolution techniques were used in the study. It was concluded that neither of the two methods was economically feasible for metal recovery from the combined electroplating wastes. Hence the precipitation technique is the best option to treat the electroplating wastes without metal recovery.

Based partially on the UNEP-funded study, The Ministry of Industry (MOI) is setting up a central plant for treating electroplating wastes and textile wastewater. Removal of heavy metals and color will be achieved by lime precipitation. Metal sludges will be cast into concrete blocks, to be hauled to a burial site in Rajburi province, about 200 kms west of Bangkok. If this project proves to be successful, two more similar plants will be established. For the next 5 years, the MOI has requested a budget of 47 million baht for this program.

From this plan, the implication is that a waste treatment fee will be levied on electroplating shops based on the volume and the metal concentration in their wastes. The pollution fee will become an additional burden for all electroplating shops. Hence, they will, in the near future, have the financial incentive to invest in process improvement.

4.2 CLEAN TECH # 8 : LOW-WASTE ELECTROPLATING PROCESS FOR ZINC

As tabulated in Table 4.1, there are eight zinc electroplating shops in Thailand plus 24 more which perform zinc electroplating together with other metals. This section is relevant only to the eight zinc electroplating shops since the effluents in other shops are not segregated and hence are not applicable to be treated by the proposed clean technology.

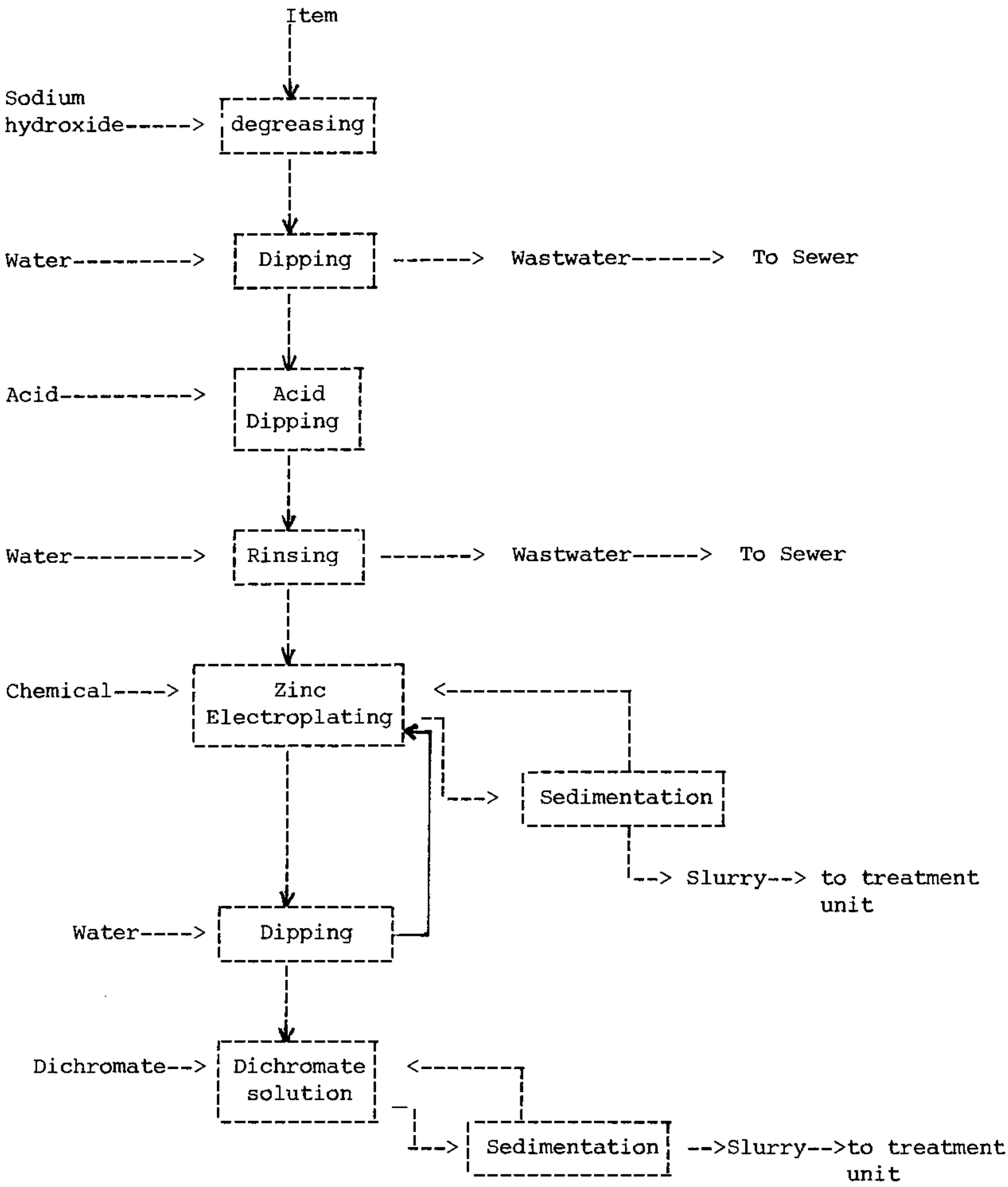
Figure 4.4 shows a typical flow diagram of a zinc electroplating shop including wastewater treatment.

4.2.1 Proposed Technology

The low-waste zinc electroplating process, as shown in Figure 4.5 is basically similar to the conventional process except a new rinsing technique and new metal recovery methods are employed. Wastewater volume generated will be much lower than that of a conventional plant. An unlimited service life of the electrolyte is achieved by soda precipitation of the zinc electrolyte. Chromium recovery from the spent chromating solution is obtained through ion exchangers.

By the use of the new rinsing technique, soda precipitation and ion exchangers, the proposed process yields lower waste volume and consumes a smaller amount of chemicals than the conventional process. These proposed techniques are, in fact, well known in the chemical engineering field and are commercially available. Therefore, the process is feasible technically and is not too complicated to operate. Moreover, as mentioned earlier, a local demand for zinc electrocoating exists.

However, any introduction of a new treatment process should bear in mind that as far as metal-plating is concerned, the government is proceeding with its plan to construct a central treatment plant, as reported in the earlier section. A site has been selected and the engineering design has already been completed. At present, the government is calling for the bidding of the construction and operation of this central treatment system.



Source : Tunk King Hang Factory, Bangkok, 1986

Figure 4.4 Typical Flow Diagram of a Zinc Electroplating Shop

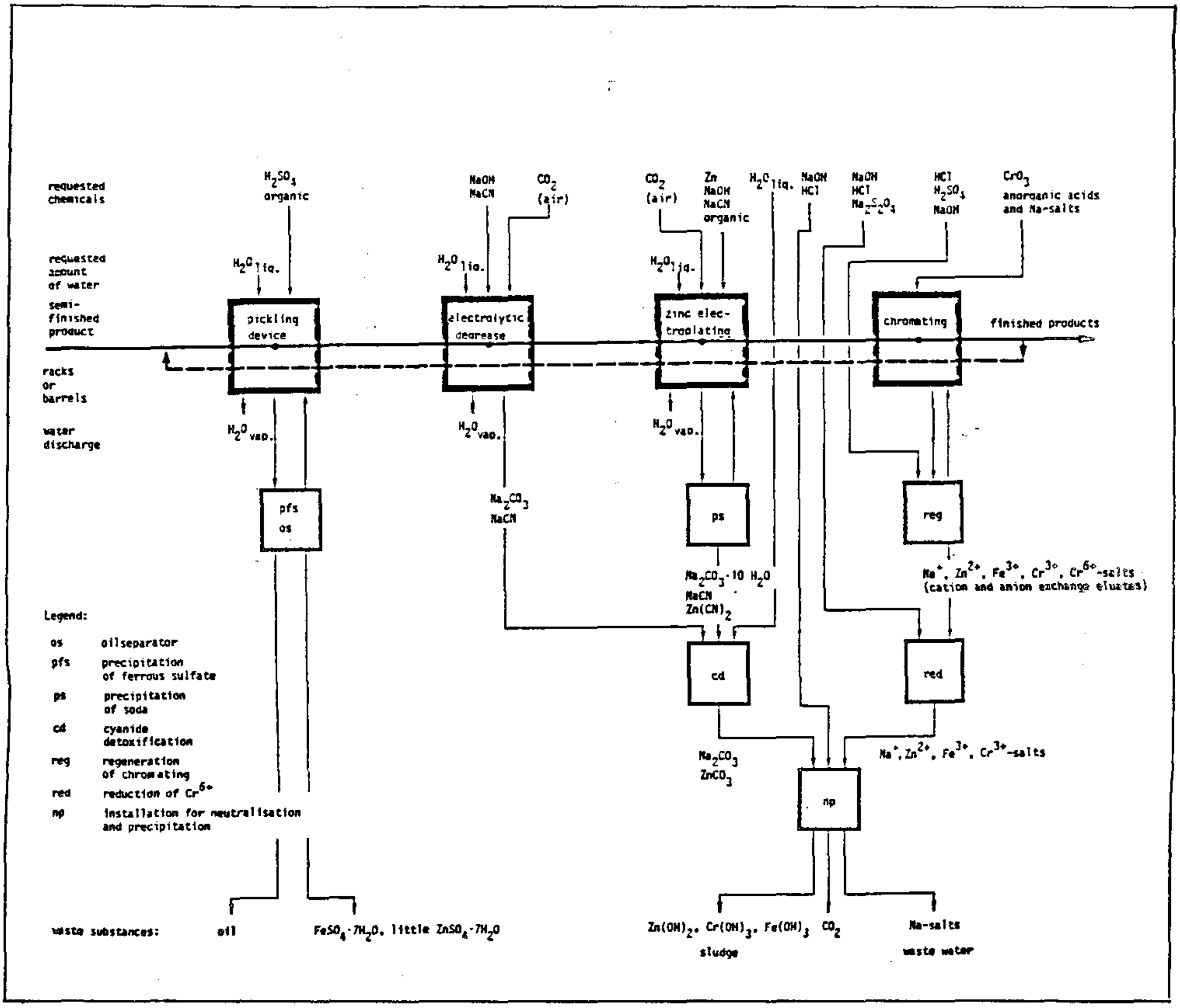


Figure 4.5 Flow Diagram of the Proposed Zinc Electroplating Process

Thus, rather than the wholesale import of the proposed clean technology, emphasis should be given to the adaptation of the proposed idea and the consideration of the comparative advantage of installing a low-waste process vis-a-vis the subscription to the government's central waste treatment system.

With this premise, a simple rinsing technique, the cascade batch dipping-rinsing system as shown in Figure 4.6, should be employed rather than the triggered, compressed air cascade dip-spray-rinse system suggested in the clean technology.

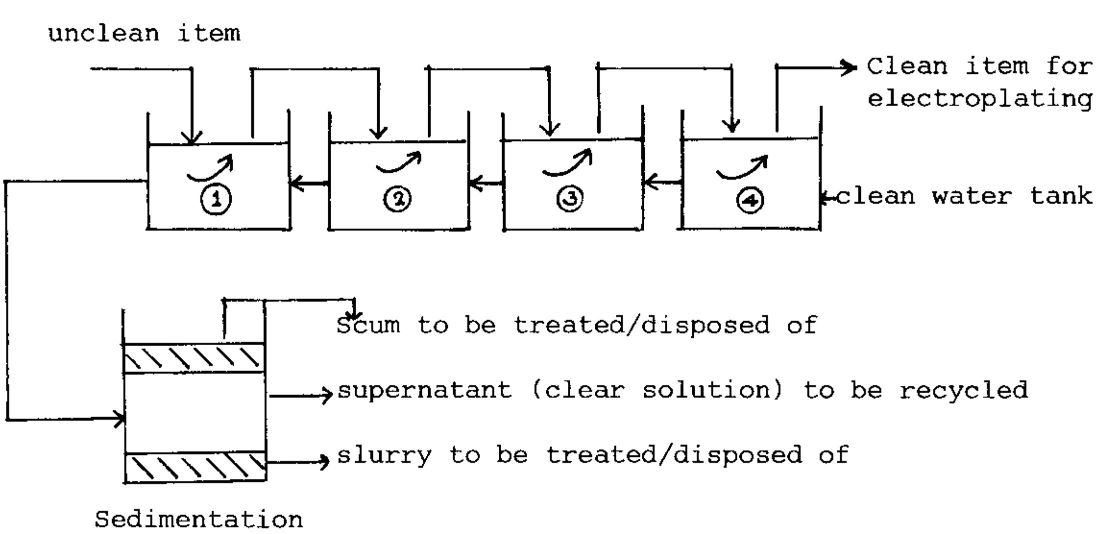


Figure 4.6 The Cascade Batch Dipping-rinsing System

This technique is simple and easy to handle. The initial cost is low since it only requires four to six small containers for each rinsing step. The empty chemical containers available in electroplating shops can be used for this purpose. Chemicals such as sodium cyanide and chromate can first be recycled by using precipitation techniques. Solids in the depleted electrolyte from electrolytic baths and turbid chromate solution are allowed to precipitate through sedimentation. The clear solution can then be recycled. It was found that several electroplating shops are already employing this technique.

For a 500 kg/month zinc deposit plant, the approximate amount of waste produced in the form of slurry would not be more than 30 l/d in comparison with the present volume of 300 l/d which is the amount in the zinc electroplating plants in Thailand.

For the treatment of cyanide, the local practice is to use NaOCl as shown earlier in Figure 4.3. The monograph of the proposed Clean Technology (Figure 4.5) implies the use of hydrogen peroxide (H_2O_2) as the chemical agent. Since Thailand does not produce H_2O_2, its cost in the local market (February 1986) is more than four times that of NaOCl. Hence the treatment of cyanide should follow the present practice.

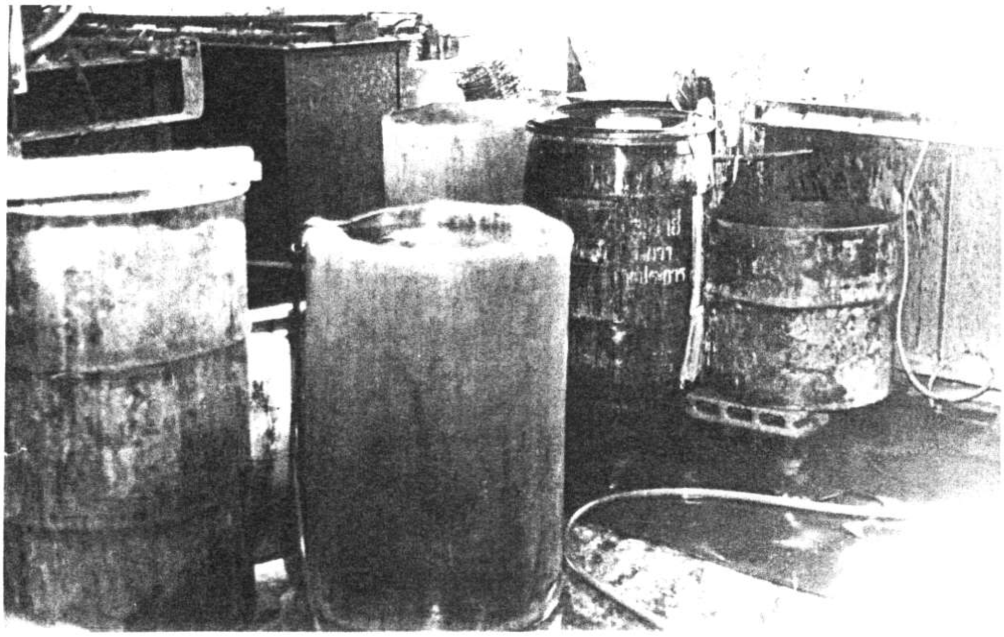


Figure 4.7 Zinc Electroplating Rinsing Containers, Bangkok

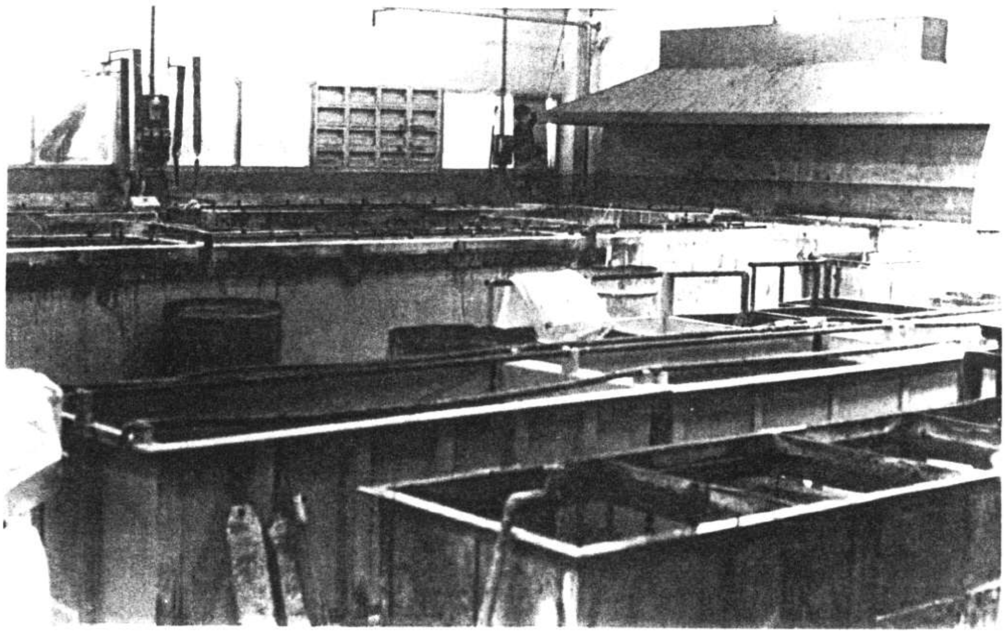


Figure 4.8 Zinc Electroplating Rinsing tanks and Plating Bath, Bangkok

4.2.2 Cost Comparison

The cost comparison will only highlight the investment needed, operating expenses to be increased, and any savings from the recovery of chromium. The cost of an ion exchange unit is about 30,000 baht. The operating cost for such unit is up to 3,000 baht/year. For a 500 kg zinc deposit plant, the annual chromate consumption is about 960 kg. If 5% chromate loss in the slurry is assumed, the maximum value of chromate saved by the process is then 3,600 baht/year given the price of chromate at 75 baht/kg.

These figures show that the annual expenses for chromate recovery (3,000 baht/year) can be compensated by the savings in the consumption of the metal (3,600 baht/year), a savings of 600 baht/year. However the investment cost of 30,000 baht has to be borne by the electroplating shop. Assuming that the life expectancy of an ion-exchanger is 10 years, then the amortization cost will be 6,557 baht per year at the interest rate of 17.5%. Therefore, the net cost of using the ion exchanger to be borne by the company will be 5,957 baht per year.

4.2.3 Recommendation

Since the Government is in the process of constructing a central treatment plant to treat wastes from electroplating shops (see section 4.1), the calculated figure of 5,957 baht should be considered when compared with the treatment fee to be established. In other words, the proposed recovery of chromium at each individual plant will be feasible only if the fee to be levied is more than this amount.

4.3 CLEAN TECH # 9 : LOW-WASTE ELECTROPLATING PROCESS FOR CADMIUM

4.3.1 Proposed Technology

The flow diagram of the low-waste process for cadmium electroplating is depicted in Figure 4.9. Similar to the zinc electroplating process, cadmium plating is divided into three main steps, pretreatment (hot degreasing, pickling and electrolytic degreasing), cadmium electrodeposition and posttreatment (chromating). The alkaline-cyanide electrolyte has an unlimited life because of the use of the soda precipitation technique. A new rinsing technique and water evaporation are employed to reduce the wastewater discharge. Cadmium in the spent electrolyte is recovered through electrolysis. Cyanide is detoxified by chemical oxidation with hydrogen peroxide. Chromium in the spent chromating solution is also recycled using ion exchangers.

4.3.2 Conclusion

Since cadmium is a highly toxic substance, it is fortunate that Thailand does not employ cadmium electroplating. As far as the quality of products to be plated, zinc can fulfill all the local requirements. The other important factor that supports the use of zinc-electroplating is the fact Thailand is a zinc producer and exporter. Since there is no local demand for cadmium coating, the setting up of a low-waste cadmium-electroplating plant in Thailand is not viable.

4.3.3 Recommendation

The proposed clean technology is not appropriate to Thailand since there is no market for cadmium-plated products.

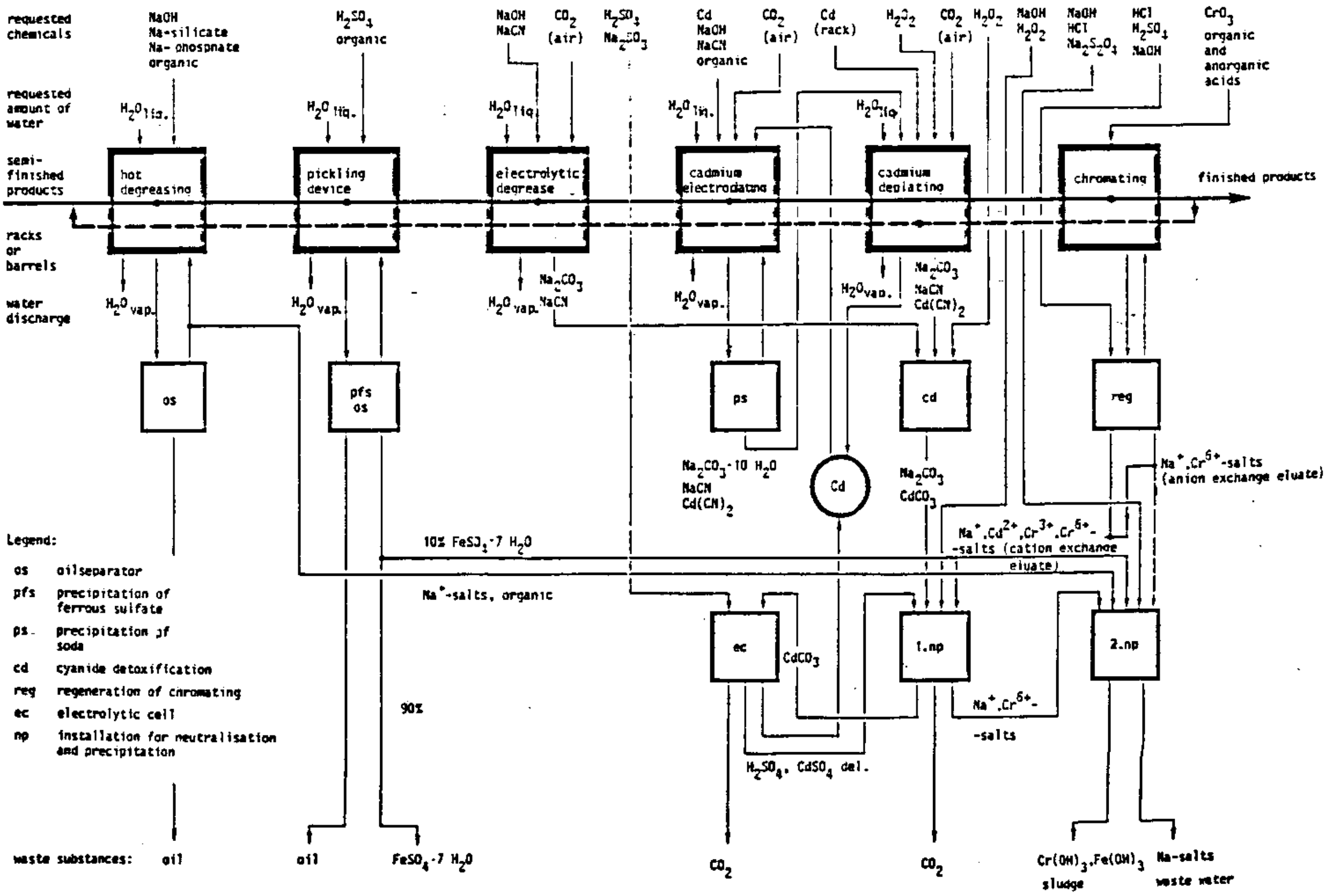


Figure 4.9 Flow Chart of the Proposed Cadmium Electroplating Process

4.4 CLEAN TECH # 10 : LOW-EMISSION TECHNOLOGY FOR ELECTRODEPOSITION OF ALUMINIUM

Aluminium coating (the coating of a base metal by a thin layer of aluminium) can be applied by a variety of methods, each of which produces a different type of coating and is suitable for different kinds of applications. For example, vacuum metalized coatings are extremely thin and because of their bright, shiny appearance are widely used to decorate plastic parts. Hot-dipped or aluminized coatings, on the other hand, are quite heavy and are usually used for heat and corrosion resistance. Depending on the application, aluminium coatings can also be applied by diffusion (i.e., colorized coatings), electrophoresis and spraying. Electrodeposition is also theoretically feasible, but no aluminium electroplating plant currently exists in Thailand.

There are six aluminium metal manufacturing plants (medium and large in size), all of which use the same process "anodic oxidation or anodizing" with the total capacity of about 400 tons/month. In addition, there are seven other smaller plants which employ the same anodizing process but at a lower capacity of less than 100 tons/month.

4.4.1 Anodic Oxidation

Anodic oxidation or anodizing is the common commercial term used to designate the electrolytic treatment of metals in which stable oxide films or coatings are formed on surfaces. Aluminum and magnesium are anodized to the greatest extent on a commercial basis. Some other metals such as zinc, beryllium, titanium, zirconium and thorium can also be anodized to form films of varying thicknesses but they are not used to any large extent commercially.

It is a well-known fact that a thin oxide film forms on aluminium when it is exposed to the atmosphere. This thin, tenacious film provides excellent resistance to corrosion. The ability of aluminium to form an adherent oxide film led to the development of electrochemical processes to produce thicker and more effective protective and decorative coatings.

Anodic oxidation should not be confused with aluminium coating. In anodic oxidation, the aluminium coating is formed by its own oxidation, whereas in aluminium coating, of which the electrodeposition of aluminium is but one alternative, the base metal is coated with aluminium.

4.4.2 Proposed Technology for Electrodeposition of Aluminium

The proposed technology is the electrodeposition of aluminium with the SIGAL process. The largest pilot plant of its kind in the world is located in Berlin. Aluminium is electrodeposited from a solution of aluminium trialkyle-alkali fluoride complex with toluene as a solvent. The SIGAL process based on this electrolyte is licensed by Siemens and comprises four steps: pretreatment, dewatering, coating with aluminium and posttreatment (Figure 4.10).

The pretreatment is necessary to achieve a clean surface on the articles to be coated with aluminium. The pretreatment procedure is comprised of several different solutions for the cleaning of different base metals. Each pretreatment step is followed by rinsing operations. Methods for the pretreatment of metals in non-aqueous solutions are also being investigated so that operations can be performed under hoods in closed systems, thus completely avoiding wastewater.

Aluminium alkyles will react spontaneously with water, resulting in a decomposition of the electrolyte. Therefore, a dewatering step is necessary before the articles to be coated can be passed into the electroplating cell. For removal of water, a boiling fluorchlorine-carbon solvent has been applied. The use of halide carbons for dewatering the pretreated substrates can bring about considerable losses of the solvent, depending on the cooling system and the convective motion of the air within the machine. Air pollution has to be avoided by adsorption of the escaping solvent with activated carbon filters.

The aluminium coating process is performed electrolytically in plating tanks which are placed under a hood in a nitrogen atmosphere. The dry articles to be coated are transferred into the hermetically encased aluminium plating tanks through a lock filled with the same solvent on which the electrolyte is based. For improved mass transfer, the racks with the articles are agitated mechanically by a reversing device. The current efficiency is nearly 100 percent. The power of the electrolyte is sufficient for most applications. The non-aqueous plating solution is circulated between the plating tanks and a peripheric system for purification and temperature control.

For posttreatment, the articles plated with aluminium can be immersed into a conversion coating solution to form a thin, yellow chromate deposit for improved corrosion resistance. Compared to cadmium deposits of similar thickness, aluminium has proven superior for many applications and, therefore, is a very important substitute for the toxic cadmium.

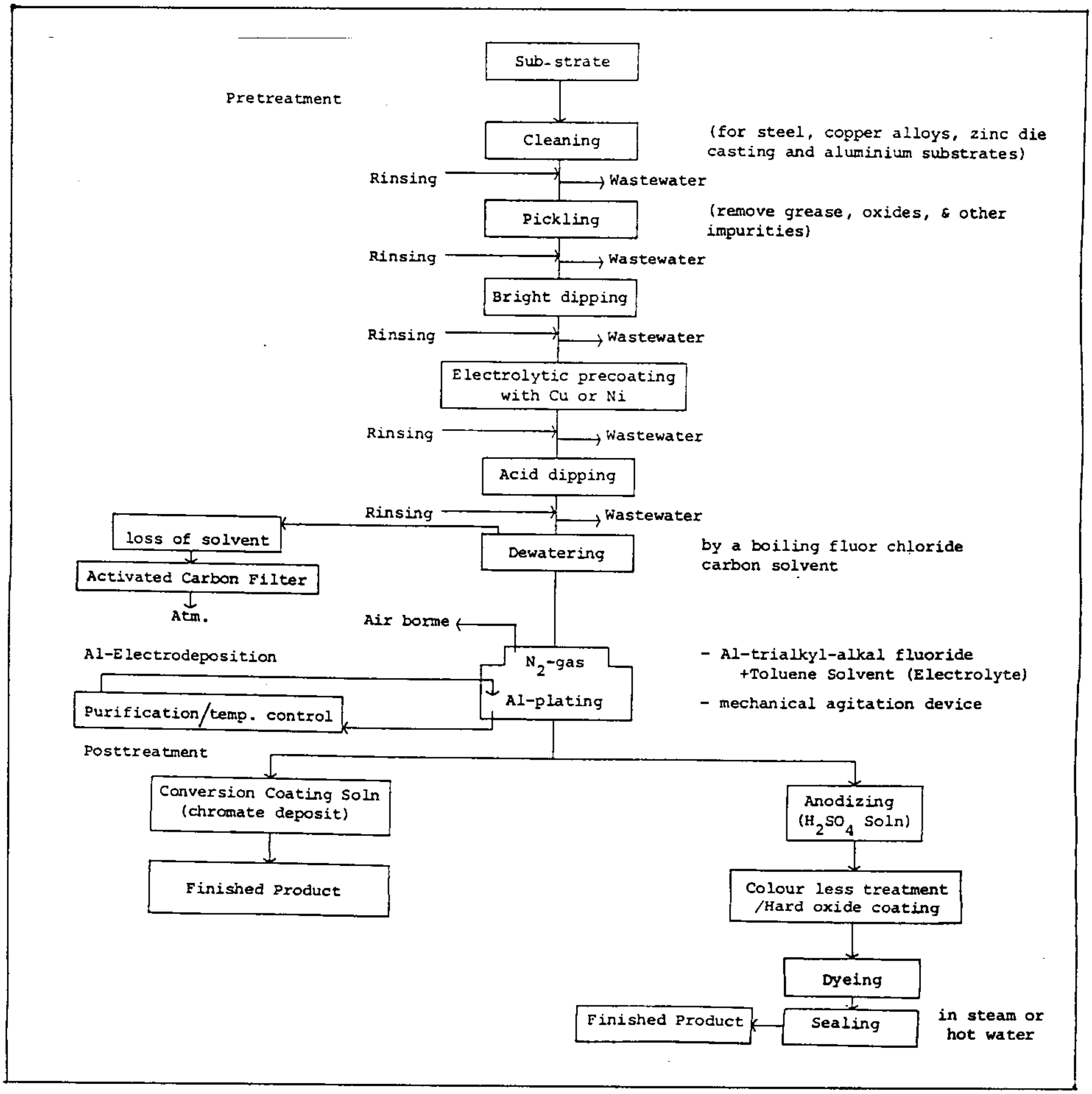


Figure 4.10 Schematic Flow Diagram of the SIGAL Process

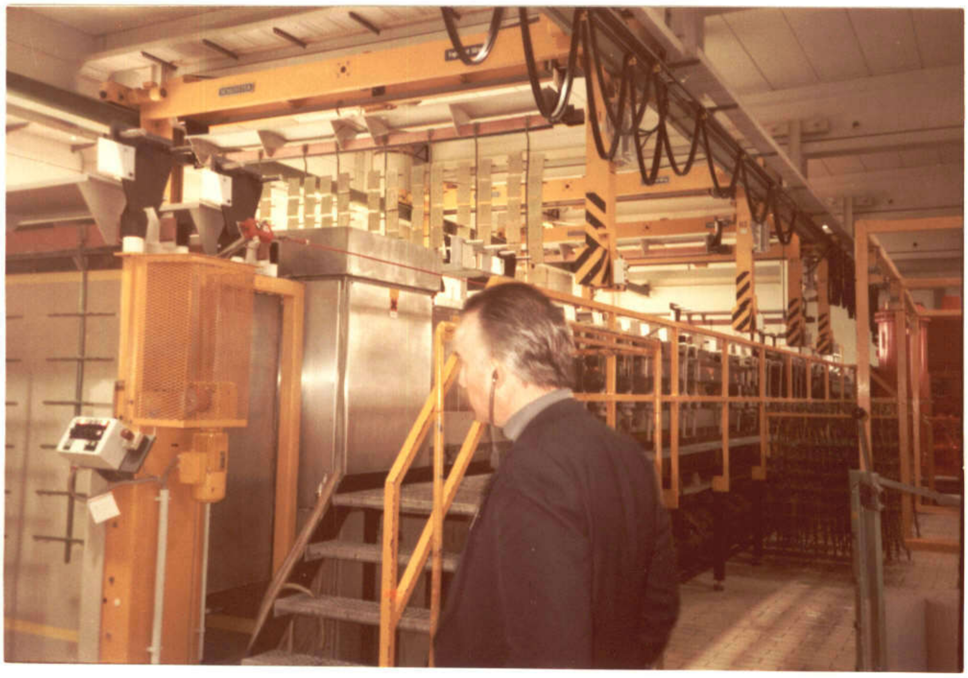


Figure 4.11 Modern Aluminium Electroplating Plant, Berlin, FRG

4.4.3 Prospect of the Proposed Technology

There is no conventional technology for the electrodeposition of aluminium. The SIGAL process is a unique new development.

This process is still under development at the pilot scale. The dewatering and plating steps need further clarification. Moreover, chemicals used in these two steps such as fluor chloride carbon solvent, aluminium trialkyl-alkali fluoride and toluene solvent are not available in Thailand and might entail excessive cost for their import. In addition, the process requires well-trained personnel who are normally lacking in most of the small or medium sized factories in Thailand although they may be available in some of the larger factories.

The main objective of introducing aluminium electrodeposition is to replace cadmium electroplating and its associated toxicity. However there is no cadmium plating in Thailand now as reported in the earlier section

4.4.4 Recommendation

There is no market for aluminium electrodeposition now. The progress of the proposed technology which is at the pilot - stage should be monitored for consideration in the future.

4.5 CLEAN TECH # 11 : LOW-POLLUTION GALVANIZING TECHNOLOGY FOR PRINTED CIRCUIT BOARD PRODUCTION

In theory, there are two techniques which can be used in the production of printed circuit boards, the substractive technique and the additive technique. In commercial applications, the substractive technique is widely used while the additive technique is still under research and development. By applying the substractive technique, most of the copper foil which is clad on the base plate will be etched away. Since the residuals generated in the etching process contain toxic substances and cause environmental pollution, it is necessary to reduce pollution by recycling. The additive technique, in which copper is applied only at places where it is needed for circuit pattern, eliminates masking and etching. Thus, the amount of waste as well as pollution can be reduced.

4.5.1 Situation of PCB Manufacturing in Thailand

In Thailand the PCB manufacturing process follows the substractive route. The difference between PCBs made in Thailand and those in the FRG is that most of the PCBs manufactured locally have the circuit pattern on only one side of the board while the opposite side serves as the component side. To fix the electronic components, holes are drilled after the circuit pattern is already printed on the board. Figure 4.12 shows the circuit side of a printed circuit board and Figure 4.13 shows the reverse side on which electronic components will be assembled.

4.5.2 Production Techniques

Two techniques can be considered in the production of PCBs, the silk screen technique and the contact printing technique.

1) Silk screen technique: This is the technique which is being employed in Thailand. An epoxy glass or another laminate, clad on the side with copper foil, is used. Silk screen is printed on parts which will become the circuit pattern. Thereafter the plate will be etched. After cleaning with solvent the circuit pattern will appear on one side of the board. After this process, the circuit board will be cleaned with solvent to remove the screen. Holes for mounting electronic components will be drilled manually. After drilling, the plate will be cleaned and coated with flux in order to facilitate the soldering of components.

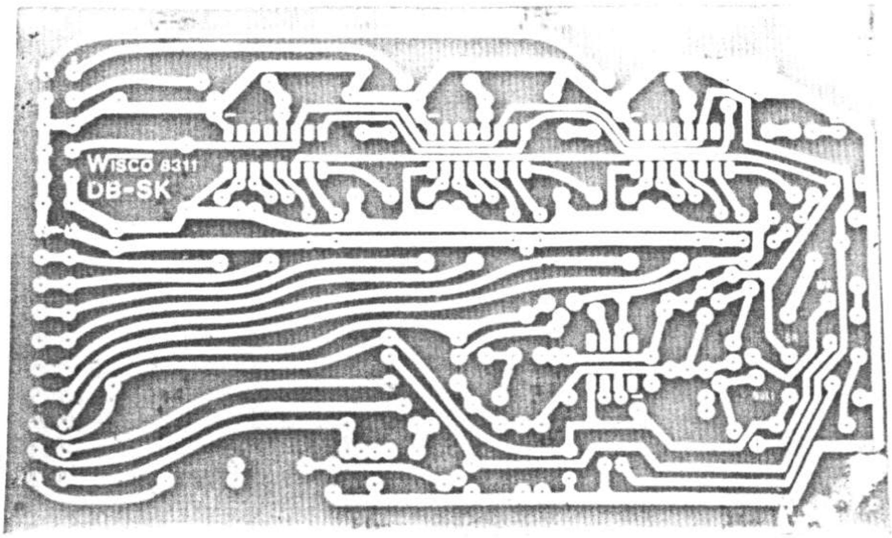


Figure 4.12 Circuit Side of a PCB Made in Thailand

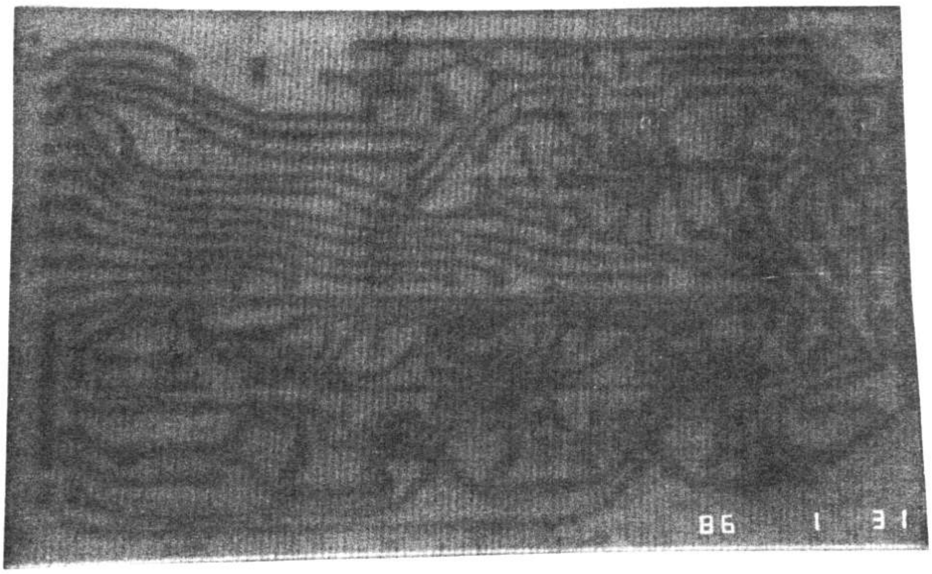


Figure 4.13 Component Side of the Same PCB of Figure 4.12

This method of PCB manufacturing is cheap, simple, labor intensive but less accurate.

2) Contact-printing technique: This is the proposed technology which is still being developed in the FRG. An epoxy glass plate is clad on one side with copper foil and coated with sensitizer. Then, the photo mask (circuit pattern printed on film) will be placed on the copper side of the base plate and the plate will then be exposed to ultraviolet light (Figure 4.14).

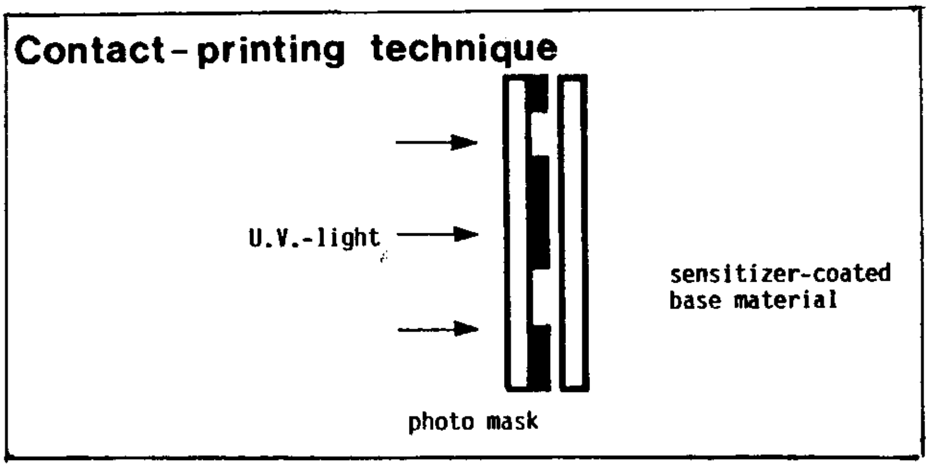


Figure 4.14 Contact-printing Technique in PCB Manufacturing

After exposure, the photo mask will be stripped off, and the plate can then be developed. In the ensuing etching process the circuit pattern will protect the copper from being etched away.

4.5.3 Comparison of Thai and German Made PCB

For PCBs made in Thailand, the circuit appears only on one side of the board, while most of the PCBs manufactured in the FRG have the circuit on both sides of the board.

The comparison of production steps between the proposed technology and the local technology is shown in Table 4.4

The additive technique as proposed is still under R & D in the FRG. At this stage, Thailand's PCB industry is still in its infancy. The amount produced and the corresponding pollution generated from this industry is still negligible. The technique employed is labor intensive taking advantage of the low labor cost in the market which is about one-tenth of the cost in the FRG.

Table 4.4 Comparison of Production Step in PCB Manufacturing

Production step	Description	PCBs made in Thailand	PCBs made in FRG
1	Copper foil	Clad on one side	Clad on both sides
2	Mechanical pretreatment (drilling)	Not required at this step	Yes
3	Catalysation	No	Yes
4	Panel plating	No	Yes
5	Masking	Yes	Yes
6	Pattern plating	Yes	Yes
7	Etching	Yes	Yes
9	Drilling (manually)	Yes	No

4.5.4 Recommendation

R & D capability on PCB manufacturing in Thailand is non-existent. It is best to follow the results of the development of the clean technology in the FRG. It will take at least a few more years before the additive technique, as proposed, is available at the commercial level.

4.6 CLEAN TECH # 12 : WASTELESS SALT BATH NITRIDING AND CARBURIZING OF STEEL

In general, the mechanical and technical properties of steel can be changed by heat-treatment. Steel hardening can be achieved by changing the microstructure of steel to a needle-like shape called martensite which is exceptionally hard. The simple procedure is to heat the steel with sufficient carbon content up to the austenizing temperature and then, cool it down rapidly by quenching it with water, quenching oil or brine. The steel hardening process can be divided into two main groups, through hardening and case hardening. The proposed clean technology belongs to the latter group.

4.6.1 Case Hardening Process

Case hardening means to make steel hard at the surface or the outer zone while its inner zone or core remains tough. The reason is to improve wear resistance and fatigue strength while retaining the capability to resist impact load.

Case hardening can be achieved by many methods, some of the widely known processes are induction and flame hardening, carburizing, carbon-nitriding, and nitriding.

(1) Induction and flame hardening

Induction and flame hardening are heat-treatment processes in which the surface of a hardenable steel is rapidly heated up above the transformation temperature by electromagnetic induction or by impingement of a high temperature flame, as the case may be, and then cooled down at a rate to produce the hardness required.

(2) Carburizing

Carburizing is a thermochemical non-metallic case hardening process in which the carbon content at the outer zone of a treated part is increased by the diffusion of the carbon atom. The diffusion takes place at a temperature between 900 to 1000 C. Practically, the carburizing of steel can be done by heating parts to be treated in a carbon-containing atmosphere, for example, in charcoal which is known as pack carburizing, in hydrocarbon gas or gas carburizing, or in carbon containing salt or salt-bath carburizing.

(3) Carbon-nitriding

Carbon-nitriding is a case hardening process in which carbon and alloy steels are held at an elevated temperature in a gaseous atmosphere from which they absorb carbon and nitrogen simultanously and are then cooled to room temperature at a rate which will produce desired case and core properties. The carbon is derived from any carbon rich gas or vaporized liquid hydro-carbon which is suitable for carburizing. Ammonia is the source of nitrogen. Carbon-nitriding is a modification of the gas carburizing process rather than nitriding.

(4) Nitriding

Nitriding is a case hardening process in which the nitrogen atom is introduced into the surface of steel at a suitable temperature (560-600 ^{o}C) by contact with a nitrogenous medium. Nitrogen penetrates into the outer zone of steel components and forms an intermetallic transition layer of iron nitrides which increase wear and corrosion resistance as well as the fatigue strength of steel parts. The nitrogenous medium can be gas or liquid. In case of gas, ammonia is usually used as the nitrogen source and the process is called gas nitriding. In the liquid case, the medium used is molten salt which is composed of sodium and potassium cyanide, cyanate and carbonate. The process is called salt bath nitriding.

4.6.2 Benefits of case hardening

There are several benefits of the case hardening process, namely, an increase in fatigue strength, an increase in wear and corrosion resistance, and impact strength.

(1) Increase in fatigue strength

The fatigue strength--that is, the resistance to alternating load of the machine parts--can be increased by case hardening, especially when the parts are subject to push-pull type of loading.

(2) Increase in wear and corrosion resistance

Due to increasing the hardness at the surface, the resistance to wear of the parts can be increased.

(3) Impact strength

By case hardening, only a thin layer of the outer zone becomes hard and brittle. The core material becomes slightly harder or unchanged. The resistance to impact load of the whole component is not much effected by case hardening.

Steel components in which case hardening is necessary, are those which are subject to wear; and corrosion resistance is required. They are also subject to alternating stress and occasionally impact load. Examples are parts of an engine such as the crankshaft, camshaft or piston pin, or parts of an automobile or other transmission systems such as gears and pinions, splined shaft, axles, and parts of tools and dies for metal working.

4.6.3 Situation of Case Hardening of Steel in Thailand

In Thailand all of the described case hardening processes are known to the local metal workers. Activities in case hardening of steel can be classified into three types: maintenance and repair workshops of large factories, manufacturers of parts which require case hardening, and service-type heat-treatment shops.

(1) Maintenance and repair workshops of large factories

The maintenance and repair workshops of large factories such as sugarmills, re-rolled steel mills, textile factories papermills, etc., carry out heat-treatment of heavy spare parts by themselves, mostly by flame hardening.

(2) Manufacturers of parts which require case hardening

Some manufacturers of simple machinery parts in which case hardening is required, such as track pins for tractors and piston pins for small engines, perform case hardening of the finished parts by themselves. Since the dimensions of these parts are fixed and the steels specified to them are hardenable, they mostly apply induction hardening.

(3) Service-type heat-treatment shops

There are about six to seven heat-treatment shops which provide case hardening service to clients. Most of their clients are metal workers who want to improve the quality of their tools and dies and some small machine shops that want to treat their spare parts after long duration of use. Some of these heat-treatment shops are owned by steel suppliers, some by experienced mechanical foremen and engineers, and some by non-technical businessmen, most of whom operate salt bath nitriding and carburizing.

4.6.4 The Cost Factor

Based on the capacity of heat-treatment shops and the amount of salts comsumed, it is estimated that 500 tons of steel are treated by case hardening annually.

The heat-treatment charge is 50-100 baht/kg of steel for case hardening service. The reason for this relatively high cost is mainly due to the high chemical cost. In Thailand the heat-treatment salts are at least three times more expensive than those in the FRG. For this kind of industry, the advantage of cheaper labor cost cannot be taken into account.

Since the main expense of salt bath nitriding and carburizing in Thailand is the cost of salts, some of the heat-treatment shops have tried to reduce the operation cost by changing the process to gas carburizing and gas nitriding. But due to the lack of experience in handling the associated equipment, their effort has not been commercially successful so far.

4.6.5 Conclusion

Both the proposed processes which are already available for the local market, namely the Tufftride (R) process for nitriding and the Durafor (R) process for carburizing, can be introduced to the heat-treatment workshops in Thailand without any excessive investment. However, the following factors have to be considered:

a) Franchising fee. Since the proposed clean technologies are registered, the franchising fee for the transfer of the process will be too high for the small heat-treatment workshops in Thailand.

b) The amount of waste salts. The disposal of waste salts does not present any significant problem now because the amount is only about 0.5% of the amount used in the FRG.

c) Quality of treated parts. As reported, the new technologies can provide slightly superior quality particularly in increasing the uniformity of steel. However, this advantage is overridden by the poor performance and inconsistency in the quality of work offered by the local heat treatment workshops. This is due to the lack of understanding of the property of steel at different termperatures, inadequate quality control, and at times the attempt to cut cost by using inactive salts. These factors in combination with the fact that heat-treatment workshops in Thailand are service-type workshops, not production workshops designed only for specific parts, are the main causes of quality fluctuation of heat-treated parts which is the prevailing situation now.

4.6.6 Recommendation

The proposed registered processes will be feasible in Thailand only when the demand in heat-treatment of specific machine parts increases; and steel hardening workshops for line production are required. At present, the existing workshops will not be in the position to take advantage of the improved quality of steel. No introduction of the improved technology is recommended now.

4.7 CLEAN TECH # 13 : REDUCTION AND UTILIZATION OF PAINT SLUDGES

There are two main reasons for painting, to color the object and to protect corrosion.

The objects for which painting is needed range from very large construction works such as buildings, industrial plants, ships, bridges, etc., to small objects such as household and office articles. Paint can be applied on metallic surfaces such as steel and cast iron and non-metallic surfaces such as plastic and wood.

There are two methods of painting, namely, brushing and spraying. Brushing is applied mostly on large construction works while spraying is used for painting small and medium-sized articles such as automobiles, pressure vessels, gas cylinders, furniture and household articles. Spraying can be done in open-air or in spraying booths. The spraying methods which are mostly used are:

- Compressed air spraying
- Airless spraying
- Air mix
- Electrostatic spraying

In all these methods, overspray is bound to happen. The amount of oversprayed paint depends on several factors, such as the spraying process, type and quality of paint, size and configuration of objects being sprayed, spray angle, etc.

By spraying in a booth, the oversprayed paint is collected as sludge. The percentage of paint loss can be obtained by determining the degree of coating efficiency.

$$\text{Degree of coating efficiency} = \frac{\text{Wet film quantity x 100\%}}{\text{Quantity of paint employed}}$$

and

$$\text{Wet film quantity} = \frac{\text{Wet film thickness x painted area}}{1000}$$

Where wet film thickness is in micron (μ) and painted area is in square meter (m^2).

As can be seen in Table 4.5, the maximum coating efficiency is obtained by the electrostatic spraying method and the minimum by air spraying.

Table 4.5 The degree of coating efficiency by different spraying methods.

Spraying methods	Coating efficiency
Air spraying	20-60 %
Airless spraying	40-80 %
Electrostatic spraying	80-90 %

4.7.1 Situation of paint consumption in Thailand

Due to industrial growth, the paint consumption in Thailand is increasing rapidly. The typical paint consumers, their products, and methods applied are given in Table 4.6

Paint consumption for industry and for automobile assembly plants amount to 600 million baht annually. The painting process for these manufacturers is semi-automatic which means the objects are transported by conveyor to the spraying booths where the objects are manually sprayed. The spraying booths are mostly 2-unit installed systems for under coating and top coating.

Figure 4.15 shows the painting installation for LPG cylinders at Sahamit Pressure Container Company (SMPC). The LPG cylinders (15kg.) are electrostatically sprayed at the rate of 10,000-12,000 units per month and the paint consumption is around 2.4 tons.

Figure 4.16 shows the painting installation for electric fans at SANYO Electric Company. The painting method is both airless and eletrostatic spraying; and the paint consumption is about 1.5 tons per month.

The paint consumption figures for selected industries, workpieces, spraying methods and the related coating efficiency are shown in Table 4.7.

Table 4.6 Characteristics of Paint Consumption in Thailand

Nature of Work	Product	Painting Method
Construction industry	Buildings, housing	Brush painting
Steel fabrication industry	Storage and piping facilities, steel structures, pressure vessels etc	Open-air spraying
Ship building industry	Ships, vessels, boats etc.	Brush painting, open-air spraying
Powerplant and chemical plant	Equipment, piping, storage tanks etc.	Brush painting, spraying
Automobile industry	Passenger cars, trucks, bus bodies	Spraying in booth
Automobile repair shops	Passenger car bodies	Open-air spraying
Gas cylinder manufacturer	Gas cylinders	Spraying in booth
LPG filling plants	Gas cylinders	Open-air or spraying in booth
Household electrical equipment manufacturer	Electric fans, refrigerators, air-conditioners, televisions, radios, washing machines, heaters etc.	Spraying in booth
Steel furniture and office article manufacturer	Steel tables,chairs, cupboards,trays etc.	Spraying, mostly electrostatic spraying in booth
Others	Small household articles, cooking pots, kettles, machinery parts etc.	Spraying in booth

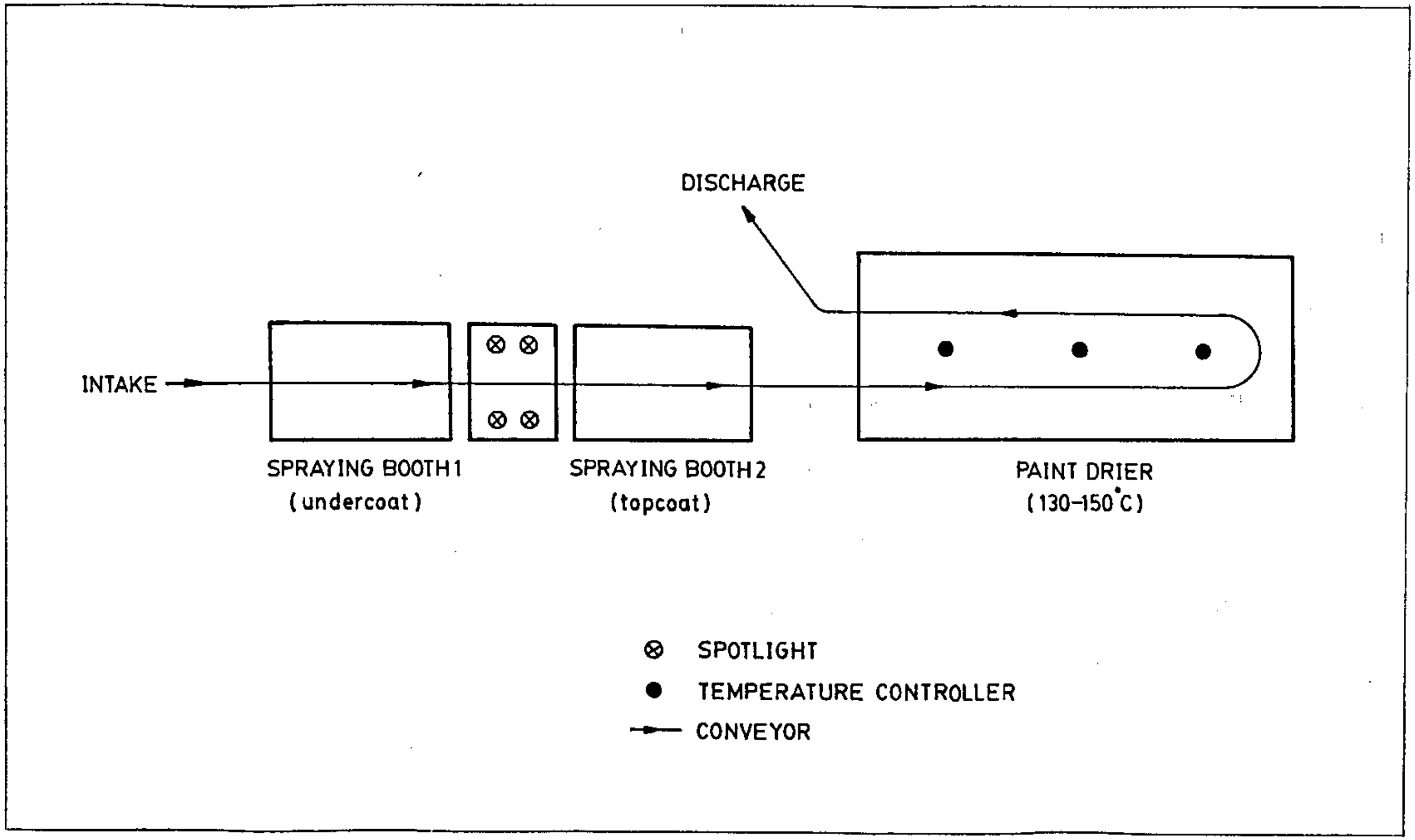


Figure 4.15 Painting Installation at Sahamit Pressure Container

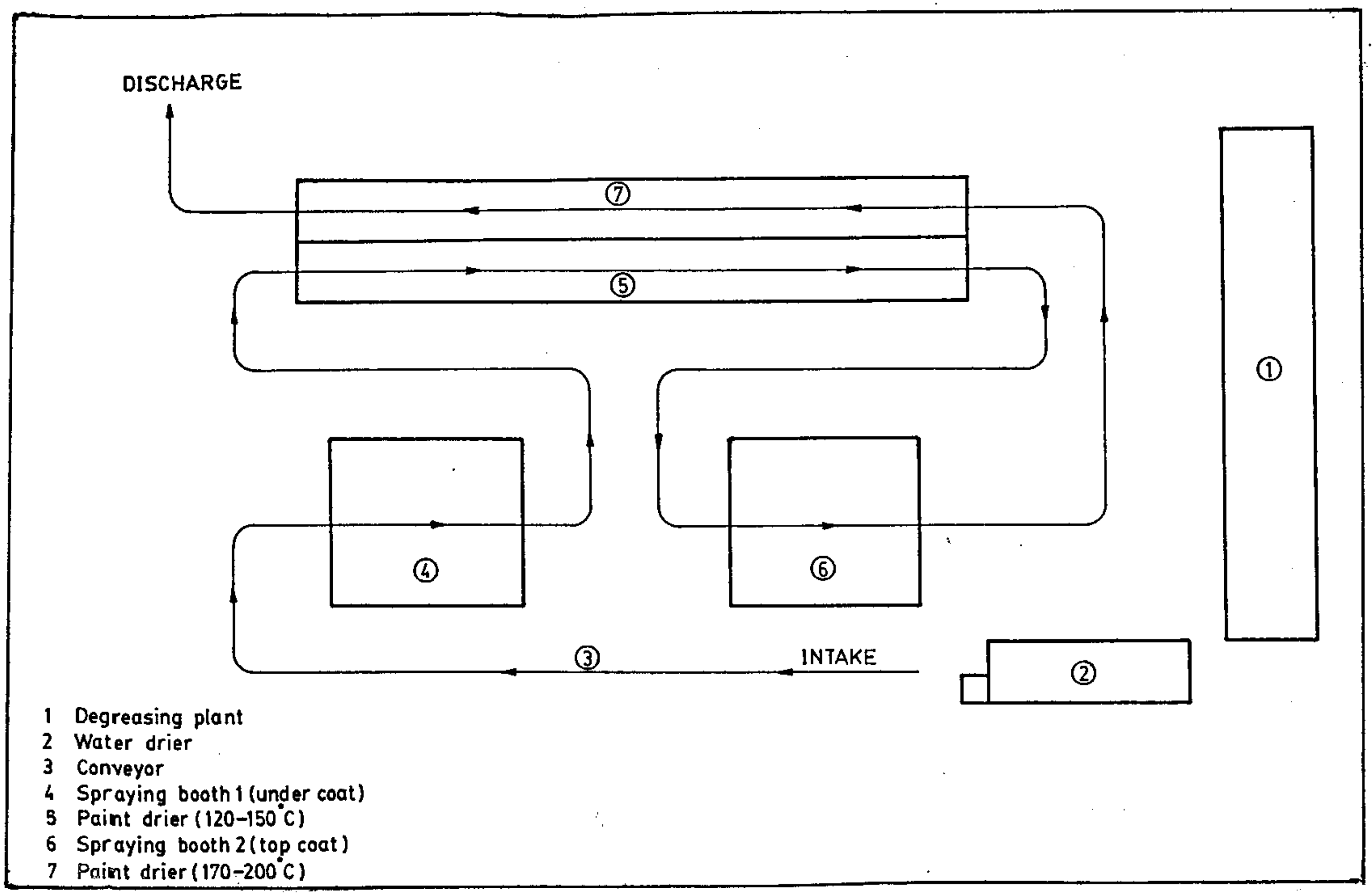


Figure 4.16 Painting Installation at Sanyo Electric Co., Ltd.

Manufactory	Coating process	Workpiece	Number of pieces	Painted area	Total paint consumption	Theoretical consumption	Coating efficacy
–	–	–	1	m^2	kg	kg	%
Sahamit Pressure Container	Electrostatic Spraying (Semiautomatic)	LPG – Cylinder (15 kg)	220	176	20	14.2	71
Unimit	Airless Spraying (Manual)	Pressure Vessel (10 t)	1	25.3	15.5	8.2	53
Sanyo Electric	Airless Spraying (Semiautomatic)	Electric Fan – Guard	2630	182	72	18	25
National Electric	Compressed – Air Spraying (Manual)	TV-Body	550	120	20	6	30

Table 4.7 Paint Consumption Figures for Spraying Methods of Some Selected Workpieces.

4.7.2 Proposed Technology

The proposed process is to recover the overspray by two successive operations:

a) Paint recovery disc for paint particles

b) Venturi wash-out for paint sludge

This is a simple technology which can be easily emulated. Figure 4.17 illustrates paint recovery in a booth by means of the rotating disc. Figure 4.18 shows paint recovery from the paint sludge of the storage tanks. The Venturi wash-out process for drawing-off air from a sprying booth is illustrated in Figure 4.19.

4.7.3 Economic Feasibility

The economic feasibility is calculated by applying the proposed technology at a selected local company, the Sahamit Pressure Container Company (SMPC).

From past record, this company operates paint spraying with 71% efficiency. To be on the safe side, we will assume that the total percentage of paint which can be recovered will not be more than 25%.

Paint consumption	28,800 kg/yr
Recovery 25%	7,200 kg/yr
At the value of 80 baht/kg or	576,000 baht/yr
Interest rate	17.5% /yr
Return period	10 years

With all these assumptions, the initial investment can be as high as **2.64 million** baht

4.7.4 Recommendation

The proposed technology is applicable to the local industries in Thailand. The investment cost is relative to the size of the paint recovery system and is believed to be within the means of medium and large scale industries. Information on the proposed process should be translated into the local language and disseminated to potential users.

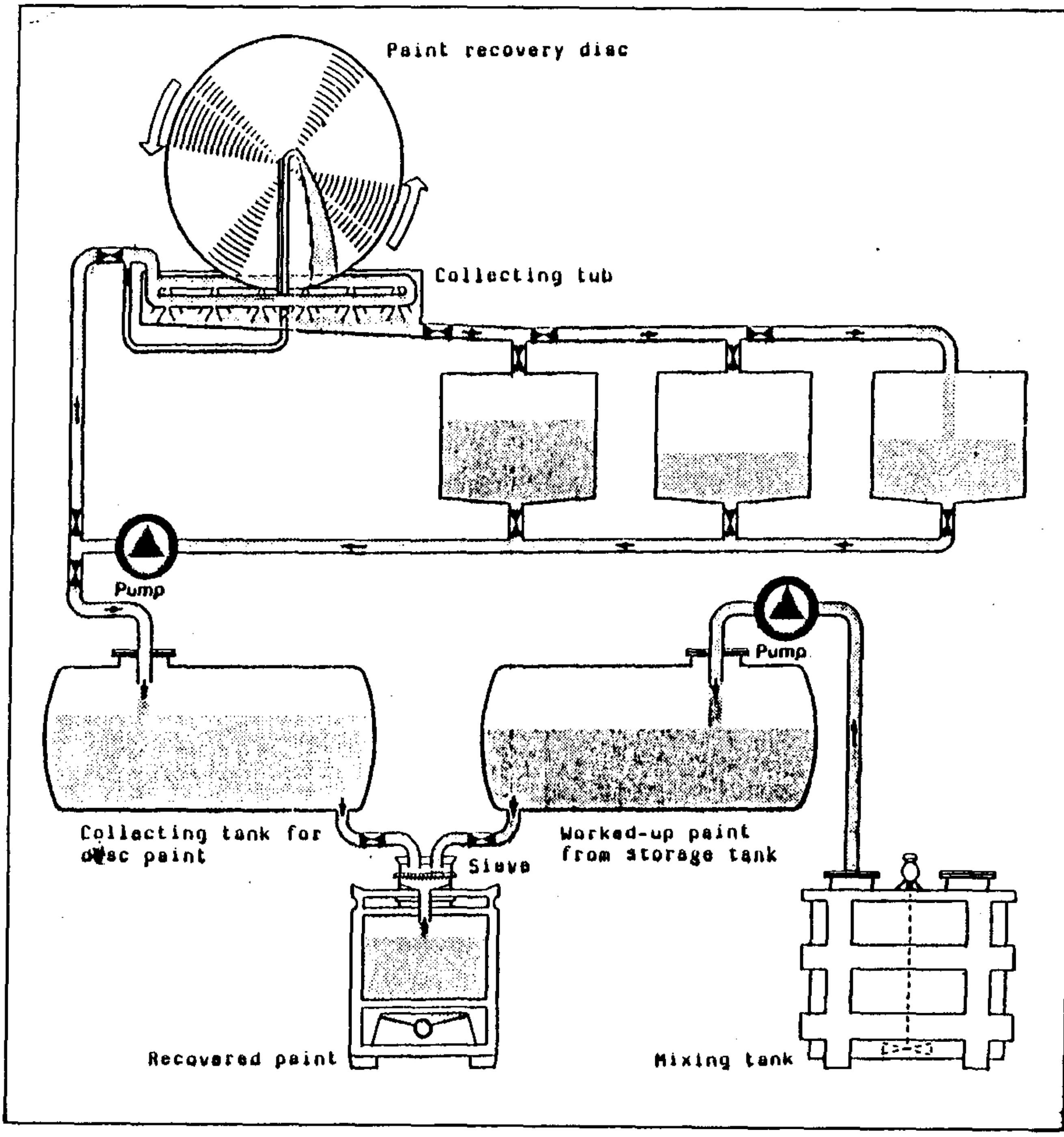


Figure 4.17 Paint Recovery in a Booth by Means of the Rotating Disc, Neunkirchen, FRG.

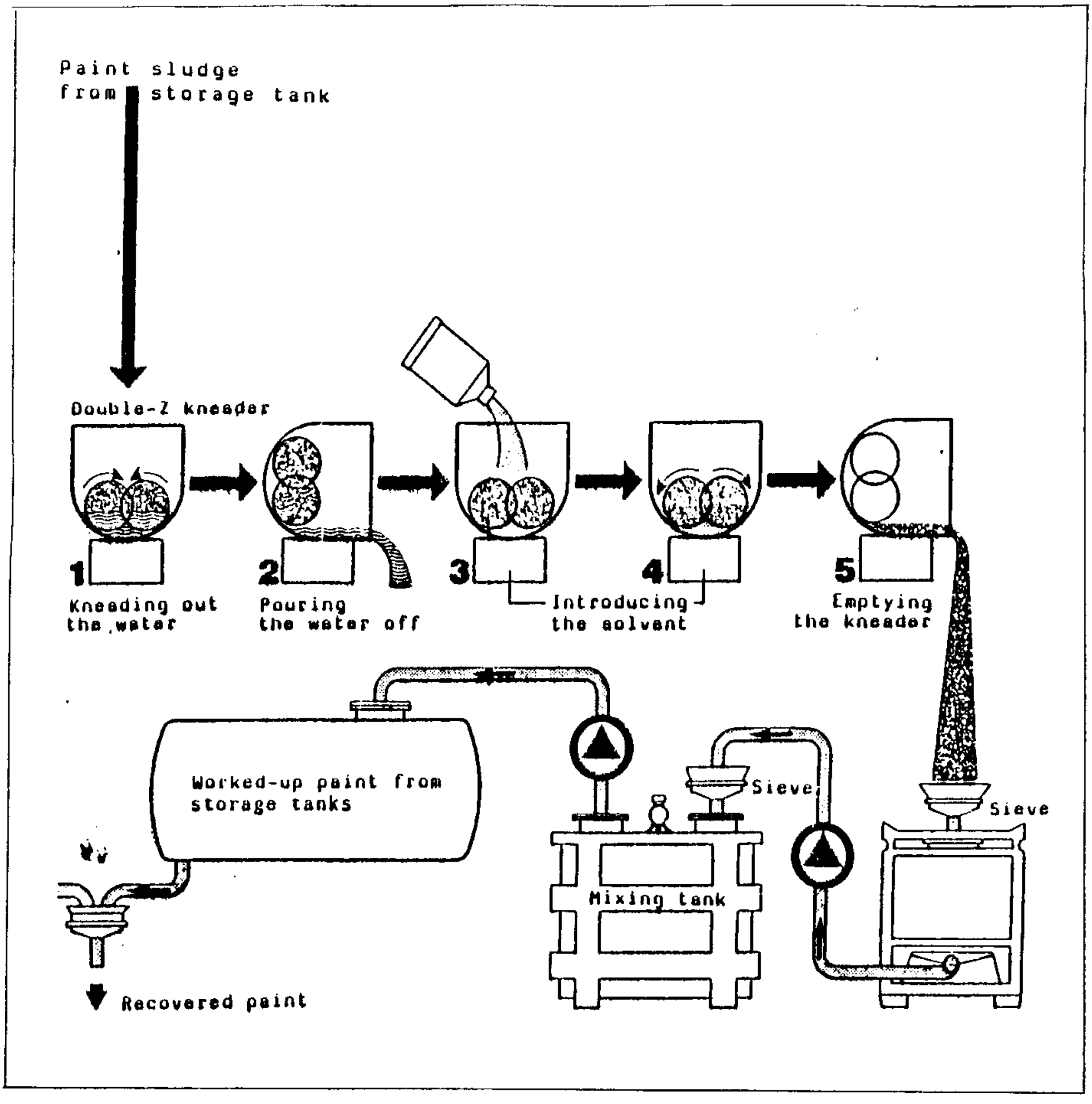


Figure 4.18 Paint Recovery from the Paint Sludge of the Storage Tanks, Neunkirchen, FRG.

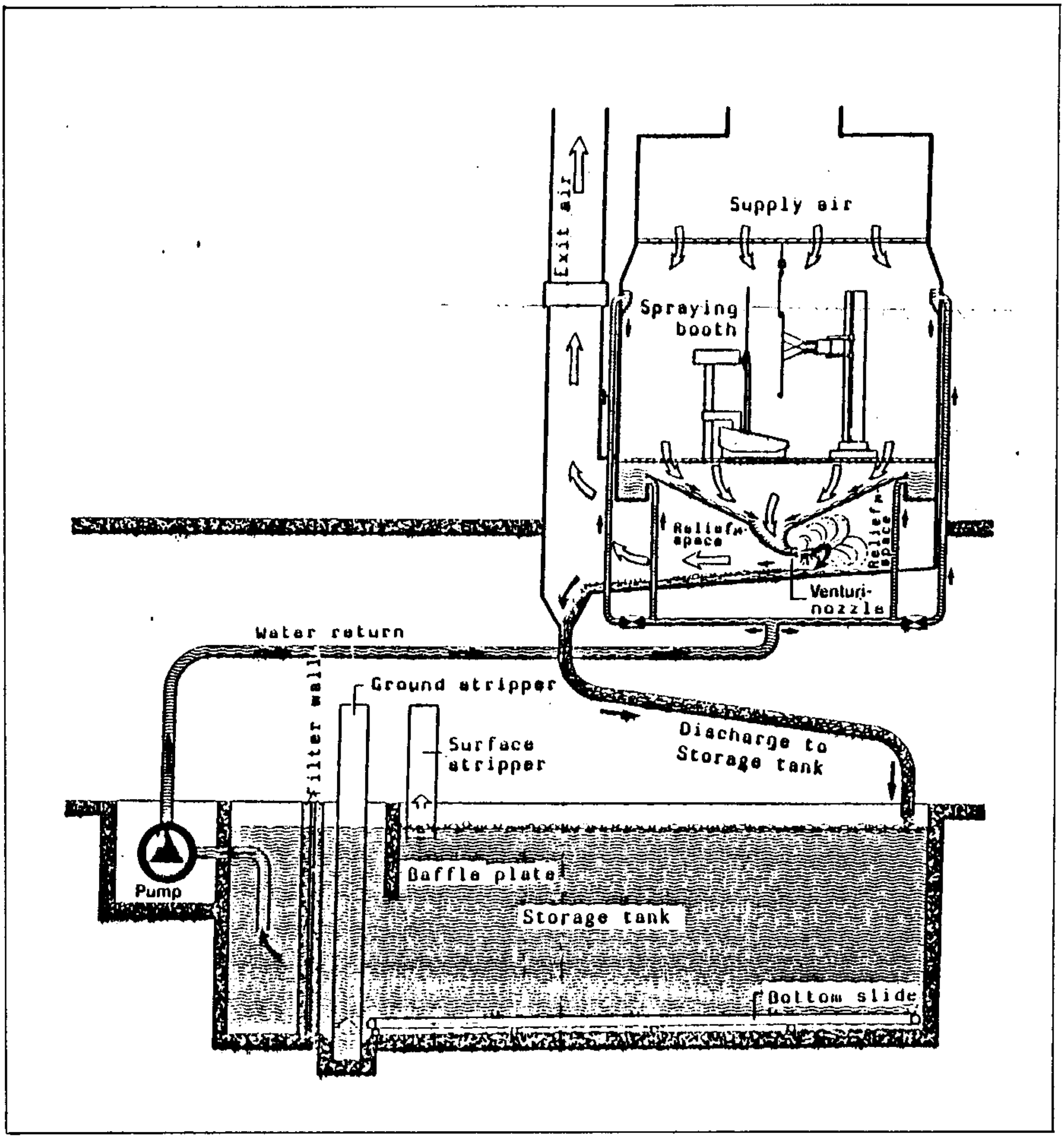


Figure 4.19 Venturi Wash-out for Drawing-off Air from a Spraying Booth, Neunkirchen, FRG.

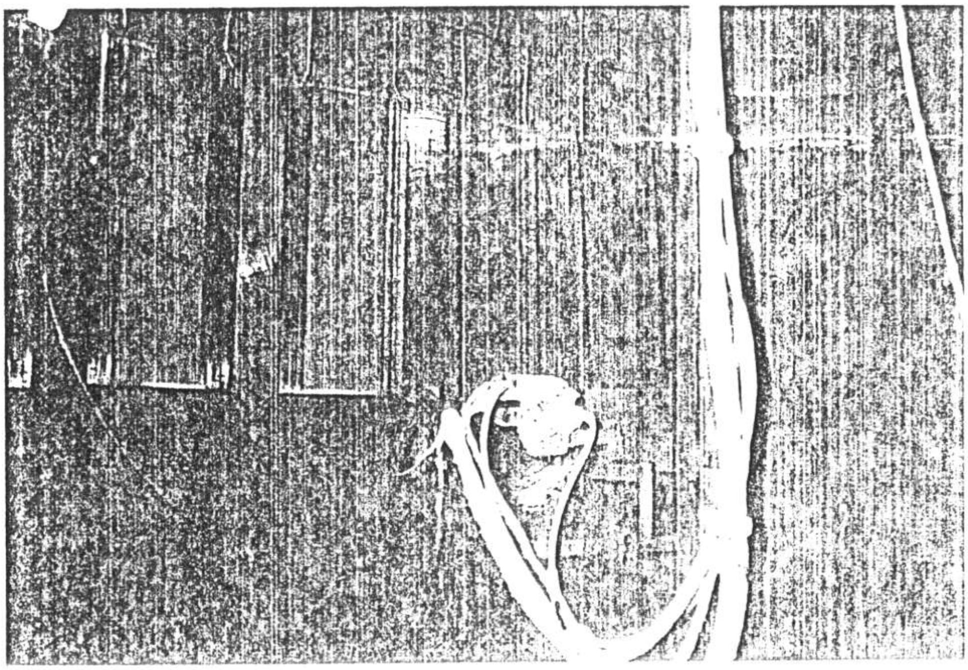


Figure 4.20 Spraying Machine in Action, Neunkirchen, FRG

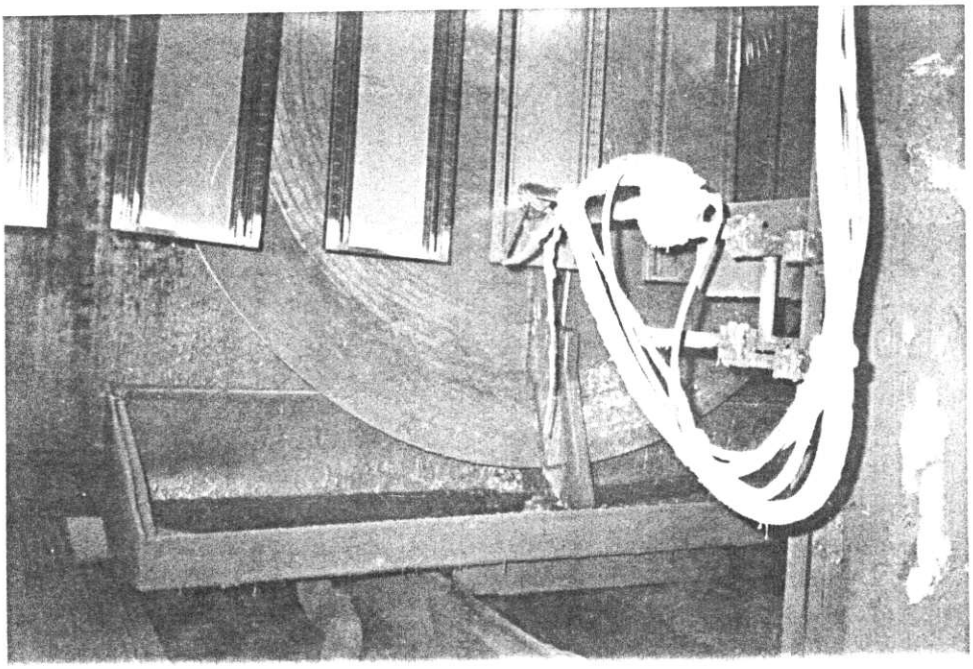


Figure 4.21 Rectangular Particles to be Sprayed in Front of the Paint Recovery Disc, Neunkirchen, FRG

CHAPTER V

THE FUTURE OF CLEAN TECHNOLOGY IN THAILAND

The principle of clean technology is to introduce preventive measures to reduce wastes or to recover by-products, rather than to rely on corrective end-of-pipe treatment of pollutants. This study evaluated the adaptability to Thailand of 13 processes in pulp and paper production, textile production, and metal finishing and coating.

5.1 THE OUTCOME

The results verify that Thailand is ready to accept five of the proposed technologies. The Siam Kraft Company, a local producer of paper using wastepaper, is ready to emulate the wastewater-free closed-circuit system of its counterpart in the FRG. Thailand Institute of Scientific and Technological Research (TISTR) is willing to initiate a cooperative pilot project on desilication of bagasse with the FRG. Concurrently, pulp bleaching by hydrogen peroxide and paint recovery are two processes which can be readily propagated locally, and the cost of chromium recovery in zinc-electroplating shops was found to be within the means of the local platers.

Market availability has proved to be the decisive factor which inhibits the present use of five other processes, namely low-pollution dry-cleaning, thermoprinting of polyester, cadmium electroplating, electrodeposition of aluminium, and wasteless salt bath for steel hardening. The remaining three processes are at the research stage in the FRG, hence their adaptability cannot be determined.

5.1.1 Pulp and Paper Production

The introduction of clean technology is easier in the pulp and paper industry. This is due to the universal manufacturing processes employed in different parts of the world and also to the fairly large size of the local pulp mills.

Table 5.1 shows the tabulated results of the four clean technologies evaluated under this study.

The pulp and paper industry as a whole is often quoted as a success story in the reduction of its dependence on raw water supply. The closed-water cycle process is being employed now in the FRG and in Canada. Furthermore, the reduction of the BOD level has been so successful that it allows governments to turn their attention to other more toxic substances, in particular the organochlorine compounds.

Three out of the four proposed clean technologies are appropriate for Thailand, which verifies that this is the industrial sector that stands ready to follow the clean technology concept. In fact, this is a positive-sum situation in which all involved parties, namely industry, governments, and research institutes of both donor and recipient countries may gain from the mutual benefits which can be derived from the transfer of clean technology as recommended in Chapter II of this report.

Table 5.1 Status and Recommendations on the Adaptability of the Proposed Technologies for Pulp and Paper Industry

Status / Name of the proposed clean technology	Ready to be adapted	Ready to be applied at the pilot-project level	Awaiting the results of R & D in FRG
Clean Tech # 1: Wastewater-free paper production technology on used paper basis	One local paper mill, the Siam Kraft Company, plans to undertake detailed financial analysis on the proposed process as part of its plant expansion		
Clean Tech # 2: Pulp production from domestic wood and annual plants with organic solvents as lignin extracting agents			UNEP should disseminate the results of this research through its established channel - the Pollution Abatement and Control Technology (PACT) publication for the pulp and paper industry
Clean Tech # 3: Bleaching of pulp	Propagation of this process to the 3 local pulp mills by Thailand Institute of Scientific and Technological Research (TISTR) and National Environment Board (NEB)		
Clean Tech # 4: Desilication of pulp waste liquors		Federal Ministry for Research and Technology (BMFT) of the Federal Republic of Germany (FRG) and TISTR should cooperate in setting up a pilot project on the desilication of bagasse	

5.1.2 Textile Production

In the case of textile production, the present slump in the market for synthetic fibers has arrested any chance for investment in the proposed processes. Marketability of the products has proven to be the decisive factor in determining the potential success or failure of a proposed process. This, in turn, is dependent upon the habit and customs of the people in a particular country.

Table 5.2 shows the results of the evaluation of the three proposed clean technologies related to the textile industry. The results show that due to the present recession in the textile industry in Thailand, it is extremely difficult to introduce any new innovation now.

Table 5.2 Status and Recommendations on the Adaptability of the Proposed Technologies for Textile Industry

Status / Name of the proposed clean technology	Not ready for promotion now due to limited market	Awaiting the results of R & D in FRG
Clean Tech # 5: Low-pollutant cleaning process with minimum fresh water pollution by simultaneous or successive use of solvent and water in one machinery assembly	Dry-cleaning is not normally employed since the local people wear mainly cotton or cotton blends which do not require dry-cleaning	
Clean Tech # 6: Low-pollutant thermoprinting of textiles with organic sol-vents as lignin extracting agents	Already in use in Thailand. However its prospect is dim due to limited export market	
Clean Tech # 7: Reduction of Wastewater pollu-tion caused by size		The results of the research in FRG should be dissemi-nated through UNEP

5.1.3 Metal Finishing and Coating

Metal finishing and coating as covered in this report is rather comprehensive, ranging from metal electroplating and steel hardening, to the recovery of oversprayed paint and the production of printed circuit boards.

Table 5.3 shows the results of the evaluation of the six clean technologies as reported in Chapter IV. Marketability and the quality of the local workmanship were identified as the dominating factors. Technologies which are applicable to the prevailing small shops must be simple and must not entail excessive investment or intensive training of the operators.

Table 5.3 Status and Recommendation on the Adaptability of the Proposed Technologies for Metal Finishing and Coating

Status / Name of the proposed clean technology	Ready to be adapted	Not appropriate to Thailand	Awaiting the results of R & D in FRG
Clean Tech # 8: Low-waste electroplating process for zinc	Government is proceeding with its plan to construct a central treatment plant for zinc electroplating wastes. The treatment fee to be set can then be compared with the cost of individual treatment as proposed in the Clean Technology		
Clean Tech # 9: Low-waste electroplating process for cadmium		There is no market for cadmium-plating	
Clean Tech # 10: Low-emission technology for electrodeposition of aluminium		There is no market for aluminium coating	
Clean Tech # 11: Low-pollution galvanizing technology for printed circuit board production			Results of R & D should be made available to local PCB manufacturers through UNEP
Clean Tech # 12: Wasteless salt baht processes		Inconsistency in performance which is prevailing in the local steel hardening workshop inhibits the fruitfull adaptation of the proposed processes	
Clean Tech # 13: Reduction and utilization of paint sludges	The proposed concept is simple and is economically feasible to some of the local industries depending on their sizes		

5.2 IS THAILAND READY ?

It is encouraging to reconfirm that technologies which abate pollution are also cost-effective. This clarifies why Thailand is ready to accept five of the proposed technologies even though there is no pollution charge which is the case in the FRG.

Unfortunately, the study also highlights the paucity of local R & D capability, hence government should take full advantage of the research works already done elsewhere.

5.2.1 R & D in Thailand

Symptomatic of the situation in developing countries, R & D has yet to be given its due priority in Thailand. In fact, the percentage of fund allocated to R & D has been steadily decreasing. From 1975 through 1984, governmental expenditures in R & D as a percentage of the annual budget has been declining from 2.48% to 1.10%. In terms of the percentage of R & D expenditures to the gross national product, it has been declining from 0.40% to 0.22% in the same period.

The normal practice in industry is to import a production technology as part of the turn-key project to construct and operate a manufacturing plant. Such practice has led to the widening of the gap between technologies used in industry and the real technological capability of the country to the detriment of the actual R & D effort.

To rectify this situation, the Ministry of Industry proclaimed in April 1985, that any factory with more than 100 million baht of capital investment or those which have received investment privileges from the government must invest in R & D and must report its performance to the Ministry on an annual basis.

On the incentive side, since November 1983, the Ministry of Finance has granted tax reductions for the import of machines and equipment in the following categories:

1) Machines, materials or equipment used in the recycling of wastes as a source of energy, or the recovery of released energy for reuse in a factory.

2) Machines, materials or equipment used for wastewater treatment, air pollution treatment, solid wastes treatment and those used in research, evaluation, measurement and monitoring activities for the protection of the environment.

More recently, the government has set up a Science and Technology Development Board to promote direct research by industry under a soft loan of US $49 million provided through

USAID. Three priority areas were selected, namely, informatics, metallurgy, and biotechnology.

However, there are no short-cuts in any R & D work: it will take at least a few more years before all these efforts start to bear fruit.

5.2.2 Environmental Regulations

One of the lessons learned from the experience in the FRG is that the imposition of an effluent tax could quickly turn the wastewater charges into an incentive for improving the production process to reduce the amount of wastewater generated. However, such an approach is not likely for Thailand, at least in the near future. A successful wastewater-charge program would require enforceable regulatory measures. In developing countries, stringent enforcement of regulations cannot normally be secured.

The present system of pollution control in Thailand still relies on the establishment of effluent standards. There are many flaws in this approach. Firstly, standard enforcement implies end-of-pipe treatment without rectifying the root-cause of the problem, i.e., the process which generates wastes. Secondly, standards can only control the degree of pollution in the effluents, not their volume. For those industries which consume large amounts of water, the total pollution load can thus be significant even when standards are followed. Thirdly, such regulatory measures require stringent enforcement which is not available in developing countries as mentioned earlier. Finally, the existing standards do not distinguish between large and small industries, resulting in the inability of small plants to comply since similar treatment methods will be required irrespective of the size of a plant. The existing standards are shown as Appendix C.

There are two main governmental organizations directly responsible for industrial pollution control, namely, the Department of Industrial Works (DIW) under the Ministry of Industry and the National Environment Board (NEB) under the Ministry of Science, Technology and Energy. DIW has the authority to regulate the established standards. It may revoke the operating license of a factory found guilty of violating the set standards. In comparison, NEB is responsible for formulating governmental policies for the protection of the environment. It has been playing the lead role in setting new standards to be followed by other governmental agencies. However, with more than 90,000 industrial establishments in the country, both DIW and NEB have their hands full trying to keep industrial pollution under control.

This general picture underlines the fact that regulatory measures alone cannot be considered as an effective tool for environmental management in Thailand. Clean technologies which are both technically and economically feasible can thus serve as a viable alternative.

5.3 THE FUTURE

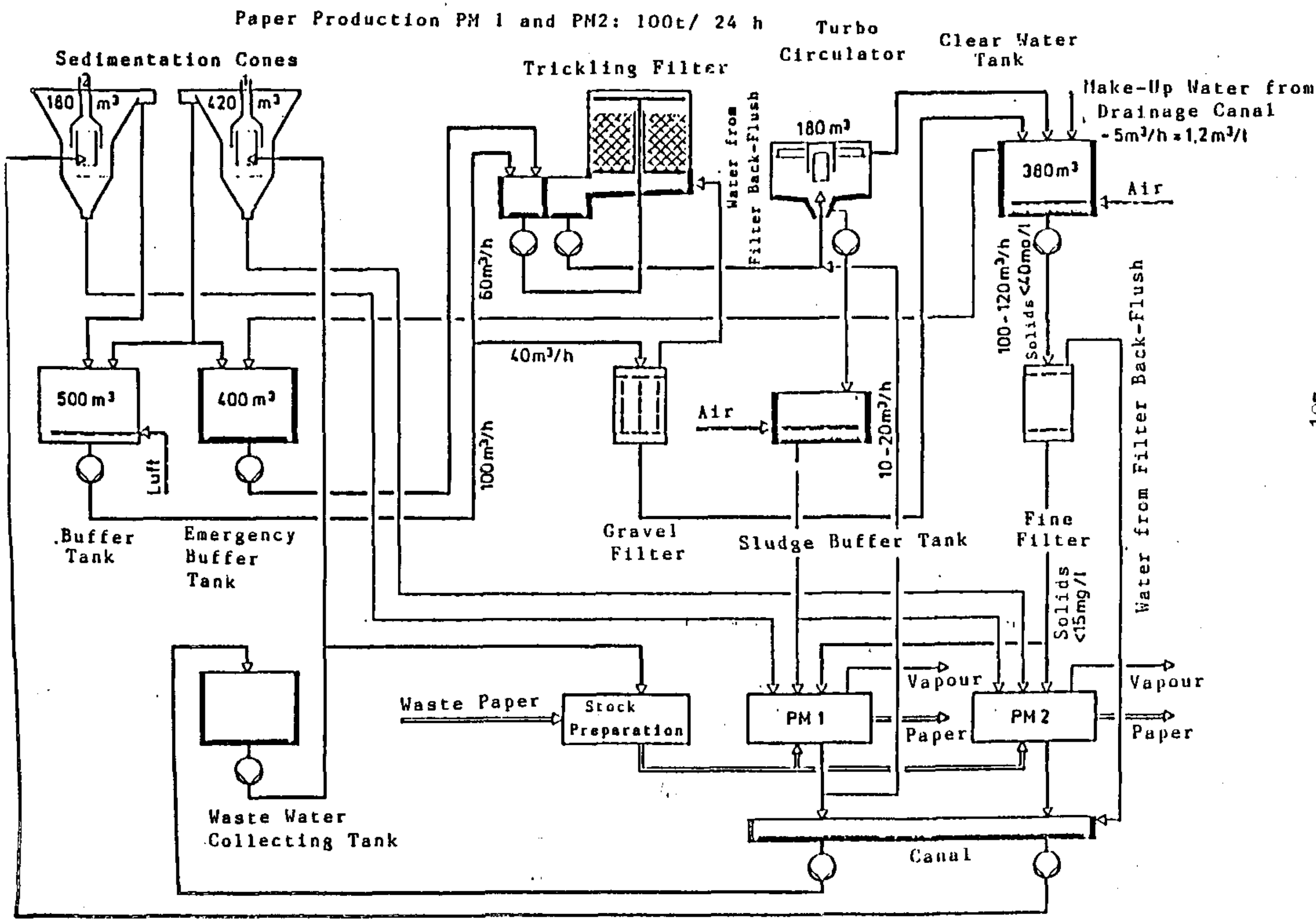
In summary, the time has not yet come for a wholesale promotion of clean technology. The approach should be selective, identifying the few local industries which are ready to benefit from the research and development already tested in the donor countries. The overruling factors are cost-effectiveness and product marketability.

Among the three industrial sectors considered in this report, it is evident that the pulp and paper sector deserves the highest attention. Direct contact should be promoted between the local paper mills and their counterpart in the FRG for a bilateral exchange of information on the proposed closed-water system in practice at Julich. Concurrently, technical cooperation between the Federal Ministry for Research and Technology (BMFT) of the FRG and its counterpart in Thailand, the Ministry of Science, Technology and Environment, should be initiated. A potential area for cooperation is the pilot study of desilication of bagasse to be conducted by the Thailand Institute of Scientific and Technological Research (TISTR) which is an organization under the Ministry of Science, Technology and Environment.

In addition, the National Environment Board (NEB) together with UNEP should continue to propagate information on the details of technologies which can be adapted now and the progress of those under R & D in the FRG. The UNEP Series of Pollution Abatement and Control (PACT) Publications could continue to serve as the vehicle to foster such dissemination of information on clean technology.

APPENDICES

Appendix A G&P Closed Water Cycle for Waste Paper Processing



Appendix B.1 Profitability Calculation (BÖWE P422)

Date: 26.6.84 / VU

Machine model: P 414 ct da EF Solvent: perchlorethylene Filter model: expander filter Heating: steam	Working time: 8.5 h/day Cycle time: 33 min + 2 min loading & unloading Loading weight: 12 kg Process: 2-bath, 1st bath to distill.		No. of loads per day: 14 per month (22 days): 308 per year: 3696	
	Unit price	Consumption per load	DM/load	DM/kg
Solvent: Cleaning aid: Filter aid:	1.10 DM/kg 4.-- DM/kg 1.50 DM/kg	2 % 240 g 1 % 120 g 0.8 % 96 g	0.26 0.48 0.14	
Average costs for material			0.88	
Electricity: Steam: Cooling water: Compressed air:	0.18 DM/kWh 0.08 DM/kg 3.50 DM/m³ 5.-- DM/m³	1.8 kWh 7 kg 100 l 6 l	0.32 0.56 0.35 0.03	
Average costs for energy			1.26	
OPERATING COSTS			2.14	0,18
Staff costs: hourly wage 12.50 DM + 30 % employer's contrib. Loading & unloading 2 min Machine maintenance 20 min		= DM 16.25 /hour = DM 0.54 /load = DM 5.42 /day	 0.54 0.39	
Variable costs (total operating costs)			0.93	
Maintenance on machine 4 % of machine price 53,015.-- Calculated depreciation 16 % of machine price Calculated interest 5 % of machine price Space: 1.2 m² floor space x 3.5 x DM 30 rent/m² month		= DM 2,121 /year = DM 8,482 /year = DM 2,651 /year = DM 126 /month	0.57 2.29 0.72 0.41	
Fixed costs			3.99	
TOTAL COSTS			7.06	0.59

Appendix B.2 Profitability Calculation (conventional dry cleaning machine with activated carbon filter)

Date: 26.6.84

Machine model: P 414 c da EF Solvent: perc with A 60 Filter model: expander filter Heating: steam		Working time: 8.5 h/day Cycle time: 28 min + 2 min loading & unloading Loading weight: 12 kg Process: 2-bath, 1st bath to still	No. of loads per day: 16 per month (22 days): 352 per year: 4224	
	Unit price	Consumption per load	DM/load	DM/kg
Solvent: Cleaning aid: Filter aid:	1.10 DM/kg 4.00 DM/kg 1.50 DM/kg	4 % 480 g 1 % 120 g 0.8 % 96 g	0.53 0.48 0.14	
Average costs for material			1.41	
Electricity: Steam: Cooling water: Compressed air:	0.18 DM/kWh 0.08 DM/kg 3.50 DM/m³ 5.00 DM/m³	0.9 kWh 12 kg 160 l 6 l	0.16 0.96 0.56 0.03	
Average costs for energy		Operating costs	~~1.71~~ 3.12	0.26
OPERATING COSTS				
Staff costs: hourly wage 12.50 DM + 30 % employer's contrib. Loading & unloading 2 min Machine maintenance 20 min per day + 20 min A 60		= DM 16.25 /hour = DM 0.54 /load = DM 10.84 /day	 0.54 0.68	
Variable costs (total operating costs)			1.22	
Maintenance on machine 4 % of machine price 52.570 Calculated depreciation 16 % of machine price Calculated interest 5 % of machine price Space: 1.8 m² floor space x 3.5 x DM 30 rent/m² month		= DM 2,103.- /year = DM 8,411,- /year = DM 2,629,- /year = DM 189,- /month	0.50 1.99 0.62 0.54	
Fixed costs			3.65	
TOTAL COSTS			7.99	0.67

Appencix C MOI Effluent Standards

(1)	pH	Between 5.0 and 9.0
(2)	Permanganate Value	60 mg/1
(3)	Dissolved solids:	
	3.1 Discharge into watercourses:	2,000 mg/l or more but not except 5,000 mg/l, depending upon discharging point
	3.2 Discharge into sea or estuaries (Salinity higher than 2,000 mg/l)	5,000 mg/l higher than dissolved solids content in sea or estuary waters
(4)	Sulfide as H_2S	1.0 mg/l
(5)	Cyanide as HCN	0.2 mg/l
(6)	Heavy metals:	
	6.1 Zinc	5.0 mg/l
	6.2 Chromium	0.5 "
	6.3 Arsenic	0.25 "
	6.4 Copper	1.0 "
	6.5 Mercury	0.005"
	6.6 Cadmium	0.03 "
	6.7 Barium	1.0 "
	6.8 Selenium	0.02 "
	6.9 Lead	0.2 "
	6.10 Nickel	0.2 "
	6.11 Manganese	5.0 "
(7)	Tar Nil	
(8)	Oil & Grease	5.0 mg/l (Except for crude oil refinery and lubricant blending plant; less than 15 mg/l)
(9)	Formaldehyde	1.0 mg/l
(10)	Phenols & Cresols	1.0 "
(11)	Free chlorine	1.0 "
(12)	Insecticides and radioactive substances	Nil

(13)	Suspended solids	30 mg/l or more depending on dilution ratio as shown below

Dilution Ratio	Allowable Suspended solids
8 - 150	30 mg/l
151 - 300	60 mg/l
301 - 500	150 mg/l

(14)	BOD, 5 day, 20 C		20 mg/l or more but not exceeding 60 mg/l depending upon discharging point, except for industries as shown below
	14.1	Fish canning (category 7 (1))	200 mg/l Until 31 Dec. 1982 100 " As of 1 Jan. 1983
	14.2	Tapioca starch: New process (category 9 (3))	100 mg/l Until 31 Dec. 1982; thereafter as in (14)
		Old process	200 mg/l Until 31 Dec. 1982 100 " As of 1 Jan. 1983
	14.3	Noodle factory, using less than 500 kg of rice per day (category 10 (3))	150 " Until 31 Dec. 1982 100 " As of 1 Jan. 1983
	14.4	Tanneries (category 29)	200 " Until 31 Dec. 1982 100 " As of 1 Jan. 1983
	14.5	Pulp mills (category 38 (1))	150 " Until 31 Dec. 1982 100 " As of 1 Jan. 1983
	14.6	Seafood processing (category 92)	200 " Until 31 Dec. 1982 100 " As of 1 Jan. 1983
(15)	Temperature		Less than 40 C
(16)	Color and Oder		Not objectionable when mixed in receiving water

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