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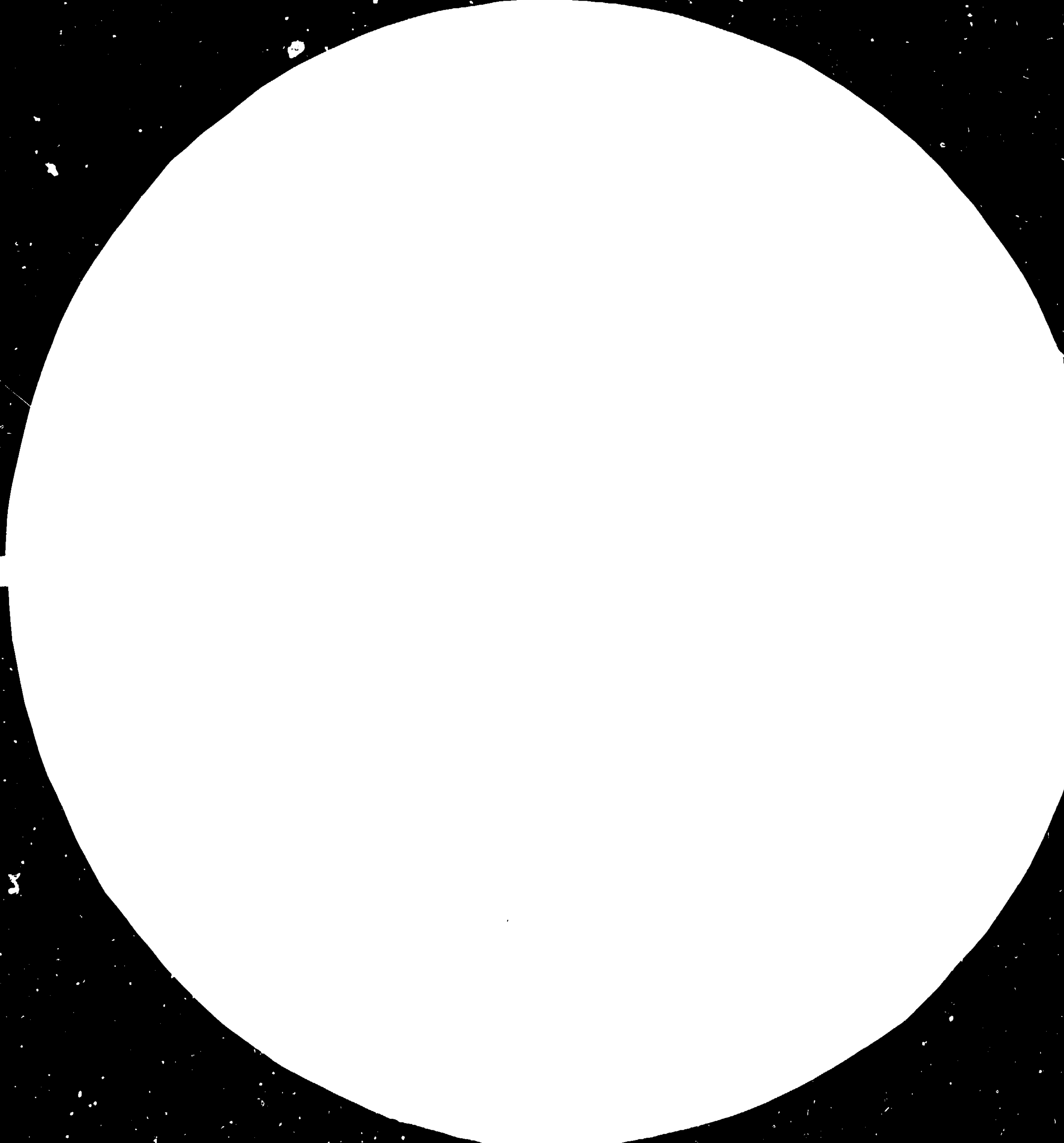

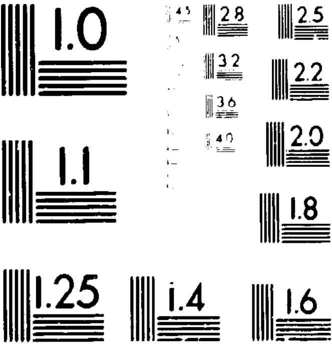
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NATIONAL CANE SUGAR INDUSTRY RESEARCH CENTRE

DP/CPR/82/005

CHINA

Technical Report: Energy Saving in the Sugar Industry*

Prepared for the Government of China
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Wilhelm Leibig
Expert in Energy Saving in the Cane Sugar Industry

United Nations Industrial Development Organization
Vienna

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ABSTRACT

This final report covers services based upon job description DP/CPR/82/005. The respective activities were initiated May 4, 1984, having the purpose to provide expertise for energy savings in the cane sugar industry for the People's Republic of China.

After briefing in Beijing by the UNIDO representative, the expert arrived May 10 in Guangzhou ending activities there May 29, 1984. There was no debriefing in Beijing; this procedure was approved in advance by the SIDFA.

Energy related matters were covered in lectures and seminars to a selected group of experts in a program already in progress by the National Canesugar Industry Research Center in Guangzhou. Three factories in the Guangdong Province (Pearl River delta) were visited.

Information provided covered energy management in general including heat pump systems, bagasse drying, and the use of enthalpy and exergy balances.

Guidelines were given to achieve reduced heat requirements taking into consideration the peculiarities of the cane sugar industry in China, which is showing a rather high degree of diversification producing paper, fiberboard, alcohol, etc., as by-products, and the urgent need to increase sugar production. The advanced design for related equipment was discussed.

INTRODUCTION

This final report describes final activities under the UNIDO job description DP/CPR/82/005, covering the topic of energy savings in the cane sugar industry in the People's Republic of China.

Per UNIDO job description dated January 6, 1984, the main purpose of the project was:

> "to furnish detailed information and make evaluation of research activities in the field of energy savings in the cane sugar industry related to the production of plantation white sugar, to give advice to the researchers on energy savings in order to reduce the specific energy consumption as much as possible".

In pursuit of this general goal, Wilhelm Leibig ventured to China, May 4, 1984. After briefing in Beijing by the SIDFA, the expert arrived May 10 in Guangzhou, ending his activities there May 29. He returned to his home base in Annapolis, Maryland, May 30, without debriefing with the UNDP office in Beijing. This procedure had been approved beforehand by the SIDFA in China.

The services covered energy related matters in the cane sugar industry by providing lectures and conducting seminars to a selected group of experts involved in a respective research program already in progress by the National Canesugar Research Center in Guangzhou. The three sugar factories in the Guangdong Province (Pearl River delta area) were visited allowing discussion of problems at site and later during the seminars.

In the lectures, the audiences were informed about advanced methods to improve the energy management in general and dealing with specific projects like bagasse drying, thermo-compression and the use of exergy balances to supplement the conventional enthalpy balances for the evaluation of more complex thermo-physical processes.

The seminar sessions were used to discuss practical examples and consideration of the peculiarities of the cane sugar industry in China, which is showing a rather high degree of diversification producing already by-products like paper, fiberboard, ethyl alcohol, etc.

Information has been given for the advanced design of evaporators, thermo-compressors, turbines, prime movers, and also on instrumentation for energy management and process control in general. Recommendations were addressed to some specific problems taking into consideration the urgency for capacity increase in the sugar industry.

LECTURES

In the following resume of the lectures, their specific content is provided.

Lectures 1 & 2
Energy Saving in the Sugar Industry

Use of basic energy and its implications taking into consideration increasing energy demands for industrial diversification and agricultural use.
Methodological approach of energetic evaluations using energy and mass balances, specification of evaporation systems, pressure evaporation, condenser losses, performance vs. installation costs, use of high pressure steam and its advantages for increased power generation, providing the basis for energy savings in general.
Requirements for condensate systems and methods to change existing operations to higher live steam pressure in several phases.
Explaining with a model case the possibility for increasing the generation of mechanical or electrical power.
Boiler operation with bagasse or coal or mixed fuel use.
Boiler control systems.
Use of high performance turbines and prime movers.

Lecture 3
Thermo-Compression in the Sugar Industry

Description of the thermodynamic principles of mechanical vapor compression.
Examination of the potential application of heat pumps in combination with evaporator and crystallization systems.
Calculation of power requirements under different operating conditions.

Economics of mechanical vapor compression and its technological feasibility and limitation.

Lecture 4

Bagasse Drying

Use of boiler flue gases for bagasse drying and discussion of basic systems. Computations for flue gas heat values and enthalpy defining its economical aspects and technical limitations. Use of low temperature waste heat for bagasse drying as a new application based upon favorable results obtained with pulp dryers in the western European beet sugar industry.
Explanation of a respective system layout providing energetic calculations to reduce bagasse moisture from 50% to 30% hereby increasing the heat potential by 37%.
Discussion of the economical impact upon the cane sugar industry.

Lecture 5

Exergetic Evaluation for Advanced Energy Management

Idiomatic and technological definition of exergy.
Exergy of matters under physical and chemical aspects.
Definition of exergetic efficiency and the relation between exergy and process time (heat transfer).
Discussion of advantageous utilization of exergy balances for the analysis of complex thermodynamic processes.
Comparison of exergy and enthalpy balances with two arrangements, the second using advanced technology.

Lecture 6

Mechanical Vapor Compression in the Sugar Industry

Expanded definition of systems and their application to a major audience.
Discussion of the Aarberg sugar factory in Switzerland as a classic case for utilization of mechanical vapor compression.
Survey of use of technical vapor compressors in the western European sugar industry. There are 11 installations in operation, three of them used for crystallization processes.
Discussion of compressor design, radial and axial. Use of stages and after cooling or inter cooling.
Economical and technological influence of the compression ratio and specific steam volume.

Lecture 7

Extraction Systems for Sugar Cane

A survey of existing extraction systems, mill tandems, cane diffusion, bagasse diffusion, and their technological and economical peculiarities was provided.
The expert rendered his views about further developments using the combination of existing components in a more pragmatic manner, which may lead to an improved extraction technology.

FACTORY VISITS

Three sugar mills were visited by the expert, all located in the Guangdong Province (Pearl River delta). Cane is received exclusively by river boats (Sampans). These factories implemented either in full or in part industrial diversification for the production of paper, fiberboard, and ethyl alcohol. The sugar cane is extremely soft and has a very low fiber content, approx. 10% on cane. The extraction of the mills is very high, approx. 95%. Fiber content and, consequently, bagasse quantity are low; and since it is used for by-products, the factories are relying heavily upon coal as fuel.

The industrial complexes seen are not interconnected with a rural power network; and, therefore, power generation must also be maintained during the downseason. The energetic efficiency of the factories was found rather on the high side showing steam consumption ranging from 45% to 50% on cane after deduction of steam required for by-products. Some mills are undergoing the transition to high steam consumption up to 40 BAR.

The visits were too short to evaluate thoroughly the respective operations. However, the energy system of the Shunde mill has been discussed later in a seminar session and recommendations were provided for this particular case.

SHUNDE Mill

With a capacity of 5,700 TCD, the biggest cane sugar mill in China, this was the operation with the highest degree of diversification. Sugar production is basically plantation white. However, also produced are refined sugar and sugar cubes (Chambon-system).

The by-products are ethyl alcohol, furfurol, paper, and fiberboard.

Steam consumption:	approx. 47% on cane
Specific coal consumption:	approx. 6.3% on cane

ZINI Mill

The capacity is 5,000 TCD. This mill is also showing major diversification actually undergoing expansion programs for steam boilers and power plant.

Steam consumption:	approx. 50% on cane
Specific coal consumption:	approx. 6.6% on cane

ZHUJIANG FARM Sugar Mill

The capacity is 1,400 TCD. Although the smallest mill visited, the energetic performance is very good.

Steam consumption:	approx. 45% on cane
Specific coal consumption:	approx. 6.0% on cane

Specific coal consumption last season was 5.9%.
For diversification, only alcohol is produced at this point. However, the installation of a fiberboard plant is under consideration. The small mill tandem is reaching an extraction of 96%.
The major data for the sugar cane is:

Pol.:	12.0%
Purity:	78.0%
Fiber Content:	9.8% (one of the lowest figures experienced in the cane sugar industry worldwide)
Moisture in bagasse:	48%

The sugar mill is actually used for an energy test program by the sugar cane research institute in Guangzhou. They are also testing a small mechanical vapor compressor in the evaporator compound.

SEMINARS

These activities were executed in 5 sessions discussing mainly the topics of the lectures. Since some sugar factories had been visited in the meantime, it was then possible to approach related problems in more detail and to provide guidelines for further developments and improvements.

SEMINAR 1
Bagasse Drying

The possibility to use boiler flue gases was evaluated using practical data. Likewise computations using low-temperature waste heat from vacuum pans and evaporators were discussed.

SEMINAR 2
Mechanical Vapor Compression

Computation of mechanical vapor compression in an evaporator and crystallization station and the combination of both systems were made and their power requirement determined. Reduction of process heat requirements were compared with the reduced potential of power generation and hence the practical limitation for implementation of heat pumps in general were defined. The direct vapor compression with live steam was discussed. The basic function, efficiency, and operational problems were described.

SEMINAR 3
SHUNDE Mill Energy System

Discussion of the SHUNDE mill energy system by checking with the technical personnel of this sugar mill some options for improvements.

SEMINAR 4
Guidelines for Improved Energy Management

Showing the layout and making computations for an energy system as it may be considered as applicable for the special circumstances in China using boiler pressure up to 70 BAR and a quintuple effect evaporator system without condenser losses.
Description was made for a modern condensate system and the progressive use of vapor bleeding for juice heating also heat exchange condensate vs. raw juice.
The use of high pressure steam combined with the low process steam consumption of 31% on cane is leading to a specific coal consumption of 3.5% on cane.
The maximum power generation with back pressure turbines would be 1.78 kW/TCD leaving under the assumption that 1.30 kW/TCD are needed to operate the sugar mill, .48 kW/TCD can be made available for unrelated consumers.

SEMINAR 5
Turbogenerators, Prime Movers and Control Equipment

A survey of modern equipment was provided showing advanced turbine design suitable for turbogenerators and also prime movers for mill drives, cane preparation, and major pumps with high efficiency, capable to operate with high live steam pressure.
Control equipment and its latest development was discussed including ways and feasibility of its application.

FINDINGS AND RECOMMENDATIONS

During the time between 1977 and 1982, the sugar production in the People's Republic of China was increased from 2.18 million tons to 3.4 million tons per year.

With the population of one billion people, the sugar industry - cane and beet combined - can actually provide only for a per capita consumption of 3.4 kg per annum. In order to reach the Asiatic average of 8 kg per capita, sugar production must be further increased by 135% to 8.0 million tons per year. Taking into account the same pace of production growth achieved in recent years, this goal should be reached in approximately 15 years to maintain self-sufficiency of the country for this commodity.

The sugar industry is facing the task to expand existing operations and to build new facilities in areas where cane cultivation is feasible. Three factories in the Guangdong area have a production as follows:

SHUNDE	5,700 TCD
ZINI	5,000 TCD
ZHUJIANG FARM	1,400 TCD

In accordance with the assignment, the expert was giving emphasis to energy related matters. The factories seen have a specific coal consumption to 6.0 to 6.6%: therefore, their thermodynamic efficiency can be rated well above average in the cane sugar industry worldwide. The factories are well maintained and operated by capable personnel. The components used for steam production, power generation and energy management in general show an elevated degree of sophistication; and rehabilitation programs are under way to achieve further improvements.

Extensive diversification is practised to produce a wide array of by-products, such as: paper, alcohol, fiberboard, and furfurol. The industry is thriving on the derivatives of the mills and is depending also on its energy supply. These are premises which dictate strongly the energy systems used, which must be capable to secure the operation of the entire industrial complexes - particularly during a full year's cycle.

Since the trend for diversification certainly must continue in the future, the sugar factories - existing or new - must be provided with energy systems which offer the possibility to produce a substantial amount of surplus power and process heat. Bagasse will be absorbed increasingly for by-products; therefore, its substitution with other fuels - particularly coal - is necessary, circumstances which are providing an additional incentive for energy conservation for economical reasons.

During lectures and seminars, the technical possibilities were described; and during seminar 4, an example was provided for an energy system which should be used as a guideline for the future development and layout of sugar mills.

As a first measure, high pressure steam boilers up to 70 BAR and matching turbines and prime movers should be implemented to increase the potential for power generation or to reduce respective steam consumption to keep the co-generation systems in balance. Reduction of process heat should be achieved by a quadruple or quintuple effect evaporator system capable to operate without condensor losses. A plantation white sugar factory can achieve with such a system a specific coal consumption of 3.5% on cane or 2,450 kcal per kg sugar production based upon a sucrose yield of 11% on cane.

The potential for power generation using back-pressure turbines can reach 1.78 kW/TCD providing .48 kW/TCD as surplus energy for unrelated customers. In case that surplus energy is not needed at this rate, it can be used for mechanical vapor recompression in the evaporator system. However, as discussed during lectures and seminars, the implementation of heat pumps must be carefully designed to keep power generation and process heat requirements in balance.

It should also be stated that vapor recompression, mechanical or direct, with live steam requires the special arangement of all components involved to assure trouble-free operation. Use of energy systems with a surplus potential for power generation is strongly recommended for the conditions found in the People's Republic of China to secure an economical possibility for the expansion of related industrial complexes also in the future.

With high fuel costs, bagasse drying is becoming important. Using flue gases for bagasse-fired boilers for bagasse drying has proven to be not practical in most cases - particularly under the circumstances where high performance boilers are in use operating with low flue gas temperatures, leaving only a limited amount of heat usable for drying purposes. Use of flue gases stemming from coal fired boilers may offer some advantages from the thermodynamic standpoint. However, ash content in the flue gases may preclude the use of bagasse for by-products other than fuel.

Use of waste heat from the sugar process - mainly crystallization vapor for bagasse drying - is an alternative which has been proven successful for beet pulp drying in the western European sugar industry. Although still under development, the application of a similar system for bagasse drying should be pursued based upon guidelines provided by the expert.

The goal should be to reduce the bagasse humidity from the present level of 50% to 30% moisture content, which would provide also an increase of the bagasse heat potential by 37%. Bagasse drying is likewise important when used for by-products such as fiberboard, and it can lead to substantial energy savings also in this area.

The SHUNDE mill energy management was scrutinized in some detail. There is a need to install an additional steam boiler for 40 BAR pressure and an additional extraction condenser turbogenerator. The feasibility of higher steam pressure than 40 BAR for these components should be evaluated. The new turbogenerator must be specified for operational capability during the grinding and downseasons. The six turbines for mill drives should be replaced with turbines operating also at 40 BAR live steam and 3 BAR back pressure steam.

The steam consumption of reduced live steam or extraction steam with 10 BAR pressure for the sugar house is very high. Particularly the drying of sugar with live steam in the centrifugals should be abolished and an adequate sugar dryer must be implemented. As mentioned before, high live steam pressure is leading to a reduced exhaust steam flow opening the way for improved energy management in the following thermophysical process and hence in general.

The SHUNDE mill is already using condensing type steam turbines, an arrangement which has been proven as very practical for given operational conditions. The expert explained the possibility to improve the efficiency of the respective Rankine cycle, which can lead to substantial energy savings particularly during the downseason and can make process heat conservation during the grinding season even more attractive.

Sugar extraction in the mills visited is achieved with conventional mills and was found to be above average. This is possible mainly due to the fact that the cane is generally soft with an extremely low fiber content. The cane is also delivered clean and free of leaves. For these reasons, the maintenance costs for mills is relatively low. There is no major incentive for the application of diffusers from the extraction standpoint. However, diffusion systems may be feasible for unit capacities above 6,000 TCD.

The possibility for future developments of more suitable extraction systems and their applications have been discussed, and the expert can visualize a beneficial application of such new equipment for future expansion programs in China.

Instrumentation and automation should be implemented to improve process control to an extent that it can have direct influence upon capacity and performance of the processes in use.

It should be stated that the technical personnel are showing high qualifications and good theoretical background. This became evident during factory visits and seminars alike. It can be concluded that there should be no hesitation to make use of any high level technology to achieve the goals set for this industry.