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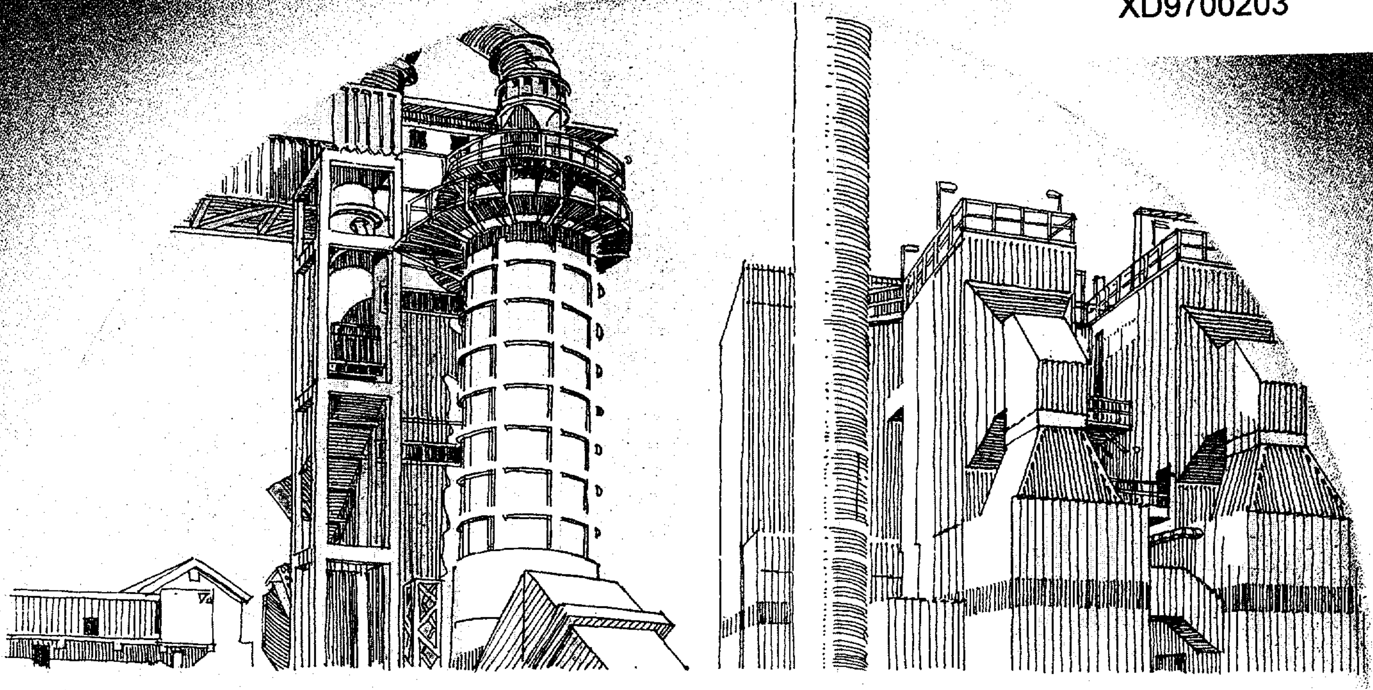
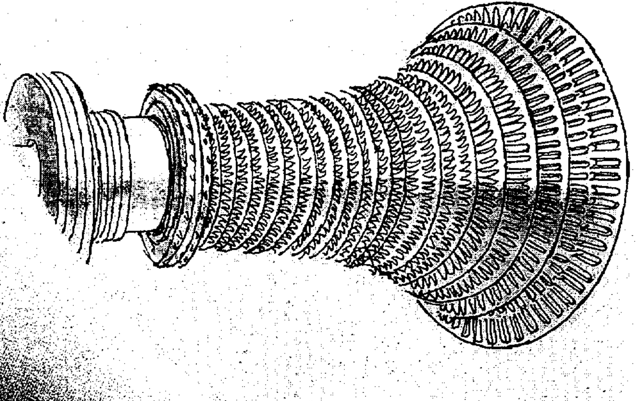
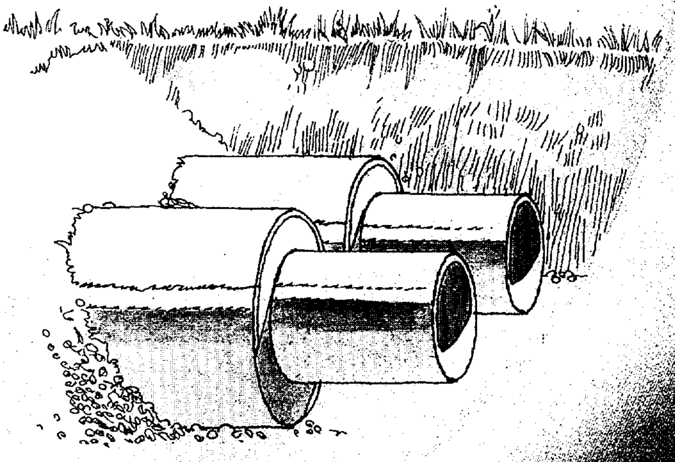
High Level Advisory Services on Energy Conservation and Environmental Protection to Petrochemical Industry "PANČEVO"







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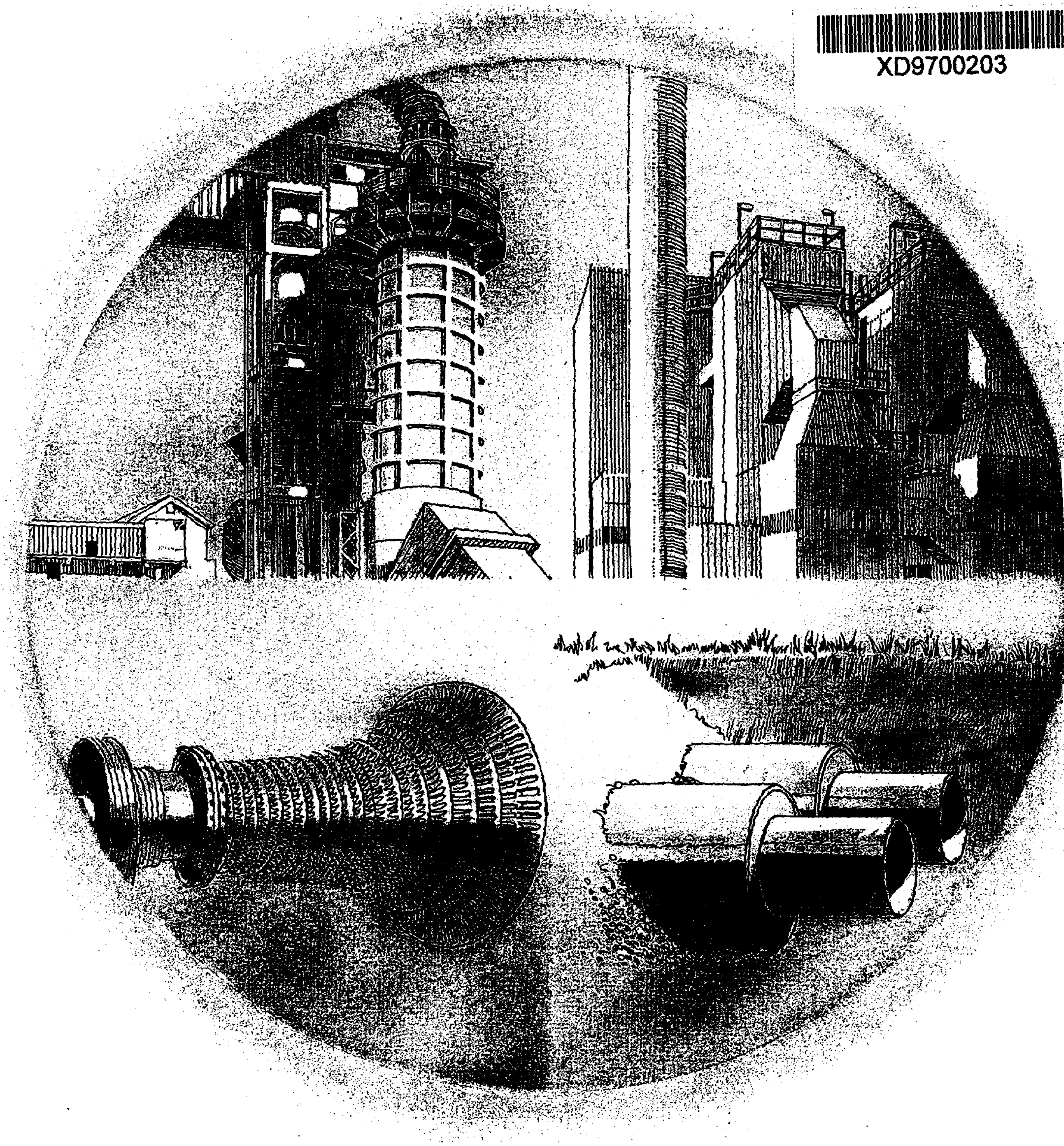

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

A study on Energy Conservation and Environment Protection to petrochemical Industry "Pančevo"

Prepared for the Government of the Federal Republic of Yugoslavia

Vienna
December 1996

The study was coordinated by V. Ishchenko of the Environment and Energy Branch, Industrial Sectors and Environment Division (UNIDO).

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FINAL REPORT

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SUMMARY

At an assignment from UNIDO, an energy conservation and environmental protection project was carried out at three companies in Pancevo, near Belgrade in Yugoslavia. The project was carried out by ÅF-Energikonsult Syd AB from Sweden with Enconet from Great Britain/Yugoslavia as sub-consultants for the local perspective. The companies studied were "NIS - Refinerija Nafte Pancevo" refinery, "HIP Petrohemija" petrochemical complex and "HIP - Azotara" fertilizer complex.

Generally speaking, there is a big potential for energy conservation in all three companies studied. For environmental improvement, the potential is even bigger as few real improvements have been implemented. The management are aware of the energy related issues and it has got plenty of ideas, but for several reasons these have not been implemented. The main factors identified in the study are:

- Lack of energy managers and clear organisational energy and environment responsibility
- Too low priority for energy and environmental matters compared to production
- Lack of incentive for housekeeping work
- The sanctions during the war, blocking investments
- Lack of maintenance
- Deterioration of stopped plants during the war
- The financial situation for the companies after the sanctions
- Too low electricity price for investing in, or even running existing, co-generation equipment
- Lack of thinking from the environmental perspective

Common for all the plants was the need for housekeeping measures, including efficient boiler control, insulation, steam trap maintenance and condensate recovery. Also the larger-size investments are motivated in all three complexes. In the plants studied it is, however, evident that the medium size energy conservation investments were implemented up till the end of the 1980's.

The investment packages recommended for the following three years are listed below:

"NIS - Refinerija Nafte Pancevo" refinery

Year 1: No cost/low cost measures in housekeeping, change to hot water circuit for tank heating, studies of flare gas recuperation, and study of WSA unit installation for regeneration of alkylation unit spent acid and utilisation of desulphurisation hydrogen sulphide. On environmental protection, study of oil sludge disposal and installation of continuous ambient air monitoring system.

Total cost:	US$ 4.4 million
Energy savings:	1,300 TJ
Annual cost savings:	US$ 5.4 million
Overall payback time	approximately 1 year

Year 2: Implementation of flare gas recuperation system and installation of WSA unit for regeneration of alkylation unit spent acid and utilisation of desulphurisation hydrogen sulphide.

Total cost:	US$ 12 million
Energy savings:	480 TJ
Annual cost savings:	US$ 7 million
Overall payback time	approximately 2 years

Year 3: Installation of new electricity generation turbine and change from steam drives to electrical motors in process.

Total cost:	US$ 4.5 million
Energy savings:	140 $\mathrm{GWh_e}$
Annual cost savings:	US$ 2.1 million
Overall payback time	approximately 2 years

In total the measures for year 1-3 will cost US$ 21 million and save 2,300 TJ or US$ 14 million annually. The overall payback will be less than 2 years.

"HIP Petrohemija" petrochemical complex

Year 1: No cost/low cost measures in housekeeping, vacuum pumps for dechlorination, power factor correction and evaporation of chlorine with cooling water. On environment, replacement of CFC in chlorine cooling and mercury reclaiming system.

Total cost:	US$ 3.2 million
Energy savings:	1,200 TJ
Annual cost savings:	US$ 3.8 million
Overall payback time	less than 1 year

Year 2: Change to membrane method for chlorine production.

Total cost:	US$ 50 million
Energy savings:	small
Annual cost savings:	small

The long term measure for the chlor-alkali plant is environmental and strategic and does not have an immediate payback.

"HIP - Azotara" fertilizer complex

Year 1: No cost/low cost measures in housekeeping, correction of steam to carbon ratio in the ammonia plant, improvements of the environmental situation and safety in the ammonia, NPK and nitric acid plants.

Total cost:	US$ 2.6 million
Energy savings:	1,000 TJ
Annual cost savings:	US$ 2.4 million
Overall payback time	approximately 1 year

Year 2: Change of ammonia synthesis reactor internals, ammonia removal from purge gas and NOx reduction from nitric acid plant tail gas.

Total cost:	US$ 15 million
Energy savings:	520 TJ
Annual cost savings:	US$ 15 million
Overall payback time	approximately 1 year

Year 3: Nitric acid NOx removal from nitric acid plant tail gas by selective catalytic reduction (SCR)

Total cost:	US$ 7 million
Energy savings:	0
Annual cost savings:	0

The measure for year 3 is purely environmental, and does not have a payback. It is therefore important that the NOx reduction in year 2 is implemented before dimensioning the SCR.

In total, the measures for all three years have an investment cost of US$ 25 million, resulting in savings for 1.500 TJ per year or US$ 17 million per year. The overall payback is thus less than 2 years.

APPENDICES

1. Background

1.1 Factory Location

Appendix 1 shows the location of the town of Pančevo with its surroundings; the sites of the Refinery (R), Petrochemical plant (P) and Fertilizer (F) are also marked. The town of Pančevo has the population of about 80,000 and the factories mentioned are situated in the near vicinity of the town. The railings of Petrochemical plant and Fertilizer are next to each other and are situated on one side of the road while the Refinery is across the road. Every factory takes up an area of 100 ha. Besides the railroad accessible to every factory, it is also important to mention the Danube river and its port which is near the Fertilizer.

1.2 Climate Characteristics Relevant for the Energy and Environment Protection

Figure 2 shows the monthly change of average temperatures and humidity averages of the town of Pančevo. It is obvious that during one part of the year it will be necessary to warm up the space. The heating season in Pančevo, according to room temperature of 18 °C, lasts 183 days, or 27 weeks, which is 50 % of the total number of days in one year. The total of degree days is 2598.6. The energy needed for heating of 1 m^3 is 9,312 kJ /(m^3 year). This shows that a considerable amount of energy is required for heating of space where people spend their time, and where the process takes place.

Air conditioning is not widely applied in this area (only if the process requires it). Regarding winds, it could be said that mostly south-east winds blow during winter time (December-February). Of the total of all winds during winter period, south-east and East component of wind produce 35-39 %. In spring (period March-May) there is an increase in frequency of north-east wind, which is then predominant. During this period there is a decrease of number of days without wind when compared to year average. During summer (June - August), there is a considerable change in the directions of winds. First of all, there are more north-west winds and less south-east ones. It is also important to notice that during this period there are more windless days compared to year average. In autumn (September-November), most of the winds come from south-east and South and make 37-43 % of all winds and calms in the area of Pančevo.

The wind averages vary from : 1.6 (South) to 4.5 m/s (south-east) in winter; 2.1 (south-west) to 5.5 m/s (south-east) in spring; 1.9 (South) to 3.8 m/s (north-west) in summer; 1.9 (South) to 4.5 m/s (south-east).

The windy days in the region occur most frequently in March, with the average of 4.7 days, and in April with the average of 4.1 days, but also in November, with the average of 3.6 days. August and September have the lowest number of windy days (2 days).

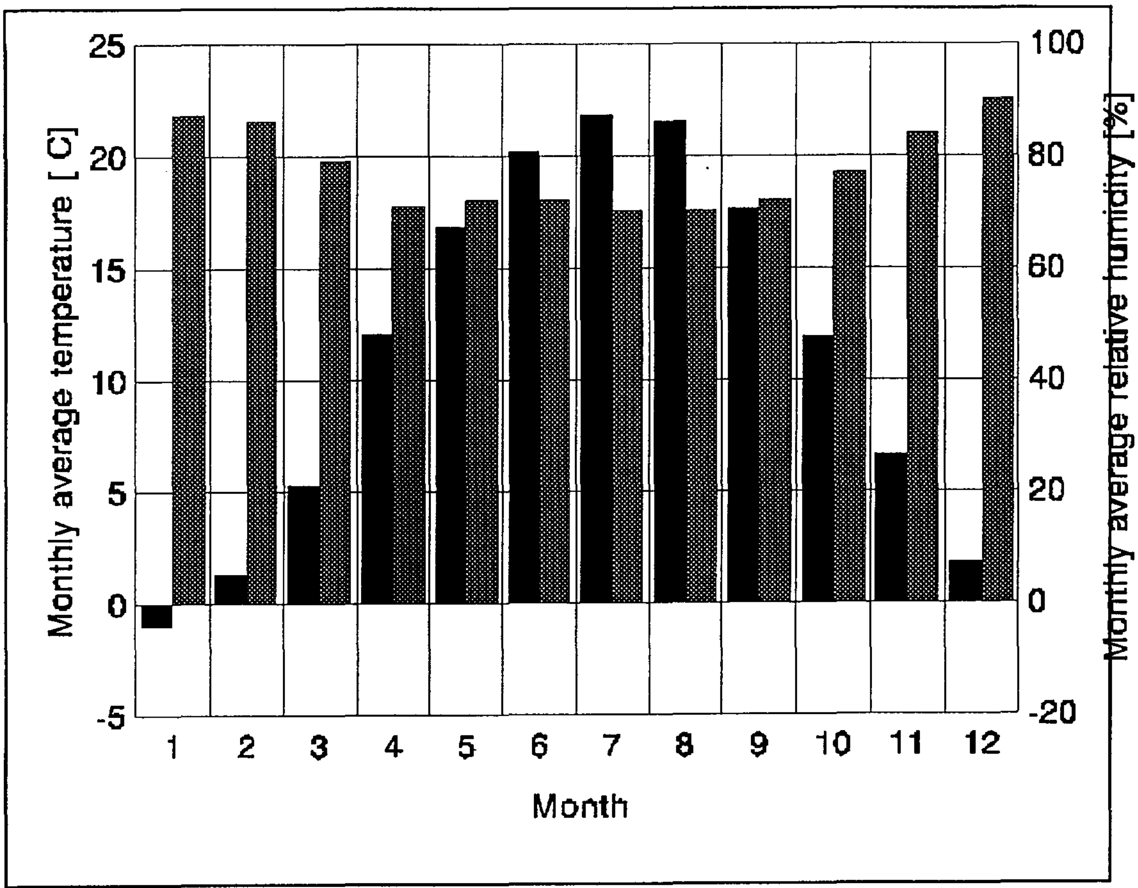

Figure 2: Monthly mean air temperature and relative humidity for Pančevo town

1.3 Background data on each plant

1.3.1 Refinery

The company is state owned. The construction of Petroleum Refinery in Pančevo started in 1964. The licenses for the plant were bought from UOP, USA, and the design was made by LUMMUS, France. The equipment was imported from England.

The plants which were built then, and which started with production in 1968/1969 were as follows:

The title of plants	**License and basic plan**	**Engineering**
Atmospheric distillation	LUMMUS	LUMMUS
Two-level thermal cracking	"	"
Processing of gases	"	"
Gasoline redistillation	"	"
Gasoline platforming	UOP	"
Merox TNG	"	"
Merox spec. of gasoline	"	"
Petroleum merox	"	"
Aromatic extraction-UDEX	"	"
Gas oil HDS	"	"

Together with the construction of the processing plants, auxiliary operating facilities were built:

Title	Design
Boiler plant	JOHN THOMSON
Turbo-aggregate	ENGLISH ELECTRIC
Chemical pre-treatment of water	LUMMUS
Reservoir space	LUMMUS
Loading and unloading installations	"
API separator	"
Pier	" and IVAN MILUTINOVIC

Within the Refinery project, LUMMUS also designed the plans of accompanying facilities, such as: laboratories, workshops, fire prevention, warehouses, traffic, etc. Domestic companies did the construction plans and works, as well as the installation of the equipment.

On the basis of these documents, in 1973, "Naftagas" determined the areas of the development of RNP stating its position as the Refinery for energy which produces fuels, solvents, bitumen etc.

The first phase of the expansion of Refinery to 4,820,000 t/year of the processed oil, included the building of the following plants according to the annex of the investment program:

Title of plant	License and basic engineering	Engineering
Atmospheric distillation	Oil and Petrochemical Institute	Ploesti, Romania
TNG Refination	Industroprojekt, Zagreb	"
Merox for light gasoline	UOP	"
Expansion of the platforming	UOP	Industroprojekt, Zagreb

A new reservoir space with the equipment from Czechoslovakia had been built. Within this phase of broadening, the reconstruction works were done on the Danube pier, various accompanying facilities, power and auxiliary systems.

In the meantime, in 1972, two-level thermal cracking was reconstructed into atmospheric distillation in order to increase the capacity for oil processing. The workers of the Refinery did this reconstruction. The plant was had been used for this purpose until the new Atmospheric distillation was built, after that it was reconstructed into Visbreaking.

The investment program for the second phase of the RNP development was created in 1975. The program included the construction of Secondary plants based on modern technologies and high valorisation of crude oils.

From the second phase, in 1982 and 1983, the first to be built and put to work was the Vacuum distillation and the plant for bitumen production. The plan and the equipment for both these plants were made in the USSR.

Secondary plants complex with Fluid Catalytic Cracking (FCC) as its basic plant, started its work between 1985 and 1988. Complex includes the following plants:

Titles of Plants	**License and Basic Plan**	**Engineering**
Fluid Catalytic Cracking (FCC)	TEXACO	FOSTER WHEELER
Light cycle gas oil hydro treater	TEXACO	"
Alkylation	EDELEANU	"
Merox TNG	UOP	"
Heavy Crack. Gasoline Merox	UOP	"
Easy Crack. Gasoline Merox	"	"
Sulphur Production (Claus)	COMPRIMO	"

The majority of the equipment (about 70 %) was made by domestic manufacturers. From 1985 to 1990, the following plants, auxiliary systems and accompanying facilities were built:

Title	**License and Basic Plan**	**Engineering**
Reconstr. of Two-level Thermal Cracking into Visbreaking	TECHNIP-France	Petrolinvest, Sarajevo
Aromatic Extraction (Sulpholan)	UOP	FOSTER WHEELER
Reservoir Space	FOSTER WHEELER	HIP-RI and Petrolinvest
Chemical Pre-treatment of Water	MINEL, Belgrade	MINEL, Belgrade
Recuperation of Gases from Torch	KOERNIG, Germany	KOERNIG
New System of Cooling Water with Cooling Tower	ENERGOINVEST	ENERGOINVEST

Several objects for manipulation were reconstructed and built (reconstruction and broadening of API separator, mixing of refinery products through conveyer belt, etc.)

In the second phase of the Refinery expansion, on the site of Petrochemistry, a common plant for waste water processing with biological treatment was built.

1.3.2 Petrochemical

The Company is state owned.

	Basic Products	**Designed Capacity [t/year]**
1.	Ethylene	200,000
2.	Propylene	85,000
3.	C_4 Fraction (up to 60 % of Butadiene)	45,000
4.	Pyrolysis Oil	38,000
4.	Pyrolysis Gasoline	138,000
5.	Chlorine	88,800
6.	Sodium Hydroxide (100 %)	100,000
7.	Sodium Hypochlorite)	8,000
8.	Vinyl Chloride Monomer	100,000
9.	Ethylene Dichloride	15,000
10.	Hydrochloric Acid (min. 28 %)	9,600
11.	Methyl Tertiary Butyl Ether - MTBE	35,000
12.	1.3 Butadiene	45,000
13.	Raffinate II	22,000

Polymers

1.	HIPLEX - High Density Polyethylene (HDPE)	50,000
2.	HIPTEN - Low Density Polyethylene (LDPE)	45,000
3.	HIPNIL - Polyvinyl Chloride (PVC)	34,000
4.	HIPREN - Styrene Butadiene Rubber (SBR)	40,000

Final Products

1. Polyethylene Pipes
   - Diameter 20 - 250 mm
   - Capacity ca 5,000 t/year
   - Gas Pipes up to 4 bar
   - Water Pipes up to 10 bar
   - Sewage Pipes

2. Electrofusion Fittings
   (coupler, reducers, tees, and caps, elbows, tapping tees, branch saddles)
   - Diameter 20 - 315 mm
   - Capacity 300,000 pcs/year

3. Corrugated Electro-Insulating Pipes (PVC, PP, PE)
   - Diameter 16 - 63 mm
   - Capacity ca 250 t/year

1.3.2.1 Ethylene Plant

The ethylene plant was designed by STONE & WEBSTER, USA, for maximum yield of ethylene which is the main product of the thermal separation of straight-run low-octane naphtha. The hydrogenation unit for pyrolysis gasoline stabilisation was designed by the INSTITUTE FRANCAISE DU PETROLE (IFP), France. Taking into consideration the composition of petroleum used for straight-run naphtha production, the design capacities are as follows:

	Designed capacity [t/year]	Production	
		in 1990	in 1991
Ethylene	200,000	183,445	133,225
Propylene	ca 85,000	84,045	59,519
C_4 - fraction up to 60 % of butadiene	ca 45,000	48,431	35,181
Pyrolysis oil	ca 38,000	39,222	32,226
Pyrolysis gasoline	ca 138,000	135,584	103,815
Total	506,000	490,727	363,996

1.3.2.2 Chlor-Alkali Plant

The chlor-alkali plant was designed by CRAWFORD & RUSSEL, USA, in accordance with the licence of OLIN CORPORATION, USA, the production of which is based on the mercury cells process technology for the electrolytic separation of sodium chloride into its components. The plant operates with 34 mercury cells and 255 kA load per each cell. The designed capacities are as follows:

	Designed capacity [t/year]	Production	
		in 1990	in 1991
Chlorine	88,800	76,003	45,267
Sodium Hydroxide (100 %)	100,000	85,706	51,332
Sodium Hypochlorite	8,000	7,070	6,845
Hydrogen		2,002	1,182
Total	196,800	170,781	104,626

1.3.2.3 VCM Plant

The VCM plant was designed by FOSTER WHEELER CO., USA, on the basis of the process technology of STAUFFER CHEMICAL CO., USA. This technology includes ethylene direct chlorination, oxichlorination and the cracking of ethylene dichloride. Pure VCM and ethylene dichloride as an intermediate product are produced by fractionation.

The capacity of this plant is 100,000 t/year of VCM. About 40,000 tonnes of the said quantity is used within HIP - PETROHEMIJA for PVC production, and the rest, which consists of about 60,000 tonnes, is sold. The waste chlorine derivatives are transformed, under the design and license from German firm LURGI, into hydrochloric acid, ca 9,600 t/year.

Produced [tonnes]	in 1990	in 1991
VCM	94,002	62,220
HCl	6,219	8,042
EDC	553	
Total	103,755	70,262

1.3.2.4 PVC Plant

The PVC plant was designed by FOSTER WHEELER CO., USA, on the basis of the process technology of STAUFFER CHEMICAL CO., USA. This is a suspension polymerisation process that involves a charging procedure for the operation of twelve reactors. The obtained product is suspension PVC powder with various K-values. It is delivered in powder form, under its trade name HIPNIL. In addition to the license grades, some special-purpose grades are also produced, on the basis of HIP - PETROHEMIJA-s own formula. The designed capacity of this plant, when producing grades with the shortest polymerisation time, amounts to 40,000 t/year. When producing special grades with longer polymerisation time, the capacity is somewhat lower - about 34,000 t/year. In 1990 and 1991 mostly special grades were produced, and the total PVC production was as follows:

1990 -	33,626 t
1991 -	25,086 t

1.3.2.5 LDPE Plant

The LDPE plant was designed by FOSTER WHEELER CO., USA, on the basis of the process technology of NATIONAL DISTILLERS CO., USA. This is a process of ethylene polymerisation in the continuous autoclave reactor at pressure of about 2,000 bar. The continuous production on one line gives products of great flexibility, suitable for many purpose and various methods of processing. In addition to the license grades, there are also some special grades produced under the HIP - PETROHEMIJA's own formula. The trade name of LDPE produced is HIPTEN. It is delivered in pellet form. The designed annual capacity of this plant is 45,000 tonnes.

The realised production:

1990 -	48,586 t
1991 -	38,313 t

1.3.2.6 HDPE Plant

The HDPE plant was designed by CRAWFORD & RUSSEL, USA, on the basis of the process technology of PHILLIPS PETROLEUM CO., USA. This technology involves a continuous process in loop reactors at medium pressures. There are two identical lines which provide great flexibility of products. A number of different grades are produced, both in pellet and powder form. The trade name of HDPE is HIPLEX and it is used for many purposes and various methods of processing. In addition to the license grades, there are also some special grades produced under HIP - PETROHEMIJA-s own formula. HIPLEX is delivered in powder and pellet forms. The annual capacity of both lines amounts to 50,000 tonnes.

The realised production:

1990 -	60,782 t
1991 -	44,302 t

1.3.2.7 Synthetic Rubber Factory

The synthetic rubber factory is located at Elemir, near the town Zrenjanin. The factory consists of three plants: 1) Styrene - Butadiene Rubber (SBR) Plant, 2) Butadiene Extraction Plant, and 3) Methyl Tertiary Butyl Ether (MTBE) Plant.

1.3.2.8 "Hip Petroplast" - Pe Pipe And Fitting Production Plant

The Pe pipe and fitting production plant was erected in 1991. The basic raw materials used in this plant are high and medium density polyethylene, produced especially for these applications, and tested in the VEGGAS INSTITUUT, Holland, where the suitable and reliability of these materials were approved for gasification system application. Electrofusion fittings are produced of the same materials, what improves and simplifies the jointing of pipes, providing compatible, safe, and long-lasting systems.

1.3.3 Fertilizer

The company is state owned. From 1962 the products of "HIP-AZOTARA" PANČEVO complex have been used for agricultural needs. The present manufacturing program includes three basic products:

CAN
urea
complex NPK fertilizer

At the same time, it provides other factories for fertilizers with the liquid ammonia and nitric solutions.

The production program includes the following technological units: sections for the production of basic raw materials, intermediate sections, and sections for the manufacturing of final products. Those are:

Sections for the production of ammonia (in the process of operation are sections for ammonia II and ammonia III)
Section for the production of AN and N solutions
CAN section
Urea section
NPK fertilizer section

The production program has been supported by the following facilities:

storage of the products
power plant
maintenance services
railway transportation
control and exploration
commercial section
general service

The American technology has been applied, except for the production of CAN for which the French technology is used.

Chemical Construction Corporation (CHEMICO), New York, is the main designer of all sections; it also gave its own methods for manufacturing of ammonia II, nitric acid, urea and solutions. The technology for manufacturing of ammonia III is also American (Kellogg Company). The plants for CAN production are designed according to the concession of a French company, R. Kaltanbach from Paris; the plant for the production of NPK fertilizers is designed according to the American TVA technology (Tennessee Valley Authority). This complex also has a plant for ammonia I which is closed down due to its outdated.

The basic raw material for all sections is natural gas together with added materials and intermediators such as lime for CAN, carbon dioxide for urea, phosphates and potassium salt for NPK fertilizers.

1.3.3.1 Ammonia II

Ammonia is produced through the reforming method. This section was designed in 1969 with the capacity of 635 tonnes per day, that is 200,000 t/year. It started with the production in 1970, with approximate manufacturing of 580 t/day. The electric energy and natural gas consumption for 1 tonne of ammonia being about 135 kWh and 1,300 Nm^3.

1.3.3.2 Ammonia III

The ammonia is produced according to the license of Kellogg Pullman, London and the production is based upon catalytic reforming of natural gas with steam under high pressures. It was designed in 1979 with the capacity of 938 t/day, i.e. 300,000 t/year. It started its work in 1984. Estimated consumption of natural gas for the process and heating is 1,073 Nm^3 per 1 tonne of ammonia

1.3.3.3 Nitric Acid I

It is produced according to CHEMICO technology with equal pressure in the whole process. The plants were designed in 1962, and started their work in 1963. In this section nitric acid is produced in two parallel production lines of the same capacities, which is 515 t/day of 100 % pure HNO_3 . That is 173,000t of nitric acid per year considering 100 % pure acid. During 271 days of production in 1989, the consumption of natural gas and electric energy was 7.6 Nm³, and 3,158 kWh per ton of 100 % pure HNO_3.

1.3.3.4 Nitric Acid II

The production technology is basically the same as in section I, with some updating and higher level of automatisation in the section. Its capacity equals to 181,500 tonnes per year of 100 % pure nitric acid. In the same year (1989) the realisation of consumption was 30.7 Nm³ of natural gas and 3.2 kWh of electric energy per tonne of 100 % pure nitric acid.

1.3.3.5 CAN

The plant for CAN production consists of three parts: AN production plant, N solution production plant and CAN production plant.

The section was designed in 1959 and started its work in 1962 for the production of 2 times 600 t/day of AN, having the total capacity of 400,000 tonnes of CAN with 27 % of nitrogen.

Estimated energy consumption equals to:

AN production plant for 100 % AN:

- electric energy	0.7 kWh/tonne
- cooling water	2.08 m³/t
- steam	(3.5 bar) 0.10 tonne/tonne

N solution production plant:

- electric energy	2.58 kWh/t
- cooling water	20.8 m³/tonne
- steam (in winter)	31.0 kg/tonne

CAN production plant:

* lime preparation section	
- crude oil for drying	1.1 kg/t CAN
* wet and dry section	
- electric energy	24 kWh/t
- technological water	8 m³/t
- steam 18 bar	0.20 t/t
- steam 4.4 bar	0.15 t/t

1.3.3.6 Urea

It operates according to CHEMICO's method of total recycling. It was designed in 1969 with the capacity of 300 t/day, i.e. 100,000 t/year of urea with 46 % of nitrogen. Estimated energy consumption for 1 tonne of urea: 0.635 tonnes NH_3, 0.800 tonnes CO_2, 120 kWh of electric energy, 0.810 tonnes of steam of 18 bar and 0.05 tonne of steam of 4.4 bar.

In 1989, during 210 working days the consumption of energy for 1 tonne of urea were as follows:

electric energy	179 kWh
steam 33 bar	0.76 t
steam 18 bar	1.10 t
steam 4.4 bar	-

1.3.3.7 NPK

The NPK production plant operates according to the American TVA method. The production capacity per year goes from 260,000 tonnes up to 420,000 t. The plant was designed in 1968, and it started with the production in 1969. Specific energy consumption depends upon the type of products. The average energy consumption is:

electric energy	32 kWh
technological water	15 m^3
natural gas	21 Nm^3
steam 4.4 bar	160 kg
compressed air	5.5 Nm^3

In 1989, during the production of various formulations the consumptions went as follows:

electric energy	38.8 kWh
natural gas	18.1 Nm^3
steam 4.41 bar	146 kg

2. Methodology

In order to assess the energy conservation and the environmental liabilities associated with the Panchevo Complex, ÅF ENERGIKONSULT, Malmö, senior energy conservation and environmental auditing specialists performed a physical inspection of the operations and facilities of all three companies which formed Panchevo Complex. All relevant departments in all factories were subject of inspection too. Key plant operations, energy and environmental staff were interviewed. Federal and republic regulatory officials were interviewed as well. No visits were made to departments located out of Panchevo.

Review of the relevant documentations were made (basic and detailed designs, monitoring reports, regulators, studies concerning energy and environmental issues, etc.) and some basic measurements were performed during the visit.

During the preparation of the Inception report, submitted in October 1996, preliminary talks were held with persons in charge of the matter in the factories. The teams responsible for the realization of the project are formed in the factories, as well as teams in some plants of greater importance within the factories. During the period of seven days the experts from ÅF ENERGIKONSULT, Malmö, explained to the persons who are in charge of the project the methodology of process necessary for the realization of the project. While on the spot, they made a survey of the factory as a whole as well as of the particular plants, and determined the directions of further activities in order to increase efficiency of energy and environmental protection according to Terms of Reference.

After the analysis of the collected data and after the talks, there was a two-week Walk Through Audit (from October 21 to November 1, 1996) in which five experts from ÅF ENERGIKONSULT, Malmö, and a larger number of factory specialists in particular fields took part.

The collecting of data is performed according to General Questionnaires follows:

First priority data:

- List of plants (existing, under constriction and approved for construction) grouped into refinery, petrochemicals, fertilizers, utilities;
- For all listed plants:
  - contractors' design specifications;
  - process flow diagrams;
  - operating and production records;

Second priority data:

- Operating manuals;
- P&IDs;
- Maintenance records;
- Major plant disruption incidents, regular failures;
- Plant availability: on-line times, off-line times (scheduled and unscheduled);
- Expansion: in hand, planned or anticipated;
- Raw materials: quality, quantities, cost;
- Finished products: quality, quantities, prices;
- Raw water and treated, water: quality, quantities, costs;
- Imported power, fuels: quality, quantities, costs, premium rates
- Meteorological data;
- Energy management: organization, procedures, records, systems, equipment, monitors;
- Environmental management: organization, procedures, records, systems, equipment, monitors;
- Environmental regulations, controls, authorities;

Specific environmental data necessary for study are:

- **Atmospheric Pollution**

- Collated data defining ambient air quality and its variation, in terms of SO_2, H_2S, NO_x and particulates as a minimum:
    - at the battery limits;
    - outside the battery limits including specified locations in the city of Panchevo;

- Emission data from the major emitters within the battery limits ;
- Fuels composition and quantity data;
- Identification of existing emission control equipment and data on efficiency of performance;
- Emission control regulations, existing and proposed;
- Target ambient air quality at batter limits and at other specified locations;
- Meteorological data including wind rose.

- **Liquid Effluents**

- Quantity and analytical data for discharges from each of the three principal production plants, with details of sampling procedure;
- Description including process design data and performance data for liquid effluent treatment plant(s);
- Quantity and analytical quality data for discharges from the site to the river;
- Details of processing/disposal of sludges separated in effluent treatment plant(s);
- Details of known deleterious effects of effluent discharges upon the river;

- Details of existing, proposed and future target quality of liquid effluent at point of discharge to river;

- **Solid Wastes**

- Details of quantities and nature of materials;
- Description of current disposal practices eg. incineration, landfill;
- Details of regulations covering disposal, existing and proposed;

An additional questionnaire has been made for each factory, concerning a more detailed analysis of particular relevant plants when energy and environmental protection are concerned.

The methodology applied:

1. provided the survey of the current state of energy management and environmental protection in the vicinity of the factories as wholes and in their major plants;

2. provided a sufficient amount of objective data for the proposition of the improvement measures when energy efficiency and environmental protection of the type n/l cost measures are concerned;

3. provided the insight into functioning of operational management when energy and environment are concerned.

4. offered sufficient amount of data in order to give suggestions for possible directions of improvement and enhancement of the existing technologies for the important production units.

3. Data and assumptions

All units are, when not otherwise stated, in accordance with the SI-system, with the exceptions that pressure is given in bar. All tonnes refer to metric tonnes.

The exchange rates used for the report has been
1 US$ = 6.6 SEK
1 US$ = 5.0 DIN
1 US$ = 1.5 DEM

Costs for raw materials, electricity and fuels are given for the current local situation, Nov. 1996, that is with the present subsidies on e. g. electricity. In some cases, however, the calculations are repeated for reference with an international price level since it is reasonable to assume that the prices will adjust to the market cost. The following prices are used:

Average electricity price[1]:	Refinery		17	US$/MWh
	Petrochemical		22	US$/MWh
Fuel prices:	Refinery	fuel oil fuel gas	3.5	US$/GJ
	Petrochemical	fuel oil	5.1	US$/GJ
		gas	4.5	US$/GJ
	Fertiliser	gas	4.5	US$/GJ
Steam prices[2]:	Refinery	45 bar	16.0	US$/ton
		17 bar	14.8	US$/ton
		4 bar	13.0	US$/ton
	Petrochemical	38 bar	22.3	US$/ton
		17 bar	21.6	US$/ton
		3.5 bar	21.1	US$/ton
	Fertiliser	33 bar	31.2	US$/ton
		18 bar	20.0	US$/ton
		4 bar	13.5	US$/ton
Boiler feed water			3.4	US$/ton
Raw materials:	Crude oil:		151	US$/tonne
	Natural gas:		0.15	US$/nm^3
	Sodium chloride		38	US$/tonne
	Mercury:		5 550	US$/tonne
	CFC R12		2 234	US$/tonne
Products:	Ammonia		200	US$/tonne
	Sulphur		100	US$/tonne

[1] including installed power and reactive energy costs, for detailed break-up of tariff, see Appendix 3.1:

[2] for the petrochemical plant, without generation capacity, the production price is distributed according to steam enthalpy. For the others, the price is set as the alternative price for electricity production. This means that for a higher electricity price, the price difference between the pressure levels will increase.

The production and consumption rates are taken from representative years between 1989-1991, due to the atypical production patterns during the sanctions 1992-1996. In a few places the present values have been deemed representative and used, in those cases it is especially stated.

No environment taxes on fuels and raw materials have been used, as it is not enforced in Yugoslavia at present. There is, however, a 1% environment tax on investments.

4. Findings

4.1 General

For a review of the legal situation on the environment in Yugoslavia, please refer to Appendix 1.1.

4.1.1 Boiler Houses and Steam & Condensate Systems

Total install capacities of steam production in boiler houses in all three companies are:

1.	Refinery	3x70.8 = 212.4 t/h	45.5 barg; 412 C
2.	Fertilizer	3x40 = 120 t/h	33 barg; 313 C
3.	Petrochemical	3x80 = 240 t/h	38 barg; 350 C

Total steam production: 572.4 t/h

At the same time it is possible to produce electricity (only in the refinery) as follows:

1.	Refinery	2x6 = 12 MW (steam consumption is: 2x50 t/h)	(6 kV)

Total fuel consumptions calculated as a ton of oil equivalent[1] (TOE) are:

1. Refinery

$$\text{Mass flow rate of fuel oil} = \frac{3 \cdot 70.8 \cdot (3{,}228 - 379)}{0.82 \cdot 42{,}700} = 17.3 \text{ TOE/h}$$

It is assumed that 100% of condensate is returned with the temperature of 90 C, and that the thermal efficiency of each boiler is 0.82.

2. Fertilizer

$$\text{Mass flow rate of fuel oil} = \frac{3 \cdot 40 \cdot (3{,}004 - 379)}{0.82 \cdot 42{,}700} = 9.0 \text{ TOE/h}$$

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[1] One Ton of Oil Equivalent (TOE) = 42,700 MJ
= 4.0 MWh (mega watt hour of primary electricity at thermal replacement values based on efficiency of 34 % in thermal power generation)

3. Petrochemical

$$\text{Mass flow rate of fuel oil} = \frac{3 \cdot 80 \cdot (3{,}089 - 379)}{0.82 \cdot 42{,}700} = 18.6 \text{ TOE/h}$$

For the production of 472.4 t/h [(3x70.8 - 2x50) + 3x40 + 3x80] of high pressure steam and 12 MWh of electricity (in Refinery) 44.9 TOE/h has to be spent. The total fuel consumption is calculated as ton of oil equivalent for all factories because of easier comparison of consumption among the factories. If the average number of working hours in all these factories are 8000 h/year and if the average use of the install production capacity is 60% (according to analysis of annual reports), it means that the following sum of money for fuel has to be spent in a year:

$$8{,}000 \cdot 0.60 \cdot 44.0 \text{ t/h} = 215{,}520 \text{ t/year}$$

or, if
the price of fuel oil is 218 US$/t, one can calculate the total price for purchasing the fuel as:
US$ 47.0 million

By splitting this value per factory the sum are as follows:

Refinery	US$ 18.1	million
Fertilizer	US$ 9.4	million
Petrochemical	US$ 19.5	million

These figures have to illustrate the total amount of money spent for fuel. Of course, the analysis of energy conservation would be estimated as a percentage of these total sums.

In case of the refinery, the part of steam production is partially used for electricity production. It means that it has to be spent US$ 8.5 million of total fuel expenses (US$ 18.1 million). Of course, some part of this steam is used in the process as well (medium pressure steam). However, for buying the same electrical energy (as they produce) from national grid, they have to spent only US$ 1.3 million. This disparity of prices are the reason while they run the plant in the way of minimum electricity production.

For calculations mentioned above the real current fuel and electricity prices are used and desired efficiencies of boilers are 82 % (having in mind their age) and it was assumed that 100% of condensate is returned with temperature of 90 °C. However, as it will be shown, the present situation in plants is not so good.

The past five years were peculiar for the work of these factories. They operated with very low capacities or did not operate at all. At the same time, the equipment was not protected or properly stored, neither in its parts nor as a whole. When the factories restarted with their work successively (in 1995 and 1996), there was a series of shortcomings and inefficiencies of the plants which haven't endangered their effectiveness but have lowered the energy efficiency and also increased the negative influence of the plants on environment. Such a situation required an analysis in the fields of maintenance process control and operational management. In this analysis the first group of necessary energy efficiency measures was affected and also measures for decrease of environment pollution, and only after that it was possible to proceed with a detail analysis of the possibilities for the development of the existing technologies or, their substitutes where it is necessary. On one hand, this procedure stems from the economy potentials of the factories and from the fact that the first group of activities, connected with housekeeping can provide a considerable decrease in the use of fuel and thus, a decrease in expenses in a relatively short pay back period.

In all three factories an increase of energy efficiency of boiler house and steam and condensate systems of 15 - 25% can be expected, with the pay back period of two years, which will save US$ 7 to 11 million per year.

The efficiency of a boiler is affected by numerous operating and design variables. These include:

1. *Fuel mixing:* To achieve proper combustion, the fuel must be well-mixed with combustion air. Mixing is complicated phenomenon particularly when liquid fuels are used.
2. *Excess air:* This is a crucial variable affecting efficiency. Every attempt should be made to provide the lowest excess air level possible for efficient operation.
3. *Stack gas temperature:* This is a measure of the unrecoverable heat being wasted to the atmosphere. The higher the stack gas temperature, the greater the heat carried by the dry flue gases and water leaving stack. An estimated 1% efficiency loss occurs with every 17 °C increase in stack temperature.
4. *Boiler tube cleanliness:* Tube deposits and fouling on external surfaces seriously affect heat transfer from the hot combustion gases to the water side passages, thereby reducing efficiency.
5. *Boiler steam pressure:* Reducing, whenever permissible, the boiler steam pressure is an effective means of reducing fuel consumption by as much as 1 to 2%. Lower steam pressure gives a lower saturated steam temperature, and without stack heat recovery, a similar reduction in final flue gas temperature will follow.
6. *Blowdown:* This is the customary procedure for removing boiler water with high impurity concentrations. It represents a loss of sensible heat energy in the waste water.

The adequate control and operation of the boiler require the following accessories:

1. *Water-level gauges:* These indicate the water level in drums. Low pressure boilers use simple tubular glasses while higher-pressure units need more sturdy construction (flat glass plates in metal housings). For remote observation, optical system using periscope mirrors, electric transmission and television methods are used.
2. *Safety valves:* These are used to automatically relieve overpressures in the drum, superheater and reheater. Superheater relief valves are set to open before drum relief valves to ensure the flow of steam through the superheater and thus prevent tube burn-outs.

3. *Soot blowers:* These consist of pipes and nozzles that blow jets of air or steam over the fire sides of heat transfer surfaces to remove soot and ash deposits.
4. *Feedwater regulators.* These are used to control the drum water level between safe limits during constant and varying loads. They must compensate for the change in the total boiler water with load.
5. *Blowdown valves:* Valves in the lines connected to the lowest part of the boiler water circuit drain off containing solids under full boiler pressure. On the other hand, lines placed at water level skim off any foam. Blowdown water drains to a blow off tank for cooling.

4.2 "NIS - Refinerija Nafte Pancevo" refinery

4.2.1 General

4.2.1.1 Background

The total design crude consumption of the NIS - Rafinerija Nafte Pancevo refinery is 5 million tonnes per year. During the sanctions, only domestic fuel was available, and the throughput went down to approximately 1 million tonnes per year. The refinery during that time only operated the primary plants. Now crude is also supplied on barges from Romania and in a pipeline from the Adriatic sea which was reopened in October 1996.

A flow chart of the processes is presented in Appendix 4.2. The total storage volume is 700,000 m^3. Crude oil and gas is stored in floating roof tanks, gas oil in cone roof tanks, LPG and butane in spheres, and propane in cylinders. A map of the site is presented in Appendix 4.3.

The visbreaker (rebuilt old 2-stage thermal cracker) is under rehabilitation, the platforming process is operating and Udex and Merox units are starting up.

4.2.1.2 Selection of target plants

The processes targeted at the refinery were the plants directly affecting the environmental situation, and the utility system. Several of the main processes are planned to be reconstructed after recommendations from an earlier energy study. The utility systems were added during the study since it is an integrated part of all processes and it was obvious that considerable savings were possible at low cost and by simple means.

4.2.1.3 Alkylation

The alkylation unit has been out of operation since 1989, because of a problem to dispose of the spent acid catalyst. It was earlier intended to send it for regeneration at a sulphuric acid producing plant, Subotica "ZORKA" some 50 kms from Pancevo, but the plant refused to accept it because of smell and workplace environment problems. The spent acid amounts to 24 tonnes/day at full production, with a concentration 88-90 %. The refinery has a plan to invest in a regeneration unit of their own, approximate investment US$ 5 million. See Appendix 4.4.

The discontinuation of the alkylation plant leads to other problems. Since the isobutane as a result is in surplus, it is added to the LPG. This is, however not always possible, especially during short changes in production. The butane is then flared, or the FCC unit, producing the isobutane as one of its products, has to go down in capacity. Furthermore, the demand for LPG is limited, so some of the isobutane is used as fuel gas for the own consumption. The LPG demand is, however, expected to rise when the public realises that it is available again.

4.2.1.4 Claus unit

The Claus unit is sensitive and often stops due to corrosion problems, leakages etc. Furthermore, it is designed for a high production and high sulphur content. The maximum sulphur production is 60 tonnes of sulphur per day, minimum 15. With a lower sulphur content in the oil and at operation below full capacity of the fluidised catalytic cracker (FCC), the Claus unit often must be stopped due to too low load, ironically resulting in higher emissions of sulphur dioxide than for oil with higher sulphur content. The staff has plans to install another Claus unit with lower capacity to operate at lower sulphur contents and to take over during breakdowns in the existing Claus unit, approximate investment US$ 5 million.

4.2.1.5 Flare Gas System Recuperation

A system for recovery of gas to the flare system to fuel gas was constructed in 1991 by Koernig KG in Germany, see Appendix 4.5. The system is, however, never been operative due to several operational problems, the major of which are listed below.

- uneven load on compressor
- computerised control system not working
- backward rotation of the compressor at stops, damaging it
- low efficiency of gas-liquid phase separators
- start-up problems

The main gas components are typically; methane, 10 %, ethane, 7 %, propane/-propane, 27 %, butanes/butanes, 27 % and pentanes, 10 %. The amounts of gas to flare are quite high, up to 3,750 kg/hour, possibly partly as a result of the faulty alkylation unit.

4.2.2 Energy

4.2.2.1 General

An energy study was conducted in 1989 by KBC of England. Some of the suggested measures are now planned to be implemented, including thermal integration of the vacuum, crude and visbreaker units; revamping of the vacuum tower; and revamping of the FCC unit. See Appendix 4.6. The low cost-no cost measures of that study are reported to have been implemented. However, the housekeeping situation still leaves considerable scope for improvement.

4.2.2.2 Utility

The boiler house operates 3 x 60 tonnes/hour English GE boilers, commissioned in 1968. The high pressure steam net is for 44 bar(g) and 412°C. The combined boiler capacity is presently estimated at 155 tonnes/hour due to reduced capacity.

The combustion efficiency is reported to 92 %, The lower heat value of the oil is on average 41 MJ/kg. Fuel oil is used with steam atomisation. The reserve fuel is gasoline. There are 4 boiler feed water pumps, turbine driven, with inlet pressure 45 bar and backpressure 4 bar. The combustion air intake is situated at the boiler room floor. The temperature there is 28 °C , while the temperature at the boiler room ceiling is 34 °C. Blow-down is done manually once per shift, amounting to approximately 3-5 % of steam production. There is also a continuos bleed, which is used for preheating make-up water 1-2 °C.

Only condensate from turbines is recovered, 7 tonnes/hour. There are 2 condensing turbines, each 6 MW with extraction at 16 bar, operating at maximum extraction and minimum condensing power since the electricity price is lower than the condensing generation price. The current total generation is therefore totally 5 MW, of which approximately 2 MW from the condensing part.

The steam system is divided into three levels, 45, 16.5 and 4 bar(g), see steam system, Appendix 4.7. The 16.5 bar steam is produced from extractions from power turbines and by throttling, the 4 bar steam as back pressure from process turbines and by throttling of 16 bar steam. The present operation steam balance is as follows:

45 bar steam:	136 t/h from boiler house and 65 t/h from FCC CO-boiler = 200 t/h.
16.5 bar:	29 t/h from each turbine and 50 t/h reduced in boiler house = 108 t/h.
4 bar:	only from 45 bar process turbines, approximately 40 t/h.

The own generation price is reported to be 0.175 Din/kWh while purchase price from the grid is only 0.086 Din/kWh (average including peak power tariff). 7 - 8 MW electricity is normally bought

Still, a new boiler, 45 bar and 120 tonnes per hour and a 12 MW turbine is planned to be installed in addition to the existing system. The extraction will then be 30 - 50 tonnes/hour at 17.5 bar and 6.6 bar backpressure. As an alternative, there may be an additional extraction at 8 bar and 4 bar backpressure. The old turbines will be operated in parallel with the new system in order to stabilise the electricity production, since it is desired to cut off from the grid due to bad stability.

The internal fuel for furnaces is mainly internally produced fuel gas and some fuel oil. The fuel oil has a heat value of 9-10 kcal/kg, or 37.8 - 42.0 kJ/kg. The fuel gas has a very variable quality since it is produced from excess fractions with variable hydrogen gas content 35 - 45 %. The heat value is 10-16 kcal/kg, or 42.0 - 67.2

kJ/kg. An example oil analysis was given from 1989: C 86.7 %, H 11.1 %, S 2.2 %, Hi (high) 43,504 kJ/kg. The consumption is around 4,750 kg/hour.

Installation of a gas turbine to the FCC furnace has been discussed with Foster Wheeler, but the idea was dropped due to space limitations.

Compressors etc. are mainly driven by electrical motors, but some also with condensing and backpressure steam turbines. There are in all 42 turbine drive motors in the processes.

The old parts of the plant was not currently in use during the study but numerous steam plumes rose from the lines in it.

The platformer has old reciprocating Cooper Bessemer compressors for hydrogen rich gas. No spares are available and one compressor is broken, leading to reduced capacity of plant (80 % production). The hydrogen rich gas consists of 75 % hydrogen, 12 % methane and the rest C_2 - C_5 in falling order. The furnace has provision for steam generation waste heat boilers.

The new process units have mainly manual/pneumatic control systems, but the FCC has a computerised TDC2000 system

Test were made on boiler house, see Appendix 4.8, and new crude unit furnace, Appendix 4.9. The boiler efficiencies were between 78 and 79 %, combustion efficiency 90 - 91 %, compared to the stated 92 %. This indicates at least 5 - 10 % savings possibilities in the boiler house, of which 1-2 % savings potential in the combustion itself.

The new crude furnace was operating at 80 - 85 % combustion efficiency, which should be possible to improve by a few percent. At the time, the furnace was running on 90 % of design capacity, i. e. 9,000 tonnes/day of design 10,600. The burners can be operated on both gas and fuel oil, and during the test, the fuel was mixed. 22 burners were operating on gas and 14 on oil. The distribution of burners between the fuels is done manually, according to the availability of gas.

4.2.3 Environment

4.2.3.1 General

The environmental problems from refineries are above all the emissions to the atmosphere but also hazardous waste like oil sludge containing heavy metals.

No environmental fees are used in Yugoslavia but 1% of an investment is paid as environment tax.

4.2.3.2 Emissions to air

Sulphur dioxide

The total emission of sulphur from the refinery is approximately 3,900 tonnes per year, 7,800 tonnes SO_2 per year. The two major contributors are the power plant, 1,650 tonnes per year, 3,300 tonnes SO_2 per year, and the FCC, 450 tonnes per year, 900 tonnes SO_2 per year. The values are calculated from average emissions from mass balances, no measurements, presented by Pancevo, Appendix 4.11.

Grab samples from the flue gases were taken at distillation tower no 1, 2 and 3 at the crude unit II and at boiler no 2 and 3. The measurements were performed 30.10.96, the results are presented in Appendix 4.8. Calculations from the measurements show lower emissions of SO_2 compared to the average concentration from Pancevo's mass balances. The reason for this is probably lower sulphur content in the oil used at the time for measurement compared to the average use. The total average fuel consumption is 320,000 tonnes per year, divided in 200,000 tonnes per year of oil, 2%wt sulphur, and 120,000 of fuel gas, 0.9 and 0.01 %wt of sulphur, depending on amine wash.

For comparison, the permitted limit value, set by the Swedish Environmental Authority, of total emission of sulphur for one example of a Swedish plant with a total through-put of 10 million tonnes per year of crude oil is 1,000 tonnes sulphur per year. The limit value for the cracker is 350 tonnes per year for 1.75 Million tonnes per yearflow to the cracker, and the limit value decreases 20 tonnes sulphur per 100,000 tonnes incoming to the FCC which gives 200 tonnes sulphur per year for 1 Million tonnes per year to the cracker. This is approximately the same amount that is processed in the FCC in Pancevo. The average sulphur emission from the FCC in Pancevo is 450 tonnes per year. Even if the low sulphur gas is used at the FCC, the sulphur emission is twice as high as the limit value for the Swedish example.

The limit value for sulphur emission from fuel is in the Swedish example 200 tonnes per year. Only at the start-up of the refinery oil with a sulphur content of max. 0.8% is used. After start-up the only permitted fuel is gas. The limit value is still valid for a usage of 10 Million tonnes per year of crude oil. The design usage of crude oil at Pancevo is approximately 5 Million tonnes per year. The power plant uses only oil and depending on the high sulphur content in the fuel oil, 2 %wt, the average sulphur emission from the power plant is 1,650 tonnes per year.

The reason for the big differences between sulphur emission in Sweden and Pancevo is the high sulphur content in the fuel used at Pancevo. The crude oil, used in Pancevo, contains 1-2 % sulphur. The fuel gas from the old unit is normally not desulphurised. It is used internally. The fuel oil sold contains 2.5-3% sulphur.

A further comparison to Swedish conditions is the Swedish tax-system. Normally, oil with higher sulphur content than 0.8 % is not used and therefore the tax-system the tariff used for 2 % sulphur content is extrapolated.

Sulphur content (%)	Tax (SEK/m^3 oil)	Tax (US$/$m^3$ oil)
2	540	82
0.8	216	33
0.5	135	20
0.2	54	8

Using the average consumption of oil in the power plant, 110,000 tonnes per year, and a density of 900 kg/m^3, the tax would be 10 US$ million per year with the Swedish system. Since the fuel oil used in the power plant is approximately half of the total amount of fuel oil used at the plant, the total sulphur-tax would be almost 20 US$ million. The tax can also be calculated from the amount of energy produced per year but it gives approximately the same result. The Swedish system has been developed and changed during the years and of course it would not be realistic to implement it directly in other countries. But it can be used as a value on the environmental cost.

Nitrogen oxides

The total emission of nitrogen oxides from the refinery is approximately 1,300 tonnes per year. The two major contributors are the power plant, 550 tonnes per year and the FCC, 300 tonnes per year. The values are calculated from average emissions presented by Pancevo, appendix 4.13.

The measurements performed 30.10.96, appendix 4.8, are presented in the table below together with the average value from Pancevo, appendix 4.12, values from one Swedish example and some typical values for comparison.

NO_x in flue gases from combustion of oil at the power plant

Average of Grab samples 10.30.96 from boiler no 2 and 3		**Average value, Pancevo**	**Typical values in Sweden**	**Low NO_x burner**
mg/MJ	**mg/Nm³**	**mg/Nm³**	**mg/MJ**	**mg/MJ**
210	580	440	70-170	20-30

Measurements were also done at the distillation tower at crude unit II. At the time of measurement 2/3 of gas and 1/3 of oil were used. The NO_x emission was 90 mg/MJ. Typical values for gas is 70-90 mg/MJ and for oil 70-170 mg/MJ. The emissions from the distillation towers shows a good combustion and will therefore not be further commented.

The permitted limit value, set by the Swedish Environmental Authority, of total emission of nitrogen oxides for the same example of a Swedish plant is 1,000 tonnes No_x per year. This limit value is connected to 1.75 Million tonnes per year load to the cracker and a total use of 10 Million tonnes per year of crude oil. If the consumption of crude oil is less than 10 million tonnes/year the permitted emission of NO_x decreases with 12 tonnes NO_x per 100,000 tonnes of decreased load to the FCC. In 1999, this permission will be lowered to 800 tonnes No_x per year. The average nitrogen emission from the FCC in Pancevo is 1,300 tonnes per year. In the table above, where the grab samples are presented and compared with typical values, it can be seen that the NO_x emissions at that moment was a somewhat high compared to the average values. When calculating the total emission of NO_x from Pancevo, 1,300 tonnes per year, the average values were used.

As for sulphur emissions, Sweden has a tax-system also for nitrogen emissions. From the 1st of January 1996, all plants producing more than 25 GW_{th} per year, have to pay 6.06 US$/ kg NO_2. The tax is calculated in two ways, either on the basis of a standard value of 0.25 g/MJ supplied energy or from a measured value. Each plant owner chooses calculation system. The tax is refunded by the Swedish Environmental Protection Agency in proportion to the average emissions of all plants in Sweden. That means, if a specific plant is operating in a more efficient way compared to the average, this plant will receive money back in proportion to the exceeding efficiency during one year. Since the surplus amount paid is refunded, it does not matter which calculation system is used before paying the tax. For the final calculation of the efficiency it is almost always more profitable to use measured values instead of the basis of 0.25 g/MJ supplied energy.

Using this Swedish system, a boiler efficiency of 85 % and design consumption of 110,000 tonnes oil at the power plant, the tax for the NO_x emissions from the power plant at the refinery in Pancevo would be 8.0 US$ million if the basis-system is used. The spot measurement of NO_x give 210 mg/MJ and 6.8 US$ million. Depending on how much was paid, the average emissions from the boilers and the average emissions from all plants, the final tax would be adjusted. The average plant in Sweden, 1993, emitted 78 mg NO_x/MJ and had an efficiency of 87 %.

One measure to reduce the nitrogen emissions is to install low NO_x burners. In the table above typical emissions from low NO_x burners are shown. At a plant in Sweden the emissions from the FCC was reduced from 300 to 50 tonnes of NO_x per year after installing low NO_x burners.

Emissions of hydrocarbons

The major part of the Volatile Organic Compounds (VOC) from refineries consists of non-aromatic hydrocarbons. Swedish experience has proved that very often the real emissions of hydrocarbons are much higher than the theoretically calculated. Not all refineries are equipped with measuring instruments for hydrocarbons but since demand from authorities as well as from the public is increasing, installation of measuring equipment should be considered.

It is most important to minimise the emissions hydrocarbons together with the emissions of nitrogen oxides since these two compounds reacts in the air and form photochemical smog.

Dust

Dust is an other environmental problem arising from combustion of fuels. The average value of dust from the FCC unit at Pancevo is 180 mg/Nm³. This can be compared to the Swedish example were the limit value is 75 mg/ Nm³.
The recommendation above about changing to gas would reduce the dust emissions by 90 %. The reduction of emissions of heavy metals would be 99 %.

Cyclones on the FCC are planned to be replaced in the future.

4.2.3.3 Emissions to water

Oil

The refinery operates an API oil separator, divided into two sections for "clean" and "oily" water respectively. The water from the "clean" side is sent to Danube after separation. This was a temporary solution since the capacity of the ETP at petrochemical complex is limited, but after acceptance from the authorities, it has been permanented. The water from the "oily" side is sent to the biological effluent treatment plant at the petrochemical plant.

The design capacity for the API is 1,200 m^3 per hour and the average load in 1990 was 450 m^3 per hour.
Storm water is taken to a tank and then gradually fed to the API oily side later. The flows scheme of oil contaminated water is shown in Appendix 4.13.

The composition of the "clean" water from the API is compared to the required standard of the water to the biological treatment in the table below:

	Average composition	Min value / max value	Internal standard
pH	7.90	2.50 / 11.0	6.5 - 9
Sulphides (mg/l)	0.4	0 / 10.6	none
Phenols (mg/l)	6.3	0.23 / 23.8	<20
Cyanides (mg/l)	-	<0.03	<0.03
Oils (mg/l)	150	4 / 3,300	<350

The problem that can be seen from this table is the content of sulphide. The standard says none but the average value is 0.4 mg/l which give a total emission of 1,440 tonnes sulphide per year. An other problem is the minimum and maximum values of pH since the bacteria in the biological treatment plant are sensitive to extreme pH. The maximum value of oil, 3,000 mg/l must also be avoided of the same reason.

The solids from the API and from tank cleanings are deposited in a concrete tank outside the area, see "hazardous waste" below. The water overflow from the basin is taken back to API. In a study for a planned project "Treatment, removal and recycling of refinery solid wastes", the water is planned to be taken to the water treatment unit.

In the Swedish example, used above for comparison, there are no limit values, set by authority, for water going into the treatment plant. The limit values concern site of outlet from the whole refinery to a nearby river and amount to:

- oil	6 mg/l
- phenols	0.2 mg/l
- cyanides	0.2 mg/l
- BOD_5	25 mg/l

4.2.3.4 Hazardous Waste

The API separator

Waste in the form of sludge or oil contaminated material is a result of several cleaning and treatment processes at a refinery.

The slop oil from the API contains lead. It is taken to a tank, and when the tank is full it will be used for straight run production in the old plant. Since lead is a toxic, heavy metal, it is important to separate this oil from other oil. The lead containing oil must be handled separately.

The sludge from the API, 100 m^3 per year, and the sludge from tank cleanings, 100 m^3 per year, are deposited in a concrete basin of 2,100 m^3 outside the area. Lead-containing sludge from tank cleanings, 10 m^3 per year, is kept in a separate disposal. The final disposal has not been solved yet, but a project is planned. The refinery in Pancevo has made chemical analyses of oily sludges from tanks and the API separator. From these analyses and from literature, the plant has prepared a project for ”Treatment, removal and recycling of refinery solid wastes”. The technologies enalling the recycling of the outlet streams are; oil is introduced in the processing unit, water is sent to water treatment unit and solids, without heavy metals, are removed to dumping or treated by the fixation method where the inorganic hazardous waste is converted to non-hazardous waste.

Spent catalysts

Approximately 28 tonnes of CoMo- and NiMo catalysts are generated in 10 years. The spent catalysts are kept in drums. Spent catalyst is also generated from the Claus unit, 16 tonnes of Al_2O_3 in 10 years and also kept in drums. Platinum catalysts are sold back to the supplier.

Alkylation unit

The Foster Wheeler alkylation unit used, is designed for 22.5 m^3 per hour of butanes/butanes. Concentrated sulphuric acid is used as catalyst. The alkylation unit has been out of operation since 1989, because of a problem to dispose of the spent acid catalyst. It was earlier intended to send the spent catalyst for restoration at a sulphuric acid producing plant, Subotica, but the plant refused to take the spent acid because of smell and workplace environment problems. The spent acid amounts to 24 tonnes per day at full production, with a concentration of 88-90%. The acid is after the process impure by water, soluble and insoluble organic substances, sulphonic acids, organic sulphates, sulphur dioxide, olefin polymer and carbon. The spent acid is classified as hazardous matter according to its properties.

Event though the spent catalyst is classified as hazardous matter and will, unrecovered, cause environmental problems, there will be another environmental problem without alkylation. The alkylate is used to increase the octane-number of petrol and the alternative for using alkylate is to use lead-additive which should be avoided as far as possible.

4.3 "HIP Petrohemija" petrochemical complex

4.3.1 General

4.3.1.1 Overview

The "HIP Petrohemija" petrochemical complex manufactures petrochemicals such as base plastics (polyethylene, PVC and SBR rubber), chlorine, sodium hydroxide and hydrogen from straight-run low-octane naphtha and salt, see Appendix 4.14. The basis for all the production is the ethylene and chlor-alkali units, which produce the key raw materials, see flow chart in Appendix 4.15.

4.3.1.2 Selection of target plants

The processes targeted at the petrochemical plant were the chlor-alkali plant and the utility system. The chlor-alkali plant was chosen due to its process, based on considerable quantities of mercury, and the chlorine handling. The utility systems were added during the study since it is an integrated part of all processes and it was obvious that considerable savings were possible at low cost and by simple means.

4.3.1.3 Chlor-Alkali Plant

The production is based on the mercury process technology for electrolytic separation of brine, saturated sodium chloride solution. When the sodium chloride solution is electrolysed, chlorine gas is formed at the anode and metallic sodium is formed at, and dissolved in, the mercury cathode. The mercury-sodium amalgam is taken to a decomposer, where the sodium is reacted with demineralised water and hydrogen gas and sodium hydroxide is formed. The mercury is then fed back to the cell, see Appendix 4.16. The produced chlorine is cooled, dried, compressed and liquefied, see process chart, Appendix 4.17. The caustic is filtered and backwashed with deinonised water, see Appendix 4.18. The hydrogen is cooled, compressed and cooled again, then led to a Pura-siv molecular sieve for mercury removal.

The plant operates with 34 mercury cells at around 4 V and 255 kA load per cell. Each cell has 12 sets of anodes, computer adjusted for minimisation of voltage in groups of 4. Each cell has 27.3 m^2 anode and contains approximately 3.6 ton mercury.

The plant was designed by Crawford & Russel, USA, on licence of Olin Corporation, USA. The anodes were already by original design of the energy efficient DSA type, and have since been replaced by new ones in activated Titanium (Runner design), which per design results in a very good electricity consumption for the mercury cell process, see below in section 4.3.2.1. The combination of computer control and activated Titanium DSA anodes makes the plant quite energy efficient by design for a mercury cell process.

The chlorine compression is done with 2 de Laval 3-stage centrifugal compressors, plus one spare compressor. Chlorine liquefaction is done with 2 high stage and 1 low stage belt driven piston compressor. The refrigerant is 3,000 kg CFC R12. Due to leakages, the R12 consumption is 6,000 kg/year, equal to 200 % losses per year.

Normally, 67 % of the chlorine is used within the complex according to design. The design capacity is 88,800 tonnes/y and 23,000 tonnes should be sold but the biggest external consumer has closed down. 1990 was highest production so far, 76,000 tonnes. Now the plant is running at 70% capacity due to low market demand.

A study by the Dutch company Comprimo has been carried out on conversion to the membrane method. Tenders were taken by HIP engineering 1991 for a production facility for 110,000 tonnes per year. The prices quoted were from Comprimo at US$ 40 million, and from German Uhde at DEM 71 million, with the current exchange rate equal to US$ 47 million. Uhde was selected for delivery, but the sanctions stopped the project and now the project is stalled due to financial problems.

4.3.2 Energy

4.3.2.1 Chlor-alkali plant

Design power consumptions kWh/t chlorine:

Mercury cell technology	
Olin with DSA	3,360
Runner Active Titanium	3,080 (present design)
Best mercury cells	2,980
Membrane technology	
35% NaOH production	2,500
50% NaOH production	2,860

Actual power consumption kWh/t chlorine: 3,394 (at 35 kVAC)

The brine shall be at least 60°C when entering the cells and below 85 °C at exit. Temperatures above 85°C will damage rubber linings of cells, but a lower temperature results in higher electricity consumption. The temperature is hand regulated by a valve on the combined heater/cooler heat exchanger between the brine preparation and the cell house. The brine temperature sensors are not in a good condition, only 6-7 sensors were believed to be reliable during our study. The temperature was measured at 65-75 °C.

In the control room, the power meter showed 30 MW consumption, while the real consumption was stated to be 20.5 MW, at a 65% production. Below 60% production is not possible to operate, since it can damage the transformers, the minimum production depends on number of cells and total voltage.

4.3.2.2 Utilities

Steam is produced at 38 bar, 350 °C, and reduced to 14 and 3.5 bar via drive turbines and reduction stations. No generation is done at the petrochemical complex.

The boiler capacity at the utility is 3 x 65 tonnes per hour. The ethylene plant has its own steam generation plant, 2 x 80 tonnes per hour (105 bar, 435°C). There is an interconnection with possibility to take steam from the refinery and fertiliser complexes. The steam balance is; high pressure 52 tonnes per hour, medium pressure 45 tonnes per hour, and low pressure steam -4 tonnes per hour, (return from process). See Appendix 4.19.

The boilers are operated at overpressure, without flue gas fans. 3 feed water pumps turbine driven, 1 electrical, 280 hp each. They are equipped with a simple combustion monitoring system, with one oxygen analyser with probes to each boiler, used for manually adjusting the fuel-air ratio. Boiler Feed water is taken from Danube, and treated by sedimentation, sand filter and ion exchange. The blow-down is believed to be 3-5 % of the steam production. It is intermittent, without vapour recovery but with heat recovery to the demi water plant. Then the condensate is sent to the effluent treatment plant.

The cooling water pumps are 6 in total, of which 2 are electrically driven. The remaining 4 are steam turbine driven, 2 with backpressure and 2 condensing, and used when required. Each is on 1500 hp with a flow 6,000 m³/h. The delivery water temperature is 20 °C and the return is 35-36 °C. Cooling water treatment is done with chlorine against bacterial growth every week, and phosphates against corrosion.

A test of the boiler efficiencies was performed during the audit, see Appendix 4.20. The combustion air is taken from outside. During measurements, the inlet air temperature was 15 °C, while the temperature at the boiler room ceiling was 28 °C.

4.3.2.3 Electricity

The petrochemical plant is said to be the biggest electricity consumer in Yugoslavia. It has its own transformer station from 220 kV to 35 and 6 kV.

It is believed that approximately 5 % of the electricity consumption in the cells are transformer losses from 35 kV down, but it was not possible to verify since the DC measurement is out of order.

There are approximately 2,000 electrical motors on site, of which 25 are for 6 kV, effects ranging from 300 to 8,000 hp. The maximum consumption at 6 kV is 25 MW, average 18-20 MW. At 220 kV the maximum consumption is 65 MW, with normal range 40-60 MW.

The power factor is measured to 0.85 at 220 kV, 0.9 at 35 kV, and 0.8 - 0.82 at 6 kV. No capacitor banks are installed presently, installation has been discussed with ABB. Four transformers, are installed. They are Austrian, OLIN manufactured, 20 years old, with forced air/forced oil cooling. Short circuit 12-9-16 %V. Iron losses 52 kW. Onload 12 steps up and 12 down, 1.25 % per step.

Demand side management is important at the chlor-alkali plant since the tariff is high for peak power consumption. The plant has installed an active computerised electrical management system 5 years ago. The average to peak power ratio is therefore normally 0.85-0.9. Presently it is, however, a low 0.6 because of production problems and small chlorine storage. This leads to intermittent high capacity utilisation to make up for production lost during stops in order to supply other plants. The number of unplanned stops per year is 20 - 40.

The above figures for transformer losses and power factors are quite normal for an industry like this. Due to the high consumption, it could be possible to reduce the transformer losses with a financial viability, but the current electricity price is too low. The power factor, however, should be improved immediately, see section 5.3.1.2.2.

4.3.3 Environment

4.3.3.1 Regulations from Authorities

The plant has no permanent permission for production and there are no regulations for the emissions so far.

4.3.3.2 Mercury Consumption - Designed And Actual (1990)

The design data for the total loss of mercury is 2,100 g per day of mercury. The design losses from the different parts of the process are shown in appendix 4.22. This figure is given together with a chlorine production of 267 tonnes per day. The designed losses per ton of chlorine thus becomes 8 g Hg. In the table below the designed value for mercury losses from different places are shown.

Place	**Design losses Hg (g/day)**	**Design losses Hg (g/ton Cl_2)**
Cell room	1,250	5.0
Caustic ventilation	140	0.5
H_2 purification (PURA-SIV)	50	0.2
Hg-treated waste water	2	0
Sludge from brine preparation	620	2.0
TOTAL	**2,062**	7.7

In the annual report from 1990 the total production of chlorine was 76,000 tonnes. The consumption of mercury was 19,900 kg (4,722 kg more then estimated). This gives a loss of mercury of 260 g per ton chlorine. However, all this mercury was not lost permanently. About 2,590 kg of mercury from sludge was returned to the plant after the sludge had been treated in Slovene. The mercury was used in the process the year after. Another 15 tonnes of sludge, containing approximately 5,000 kg of mercury, was ready to be sent but it was not sent. From the graphite filling, about 1,480 kg of mercury was permanently discarded in the sludge pool since no alternative storage could be found. In 1990, the cooling water system was not in operation and therefore some 800 kg of mercury was lost from the caustic ventilation system. This is much higher than the designed value. From the installation of new anodes, the same year, the mercury quantity per cell had to be increased. This consumed 8,450 kg of mercury.

When summarising these data, the total loss of mercury 1990, was approximately 4,000 kg. The sludge that was never sent to Slovene, containing 5,000 kg Hg, is not included in this figure since it was supposed to be recovered. Although, the consumption for 1991 must consequently have increased if this mercury could not be recovered. Since the war started no mercury recovery in Slovene has been possible and the already very high consumption of mercury, by 1990, has increased further. The mercury emissions are presented below in more detail.

The total loss of mercury to water and air from a well functioning plant of 100,000 tonnes production is between 40 and 80 kg per year. The air emission is the major problem and is normally 25 to 50 times larger than the water emission. If the total emission is, for example, 50 kg, the emission to water contributes with only 1 kg.

4.3.3.3 Emissions of Mercury

In products
The mercury content in hydrogen is <10 ppb (design: 60 ppb) and in chlorine and caustic soda 25 ppb (design <100 ppb).

Mercury traps are checked and emptied once per shift.

To atmosphere
The design value of mercury emissions to the atmosphere from the cell room is 1,2 kg per day. The atmospheric emissions are measured daily at 22 places at the plant. Emission measurement from 1990 and 1996 have been studied.

The limit value for 1990 was 0.1 mg/m^3 in the working environment. This limit was exceeded between 11 and 71 times per month. The maximum concentration per month varied from 0.25 to 1 mg/m^3. About half of the analyses were registered as toxic. Although the maximum level was exceeded every month the average value per month was lower than the limit value. The average value varied from 0.020 to 0.050 mg/m^3.

The limit value for 1996 is changed to 0.05 mg/m^3. Detailed analysis presented for September, 1996, show especially five places where the mercury emissions are a problem. The measurement data is shown in appendix 4.23 and 4.24. The places are; two measuring places in the cell room, the control room, the area for cells and the plastic-area. In these places the maximum concentration vary from 0.10 to 0.20, and the limit value is often exceeded. The mean value in the cell room exceeds the limit value. For the rest of the year the average monthly values are shown in a diagram, appendix 4.25. September has an average value for all 22 measuring places of 0.025 mg/m^3 which is low compared to may, June and July. The average value for the summer months is approximately 0.05 mg/m^3. This means that the values for the five critical places are even higher for these months.

The mean value from the five highest emission places is 0.04 mg/m^3. With an air ventilation of 34 and 60 times per hour it gives 1 and 2 kg/d respectively, without contribution from the other places. The yearly emission to the atmosphere is then between 290 and 500 kg. The design value is exceeded regularly.

In sludge

7.5 tonnes of brine sludge are produced every day and is kept in the brine pool. The mercury in the sludge is in metallic state and valence +1 state. The design value of sludge is 620 g Hg per day. No actual analysis data for sludge exists and therefore it is very difficult to calculate the mercury content in the sludge. Old measurements from 1984 and 1985 show mercury contents of 100-400 ppm. A rough calculation from these old data give a loss of 760 kg mercury per year or 10 g per tonne chlorine. The design value is 2 g per tonne chlorine.. Some data gives only the total mercury content and others separate solid and ion mercury which should be done.

The available information is not enough to make a precise evaluation of the mercury content in the brine sludge but it is clear that the mercury content in the sludge is unacceptably high.

Sludge is also produced from cell cleaning, caustic-filtering, waste water-filtering, decomposers and from cleaning of vessels, channels and pits. Each year some 15-25 tonnes of this sludge is produced. It contain 25-57 % wt of mercury, between 4 and 14 tonnes. This sludge is kept in plastic barrels and the sludge is supposed to be thermally treated, see below.

Sludge handling and treatment - the retort unit

According to design, the sludge from cell cleaning, caustic-filtering, waste water-filtering, decomposers and from cleaning of vessels, channels and pits, should be thermally treated in a retort unit, a furnace for mercury distillation, for generation before waste disposal. The retort unit has not been in operation since 1988. Some of the problems are cooling of vapour, non working control system and long pipes between the cells and the retort unit. The company plans to rehabilitate the retort at an estimated cost of 100 000 DM. They hope the rehabilitation will start in a few months time.

From 1988 to 1992 a plant in Slovene treated the sludge but since 1992 no sludge is being sent there. The sludge has been kept at the plant in Pancevo meanwhile. Untreated sludge from the last 12 years is still kept at the plant.

Mercury in waste water

Waste water from the cell building, containing mercury, is going to a waste water sump. The waste water is pH-adjusted to 7, by HCl or NaOH. Sodium sulphate, sodium sulphite and active carbon are added and mercury precipitate as mercury sulphide and is filtered. The filtrate is recycled back to the treatment until the concentration of mercury is below 20 ppb and the filtrate is then pumped to the waste water lagoon. However, sometimes one of the two charges per day, the process is a batch-process, is not treated but sent directly to the waste water sump where it is mixed with other waste waters from the plant. According to design, the water contains 1,9 g mercury per day but the average measured mercury content in the treated waste water is 10 mg/l. This give mercury emissions of approximately 500 kg 1990. The waste water continues to the treatment plant and further on to river Danube. The design value for mercury in discharge waste water is <20 ppb but no measured value exists. The sludge is presented above.

To minimise the mercury emissions from the waste waters, the company has made a project where they plan to install an ion-exchanger.

Sludge waste dump

The former deposit for sludge, containing mercury, was not safe but after demands from authorities a new deposit was made which is safe and legal. The dump for sludge is designed for 10 years of production and possibilities to expand exists. The dump has two layers of ethylene film with check-points for leakages, a bend pipe between the two layers where sludge is visible in case of leakage. The sludge water dump is situated in a locked area.

Mercury from brine solution

The filters after preparation of brine solution is in operation 8 hours and after that they are washed with brine solution. The clear brine solution goes to the process, the dirty brine goes back to preparation and the sludge from the filters goes to the mercury waste dump. The brine system is a closed system.

Mercury from the cells

The salt solution from the cells is saturated with chlorine and after dechlorination the chlorine content in the salt solution must be >50 ppm. The reason for this is to keep the mercury in ion (+II) state. If the chlorine content is too low, the mercury change to ion (+I) state and metallic state. The mercury in the salt solution is not measured.

Leakage is a problem in the circulation system. Mercury is leaking from the pipes, connections and from the cell bottoms. Within two years most of the cell bottoms (carbon steel) need to be changed. They are in poor condition since the regular maintenance has not been working well the last four years due to lack of spare parts.

The cells are cleaned approximately once a months, there are 34 cells and that means, in average one cell per day is cleaned. During the cleaning the cells are opened and that can cause emissions of mercury and of course a non-healthy working environment. A new cleaning system is planned where the cells do not need to be open so often during cleaning as today.

Mercury from the caustic ventilation

According to design the mercury emissions from the caustic ventilation should be 140 g/d or 40 kg/year.
Since the cooling water system was out of operation, the emissions from the caustic ventilation was much higher than design. The estimated loss for 1990 was 816 kg.

Mercury from the hydrogen purification

After the hydrogen is compressed and cooled the gas is going through a PURA-SIV, molecule sieve, unit. The designed emissions of mercury from the PURA-SIV is 50 g/d. (50 g/d / 267 t/d = 0,2 g/t = 200 ppb). The unit is working well and the emissions are normally below 60 ppb. The recovered mercury is reclaimed in special designed containers.

Mercury in waste water

Waste water from the cell building, containing mercury, is going to a waste water sump. The waste water is pH-adjusted to 7, by HCl or NaOH. Sodium sulphate, sodium sulphite and active carbon are added and mercury precipitate as mercury sulphide and is filtered. The filtrate is recycled back to the treatment until the concentration of mercury is below 20 ppb and the filtrate is then pumped to the waste water lagoon. The water contains 1,9 g mercury per day according to design and it continues to the waste water treatment plant and further on to river Danube. The design value for mercury in discharge waste water is <20 ppb but no measured value exists. The sludge is presented above.

Working environment
The whole plant has a rotating working scheme. This decreases the risk of too frequent exposure to mercury for the personnel. The personnel change clothes after working in the cell room. The health condition is regularly checked by measuring mercury in urine, done by the lab at the plant, and blood. Possibilities for earlier retirement exists.

4.3.3.4 Emissions of chlorine

Chlorine in cell room
The design loss of chlorine from the cell room is 0.5 tonnes per day. To prevent air in-leak to the chlorine gas, which would cause serious problem at the VCM production plant, the system was working with over-pressure. The air content had to be below 0.3% and a normal value was 0.25%. However, certain changes have been done in VCM plant to allow higher oxygen content in the chlorine and therefore the plant is now operating under low vacuum pressure and the chlorine losses have decreased significantly.

Two stops with chlorine leakage to the atmosphere have occurred because of problems with the compressor (caused by corrosion on the heat exchangers).

For emergency situations, the plant is equipped with an alarm system (indicator in control) with 8 sensors (Dräger). In the report from the plant, the alarm system is suggested to be increased by another 8 sensors.

4.3.3.5 Emission of freon

Cooling medium
The plant uses R12, freon, as cooling medium. Freon has to be added to the system several times a year due to leakages. The total content of freon in the system is 3 tonnes and the total consumption is 6 tonnes per year. Plans exists to change to a less environmentally dangerous cooling medium.

Measurements
The environment department takes samples at locations depending on weather conditions; wind directions and strength of wind.

4.3.3.6 Ideas and pre-studies at Pancevo

Before the time of sanctions a pre-study was made about changing the existing method with mercury cells to the membrane method. Ideas about keeping the existing equipment were also discussed. No decision was taken at that time. Before making decision in this issue the fact that chlor-alkali production with mercury cells will be forbidden by year 2010 within the European Union should be considered.

4.4 "HIP - Azotara" fertilizer complex

4.4.1 General

The fertilizer company HIP Azotara comprises the following parts:
- ammonia production, 938 tonnes a day design
- ammonia production, 635 tonnes a day design
- urea, 300 tonnes a day design
- nitric acid, two plants 450 and 500 tonnes a day design
- CAN (Calcium Ammonium Nitrate, 27.7 % N with limestone)
- NPK, dry process with AN (Ammonium Nitrate), MAP (Mono Ammonium Phosphate), SSP (Single Super Phosphate) or TSP (Triple Super Phosphate) and KCl as base.
- AN for supply to CAN and NPK plants and preparation of nitrogen solutions
- utility for steam production 33 bar, supplying all HIP Azotara plants but Ammonia III, that has its own steam generation.

The ammonia plant, Ammonia III, was the main scope of this study. An ammonia process is a technically sophisticated, high pressure process, characterised by a high energy consumption and relatively low emissions. Measures to be taken in an ammonia plant are often complicated and costly but much can be gained. Fertilizer plants (CAN, NPK), which include solid handling, have lower energy consumption but often high emissions. Good results can be obtained by small means. We thus also had short overviews over the nitric acid and NPK plants. As energy (gas) is the raw material for ammonia production, a waste of nitrogen compounds in the fertilizer production is a waste of ammonia and thus also of energy.

4.4.2 Ammonia

4.4.2.1 Production And Consumption

Process description. See Appendix 4.29.

Despite gas shortage during the winter 1996, the ammonia plant had its best season since 1987/88.

The gas varies in composition, due to the source, domestic or imported. At present the gas is rather pure methane (>90%) with a lower calorific value of 33,000 to 35,000 kJ/Nm^3.

Production and consumption figures for the first quarter and first half year 1996 were given and are listed in Appendix 4.26.

Specific energy consumption is 46.9 GJ/tonne or 13.0 MWh_{th}/tonne. A good energy consumption figure for a conventional natural gas plant is 36 GJ/tonne or 10 MWh_{th} /tonne. The specific energy consumption in this plant is thus rather high for a reformer plant with natural gas as a feedstock. This can partly, but not fully, be explained by the low production. Another factor taking up the energy consumption is a high steam-to-carbon ratio in the primary reformer and not optimal performance of the heating in the primary reformer and the auxiliary boiler.

4.4.2.2 Regularity

During the period Jan to June 1996 the plant had seven stops.

	Jan-March	Jan-Jun	
Number of stops		7	
Stop time	65	343	h
Time efficiency	97	92	%
Electrical failure		264	h
Machinery failure	59	59 h	
Instrument failure		14 h	
Other	6	6 h	

Most of the electrical failures were due to drop in tension on long distance transmission lines. Vital items as pumps for cooling water, boiler feed water and Carsol (CO_2 absorbent) tripped out. Most of the failures occurred in the period April-May. Work is going on to get two supply lines, but this is not ready yet, due to differences in tension on the various lines.

The regularity is low, especially for the second quarter, but not so low that it can explain the high energy consumption.

4.4.2.3 Production

The production has during 1996 been only 75 to 80 per cent of design. The explanations for that were said to be

1. Gas shortage during the winter
2. Poisoning of catalysts.

The ammonia plant is situated in the wind direction from the VCM plant, where it was a big emission of VCM two years ago. That first poisoned the catalyst in the secondary reformer. The poison could to some extent be flushed out but some of it was carried on in the process and poisoned the catalyst in the LT shift converter, that had to be changed.

3. A large part of the thermo couples in the synthesis reactor are out of order, resulting in the staff running it on the safe side to avoid hot spots.

An explanation for both low capacity and high energy consumption is the low efficiency of the synthesis reactor.

4.4.2.4 Process

4.4.2.4.1 Steam-To-Carbon Ratio

The steam-to-carbon ratio in the primary reformer is high, 3.8 - 3.9. This increases the total energy consumption substantially. Even if the heat can be recovered later on in the process, it will be on a lower level and more difficult to utilise. A decrease down to a more normal figure 3.0-3.5 will decrease the total energy consumption with approximately 1.0 GJ/tonne. The reason for the high steam-to-carbon ratio is the bad condition of the catalyst in the secondary reformer.

4.4.2.4.2 Purge Gas

The purge gas is 4000-5000 m^3/h, design 6000 m^3/h. The reasons for lower than design are low content of CO out of the shift converters and low CO_2 after the Carsol absorber, due to the presently low production. Part of the purge gas, about 1500 Nm^3/h, is used in the nitric acid plants for de-colouring the tail gas. NH^3 content in the purge gas is 3-4 % NH_3.

4.4.2.4.3 Burners In Primary Reformer And Steam Boiler

The burners in the primary reformer were originally designed for naphtha and later reconstructed for gas. This was said to give them a sub-optimal performance.
Only the plant's total gas consumption is measured. There are no special meters for process, heating of primary reformer and auxiliary boiler. To the gas for heating of the primary reformer are added the joined purge and let down gases, containing ammonia.

Measures were performed in the flue gases both from the primary reformer and from the auxiliary boiler. There were some difficulties to avoid air leakage during the measurements in the primary reformer, why the measured temperature and NOx content there can be somewhat lower than actual and the oxygen content somewhat higher. A more normal figure for oxygen was said to be 6 %.

	Primary reformer	Auxiliary boiler	
Temperature	517	615	°C
O_2	8.2	5.0	%
NOx	533	67	ppm
(NOx corrected to 6% O_2	640)		

Under the assumption that the total amount of dry flue gases from the primary reformer is 190 000 Nm^3/h, the corrected NOx content corresponds to a total NOx emission of 120 Nm^3/h NOx or 250 kg /h calculated as NO_2.

For reference, it can be calculated, that if 3.6% NH_3 in 3000 Nm^3/h purge gas is burnt to NOx, this will correspond to 108 Nm^3/h NOx. It is thus apparent that all the ammonia in the purge gas is converted to NOx in addition to the NOx formed from nitrogen and oxygen in the burners. Some of the purge gas is burnt in the nitric acid plant and forms NOx also there. 5000 Nm^3/h purge gas with an ammonia content of 3.5 % gives 2700 tonnes pro year NOx calculated as NO_2, to be compared with 3000 tonnes NOx as NO_2 from a production of 270 000 tonnes pro year nitric acid!

4.4.2.4.4 Synthesis

The synthesis reactor runs on a low pressure, 125 bar, design 155 bar. The reactor has at present a low efficiency. The ammonia content in feed gas to the converter is two per cent, which is good and indicates a good separation. Exit content, however, is only eight to ten per cent. The design value is twelve per cent and with today's catalysts and design of converter internals up to 17 per cent is achievable. The present catalyst is more than ten years old.

4.4.2.4.5 Gas Outlet

When a failure occurs in an ammonia plant, with an expected restart within twenty-four hours, the process parts upstream the failure point normally continue to run but the gas is sent to flare. At this ammonia plant, the gas is during such occasions sent directly to vent without burning. The risk for a gas cloud explosion is apparent and such explosions can be extremely violent. The most famous gas cloud explosion is the Flixborough accident 1974, which killed six persons and caused severe material damage.

4.4.2.4.6 Ion Exchangers For Preparation Of Demineralized Water

The ion exchangers at the ammonia plant are regenerated with nitric acid. The outlet is after neutralisation sent to the river and will increase the nitrogen load to the recipient. The emission corresponds to 500 tonnes HNO_3 pro year or more than 300 kg/d NO_3-N. This corresponds to 0.06 per cent of the total nitrogen turnover. This could be compared with the total nitrogen emissions to water from a whole fertilizer site in western Europe, which is 0.1 - 0.3 per cent.

4.4.3 Nitric Acid

4.4.3.1 Process

There are two nitric acid plants. Design process data are the following:

	HNO_3 I	HNO_3 II
Number of lines	2	1
Production, t HNO_3/d design	450	500
Steam export 17.5 bar, t/h	34	10
Steam export, t/tonne HNO_3	1.8	0.5
Compressor driving	El	Steam
Operation pressure, bar	8.8	8.8

4.4.3.2 Operation

Production and consumption figures were given for the first quarter 1996 and can be found in Appendix 4.28.

The ammonia consumption figures, 0.319 and 0.312 tonnes/tonne HNO_3, must be considered as high, even for a high pressure process.

4.4.3.3 Energy

The steam balance in the plants did not appear to be in good order but was not studied in detail. From plant number 1, with an electrical motor for driving the compressor, was exported 1.0 tonne 18 bar steam pro tonne produced HNO_3. From plant number 2, where the compressor is turbine driven, no steam were exported. Instead a smaller amount had to be supplied.

In one of the plants, steam is used for ammonia evaporation, in the other one water is used for evaporation and steam for superheating.

Environment

The tail gases are "de-colourized", i.e. the N_2O_4, having the yellow colour, is transformed to colourless NO_2 by heating it up to a temperature of about 500°C. The tail gas is first heated by gas/gas heat exchanging up to 200 °C and then heated by natural gas up to final temperature. NOx content in tail gas is about 1500 ppm.

A catalytic reduction of the nitrous gases down to elementary nitrogen is unavoidable in today's Europe and is considered a production cost. The present standard for NOx emissions in most European countries is 150 ppm but it is expected to be 100 ppm within a few years.

4.4.3.4 Bleaching

The acid contains very much dissolved nitrous gases as there is no special bleaching tower but a part of the absorption tower serves that function. The storage tank for nitric acid emits strongly coloured gases.

When ammonium nitrate is produced from unbleached acid, there is a substantial risk for uncontrolled decomposition of the hot ammonium nitrate melt. Maximum content of nitrite is for safety reasons normally set to 100 to 150 ppm.

4.4.4 NPK

Process description see Appendix 4.30.

4.4.4.1 Production

The NPK plant has a production capacity of 200,000 tonnes pro year. The predominating grade is 15:15:15. As phosphorous source SSS, TSP or MAP is used. If any kind of superphosphate is used, it is neutralised by ammonia in the granulator. Liquid phase for the granulation is supplied by liquid AN and steam.
During the first quarter 1996 14 100 tonnes NPK 15:15:15 was produced (budget 20,000).

4.4.4.2 Gas Cleaning

The NPK plant was studied mainly from the point of emissions.
Cyclones are installed for the air from

1. the granulator
2. the drying drums
3. the crushers

After the cyclones, the air from the granulator and the air from the dryers go to venturi scrubbers. These scrubbers have circulating water, but the bleed is so large, that they act as once through.

The air from the cyclone after the crushers is sent directly to vent. The air from the cooler, a fluidised bed, has neither cyclone nor scrubber. The cyclones are not isolated and not supplied with hot air, why they easily clog, especially during stops.

4.4.4.3 Emissions

No measurements were performed at our visit but results from earlier internal measurements were given. A lot of measurements are made regularly but normally only concentrations are measured and no flows. The amount of emissions are therefore difficult to calculate. However, results from some measurements in the NPK scrubbers were given and they have been analysed.

Granulator scrubber

The results are presented in Appendix 4.30. The scrubber mainly scrubs out gaseous ammonia escaping from the ammunition of the superphosphate in the granulator. The scrubber efficiency is low and only half of the ammoniacal nitrogen , both as gas and as dust, is caught by the water.

1.3 tonnes a day of ammonia is emitted to water and the same amount to air. The pH of the water was not given, but with 96 per cent of the ammonia in free form it must be very high and that can explain the low efficiency of the scrubber.

Drying drum scrubbers

An overview is presented in Appendix 4.30. Also the scrubbers after the dryer cyclones have a low efficiency. Only about 25 per cent of the nitrogen content in the air in to scrubber go over in the water phase. About 350 kg/day nitrogen goes out with the water from the two drying drum scrubbers and about 1,000 kg/day is emitted to the air.

Total emissions from the NPK scrubbers are thus 2.3 tonnes nitrogen a day to air and 1.6 tonnes a day to water.

4.4.5 Other Emission Sources

The plants for prilled fertilisers, Urea and CAN, were not visited. We were told that both plants have troubles with deposits on the bottoms of the prilling towers. We know out of experience that the flushing, done to remove these deposits, is the cause of very large emissions.

A lot of research has been done by the big engineering companies to improve prill nozzles to give less deposits on the prill bottoms. One of the better ways to get less stops for cleaning and substantially decrease the emissions both to air and water is to put in new prill nozzles.

5. Recommendations

5.1 "NIS - Refinerija Nafte Pancevo" refinery

5.1.1 Energy

Energy conservation measures can be grouped into six categories:

Housekeeping and operational Improvements;
Combustion and Steam System Improvements;
Waste heat recovery and reuse;
Electric system improvements;
Process modification;
Cogeneration.

Total expected energy savings in boiler house and steam and condensate system could be estimated in the range of 20-30% with pay back period about 2 years.

5.1.1.1 Lo cost / No cost measures

In this Chapter only the possibility of implementation of first three categories will be discussed. Only after implementation of proposed measures prescribed by this three categories one can have reliable entering data for further consideration of last two categories. The forth category is not the first priority one at the moment.

A walk-through energy audit cannot result in either an energy balance or evaluated energy conservation measures. What can be done and what has been the aim of this walk-through audit is to get a general view of the energy situation at the plant and to find out in which energy system possible and feasible energy conservation measures exist.

Concerning this refinery, the following n/l cost measures have to be implemented without delay because it can result in 15-20% energy savings. This analyses deals with the boiler house and the steam and condensate distribution systems.

5.1.1.1.1 Monitoring

Monitoring itself will not lead to energy savings unless the data is analysed and put in the context within the company or establishment.

Monitoring system in this refinery is not reliable and complete and it is not used for energy analysis. It is used only for running the process. Instrumentation used are not in such a good condition. For example, output mass flow rate of steam of boiler No. 3 is *greater* than the mass flow rate of feed water at the same boiler! The difference is about 10%. Or, using the measuring data (Table 3 and 4) one can calculate that the boiler efficiency is greater than 1.0 (cca 1.02 - 1.03).

Boiler efficiency measurements (Table 1 and 2) indicates that the CO content in flue gases is high. That means that incombustible fuel exists in flue gases. The reason could be inefficient atomisation in the burner. The excess air is higher than it is normal. There is no O_2 (or CO_2) control system. The NO_x and SO_2 contents are to high. Burners has to be checked and/or repaired.

Measuring system of steam from boilers has to be re-calibrate or replaced. The same has to be done with fuel consumption metering system. The ratio of steam to fuel is the main measure of efficiency of the boiler and it should be measured and maintained at a high level, compatible with good practice.

The blow-down is performed manually. An automatic system has to be implemented.

Continuously log boiler performance has to be done so that signs of deterioration soon become evident, enabling corrective maintenance to be carried out.

Meter feed water has to be re-calibrated or replaced.

Example 1.

Existing measuring and process control system in the boiler room and turbine house (power plant) are not reliable enough for the plant working balance. When the system for measuring, control and regulating of the working process of boiler and turbines is changed and completed, it will be possible to widen the control parameters and to start with the work in all plants in an energy efficient and safe way. The investments required are as follows:

monitoring equipment	825,000	US$
unforeseen 15%	125,000	US$
TOTAL	**950,000**	**US$**

By changing and completing the existing system for measuring and working parameters it is possible to save 162,000 GJ/year, which is 661,000 US$ per year. This investment would pay back in 17 months.

Example 2.

The current way of calculation of the energy consumption distribution in the plants is not energetically stimulating enough. Actually, these are internal calculations without real economic outcomes in the production units. With installing the energy consumption control system in every technologically important and closed production units, it will be possible to control and lower the energy consumption. The investment for the measuring equipment is as follows:

measuring equipment	140,000	US$
unforeseen costs 15%	20,000	US$
TOTAL	**160,000**	**US$**

With this energy consumption control equipment and the adequate calculating mechanisms, it will be possible to lower the consumption for 101,000 GJ/year, which is 412,000 US$ per year. The pay back period is 5 months.

5.1.1.1.2 Boiler improvements

There is no economiser in boiler house. Economiser for preheating boiler feed water is generally a very attractive investment. But, in this case any discussion on feed water preheating must be followed after performing the improvement of steam and condensate distribution system. After this, it is possible to calculate the real size of the economiser.

1. Flue gas analysis shows that the tested boilers operate with lower content of carbon dioxide: 11.40% for Boiler No. 2 and 10.40% for Boiler No. 3. The normal content of carbon dioxide for the heavy fuel oil is minimum 13%. Consequently the content of the oxygen is higher than it is normal (4%). Oil burners should be able to operate down to 1.15 excess air with upper limit of about 1.20. That means that in refinery case boilers operate with higher excess air (1.40 and 1.53). The content of CO is a little bit higher than it is normal, but having in mind that the excess air is higher it means that incombustible fuel is in flue gas.

The measured flue gas temperatures are higher than designed one (177 °C), which pointed out that the heat transfer surfaces has to be cleaned. This temperature would be much higher if the excess air is reduced to the normal value.

Suggestion actions are to:

a) Repair or replace the nozzles of the burners and check the pressure before the burners.

b) Improve combustion control by installing the control system for fuel-to-air ratio by measuring CO_2 or O_2.
By improving the combustion system the level of SO_2 and NO_x will be reduced as well.

c) Cleanliness of heat transfer surfaces and control the flue gas temperature history. Any increase of flue gas temperature will be recognised and proper action can be done.

2. Improve the metering system for feed water supplying, steam production and distribution to the main consumers. Establish the metering system for condensate returning.

   Control of the make up water has to be improved. If the quality of water treatment is improved and the proportion of returned condensate is increased, this should reduce the amount of blowdown necessary.

3. The temperatures of the boiler surfaces are higher than it is normal. At some points it was about 130 °C. The insulation of the boiler has to be checked and repaired. It could decrease the radiation losses for about 1.0-1.5%.

4. The boiler efficiency is (both boilers):

Flue gas loses	14.2-14.8%
Radiation losses	4%
Blow down loss	3%

Total: 78.2 - 78.8%

By performing the suggested action in items 3.1-3.3 the boiler efficiency could be increased for 5-6%. The pay back period for this is normally less then one year.

5. The next step of improving the total efficiency of the boiler house could be the analysis of possibility to use flue gases for preheating the make up water or combustion air. Both options are feasible. Efficiency improvements of about 5% are common for economiser units installed, often producing pay back period of 1-2 years. the installation of the air preheater is more expensive and the pay back period is longer.

Example 1.

The boiler constructions are old, with high temperatures of combustion products (177 °C). In the exploitation those temperatures are even higher (200 °C). The heat of the combustion products can be used for preheating of the water for supplementing in the system which would lead to a higher degree of use of the boilers. The investment for the construction of these heaters with additional equipment for all three boilers is as follows:

equipment	550,000	US$
unforeseen 15%	80,000	US$
TOTAL	**630,000**	**US$**

With using the waste heat of the combustion products, it will be possible to save energy in amount of 162,000 GJ/year, which is 661,000 US$ per year. The pay back period is 11 months.

Example 2.

The high temperature of the boiler walls (at some points even 130 °C) stresses the necessity of the insulation reparation. This goes for all three boilers. The investment for the replacement of boiler insulation is as follows:

material and construction	165,000	US$
unforeseen 15%	30,000	US$
TOTAL	**195,000**	**US$**

The boiler insulation reparation would decrease the losses through the boiler surface. The estimated saving is 61,000 GJ/year, which is 250,000 US$ per year. The pay back time is 9 months.

Example 3.

The water heat from desalination and blow down is only partly used. Before it is thrown away, this water could be used for heating the water to supplement the system. The investment for construction of heat exchanger with accompanying equipment is as follows:

equipment	190,000 US$
unforeseen 10%	20,000 US$
TOTAL	**210,000 US$**

By using the desalination and blow down water heat it would be possible to save 81,000 GJ/year, which is 330,000 US$ per year. The pay back period is 8 months.

5.1.1.1.3 Air preheating

There is no air preheaters in subject boiler house. The air is sucked from the bottom of the boiler room. The temperature in that part of the room during the audit was 21 °C and under the roof of the room it was 35 °C. The thermal efficiency of a boiler plant could be increased by 1% if the combustion air temperature was raised a further 20%. In the case of this refinery it means that only simple reconstruction of air intake (from bottom to the roof) could increase the boiler efficiency for about 0.5%.

5.1.1.1.4 Steam Trap, Insulation and Metering Survey

Existing housekeeping procedure is not effective and, which means that it is not efficient as well. A lot of leakages were found in the steam and condensate distribution system. There are hundreds of steam traps and only a small number of them operate properly. A flash steam is allowed to blow to waste (condensate tanks). There are a lot contaminated condensate which can be recovered by using heat exchangers, but now they are wasted.

About 5-10% of all steam and condensate pipelines are not insulated. Some pipes are damaged by corrosion and produce other leakages. There are a lot of non insulated valves and flanges. Many important steam leaks are hidden such as: a) leaking or stuck traps or by-pass valves discharging to sewer or condensate system; b) leaking valves leading to idle equipment; and c) leaks in heater or other equipment connected to the steam system.

Housekeeping includes measures to reduce energy use that can readily be taken by plant engineer or plant operator at little or no cost and in a short time. Examples of simple housekeeping are shutting of standby furnaces, inspecting combustion equipment, adjusting burners, and inspecting and repairing steam traps - preferably on a routine basis. At a slightly more advanced level, the operation of process equipment can be rescheduled to avoid frequent start-ups and shutdowns - generally, continuous operation is energetically more efficient than intermittent operation - or equipment can be adjusted to operate at the lowest economical temperature. Improving insulation becomes part of housekeeping if materials costs are low and the payback period is shorter than a year. For example, if the surface temperature of currently insulated steam lines or liquid piping exceeds 40 C, the insulation should be upgraded. Damaged insulation can result in much heat loss, so regular inspection of distribution lines is desirable. Combustion efficiency is major area of potential operational savings, as 1 - 5% of fuel used can be saved by regular tune-up of the air-to-fuel ratio. Modern technology enables fuel-to-air ratios to be maintained at recommended levels at all times, ensuring consistent combustion efficiency. Microprocessor controlled servo motors fitted to fuel valves and air dampers replace the traditional methods of control, providing a programmable system which will automatically select and maintain the fuel-to-air ratio specific to a particular fuel.

The flue gas temperature of the boiler was about 200 °C at both boilers. This temperature is higher then designed one (177 °C). This suggest that it is possible that boiler tubes become fouled by soot and deposits and the amount of heat transferred from the hot flue gases to the water is reduced. There is a rule which says that an increase of around 20 °C above that temperature for a clean boiler means that the tubes must be cleaned. A rise of 17 °C causes a decrease in efficiency of 1 %.

Any discussion on energy conservation in this Refinery has to start with housekeeping procedures.

1. The steam distribution system is in a very bad situation. That means that detailed reparation of the system must be done. All steam traps and valves have to be checked, repaired or replaced. Insulation must be checked as well and put on the uninsulated pipelines, valves and flanges. Corroded pipelines have to be replaced.

Just to illustrate the effect of a leak consider the following:

Steam pressure 7 bar and hole size 0.8 mm produce the loss equivalent up to 1,500 litres of oil per year.

Or, to illustrate the loss through uninsulated surface and flanges, the following example could be used:

> A 3 m length of exposed 150 mm diameter piping carrying steam at a pressure of 7 bar can waste 3,000 litres of oil per year.
> If there were five uninsulated flanges on the same 150 mm diameter pipe, heat losses would equate to another 3,000 litres of oil being wasted a year.

During the audit it was very difficult to count the number of leaks and uninsulated places. However, there is no doubt that a great energy saving potential is in improving the steam distribution system. The common pay back period for this typical housekeeping procedure is less than one year. Expected effect of efficiency improvement of steam mains in this refinery could be up to 10%.

2. As it was mentioned, the condensate from the processes are wasted. Only the turbine condensate is returned to the boilers. That means that only 10 to 50% is returned, depending of electricity production. At the moment there is

no economical reasons for increasing the electricity production because of low electricity prices.
Possible boiler fuel saving by returning the condensate is from 5 to 9%.

Example 1.

The reparation of damaged and ruined parts of the steam line and their insulation is a necessary measure. The investment for the replacement of ruined parts and damaged or ruined insulation's is as follows:

equipment	340,000	US$
unforeseen 10%	35,000	US$
TOTAL	**375,000**	**US$**

With this the waste of energy in the distributional system will be lowered, which would lead to saving of 162,000 GJ/year, which is 661,000 US$ per year. The pay back period is 7 months.

Example 2.

The reparation of valve seals, replacement of the old ones, and valve insulation are the measures which the maintenance department should always takes care of. The investment for mending these things is as follows:

material and works	85,000	US$
unforeseen 10%	10,000	US$
TOTAL	**95,000**	**US$**

This will lower the waste of energy in the distributional system which will save 81,000 GJ/year, ie. 330,000 US$ per year. The pay back period is 3 months.

Example 3.

The replacement of damaged steam trap should be a permanent task of the maintenance department. In the present conditions this has been partly neglected. Investment for this is as follows:

equipment and construction	90,000	US$
unforeseen 10%	8,000	US$
TOTAL	**98,000**	**US$**

With a regular replacement of steam traps, it would be possible to save 61,000 GJ/year, compared to the present situation. It amounts to US$ 249,000 per year. The pay back period is 5 months.

5.1.1.1.5 Condensate Recovery

When the feed water temperature is low, the cause should be investigated. It can be due to:

a low rate of condensate return;
the lack of insulation on the condensate return pipes;
losses from the feed water either as heat through the walls or as overflow.

As much condensate as is economically possible should be returned from sources where there is no likelihood of contamination. This will save heat, make-up water and chemicals used in water treatment, as well as reduce blowdown losses. The possible fuel savings resulting from increased condensate return are shown in Figure 3. The make-up water in this case is 15 °C and assumed temperature of returned condensate is 90 °C. The boiler fuel saved is calculated using the basic consumption when there is no condensate returned.

Presently, the condensate is returned and used only from the power plant. The condensate from the process is thrown away in fear of contamination. There is a possibility of constructing a system for accumulating and using it without any danger for boilers. The investment for the construction of the system for accumulating and returning the condensate, with accompanying equipment is as follows:

equipment and construction	690,000	US$
unforeseen 20%	135,000	US$
TOTAL	**825,000**	**US$**

By using the condensate heat it will be possible to lower the energy waste in the system which would save 284,000 GJ/year. It amounts to US$ 1,160,000. The pay back period is 9 months.

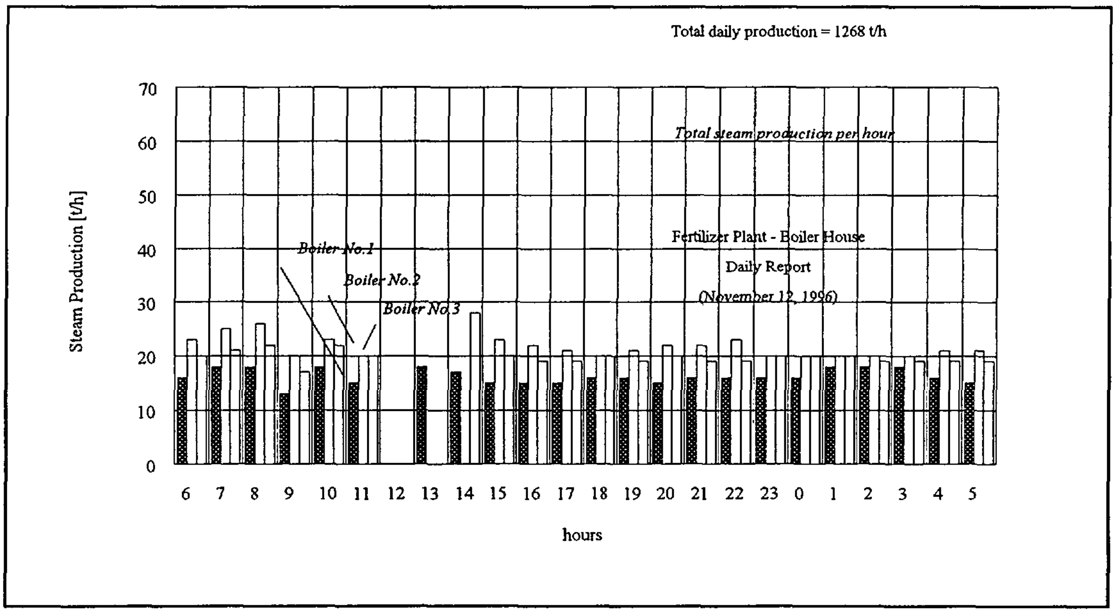


Figure 3: Fuel saved by condensate return

The case of this refinery only the condensate from condensing turbines is returned. The rest of the condensate is wasted. Returning the condensate directly into the boiler or, if it is contaminated, by using the heat exchanger or by automatic dumping by measuring the conductivity, it is possible to save fuel from 5% for 50% returned condensate to 9% for 90% returned condensate.

5.1.1.1.6 Steam trap, insulation and metering survey

Existing housekeeping procedure is not effective and, which means that it is not efficient as well. A lot of leakages were found in the steam and condensate distribution system. There are hundreds of steam traps and only a small number of them operate properly. A flash steam is allowed to blow to waste (condensate tanks). There are a lot contaminated condensate which can be recovered by using heat exchangers, but now they are wasted.

About 5-10% of all steam and condensate pipelines are not insulated. Some pipes are damaged by corrosion and produce other leakages. There are a lot of non insulated valves and flanges. Many important steam leaks are hidden such as: a) leaking or stuck traps or by-pass valves discharging to sewer or condensate system; b) leaking valves leading to idle equipment; and c) leaks in heater or other equipment connected to the steam system.

During the audit it was very difficult to count the number of leaks and uninsulated places. However, there is no doubt that a great energy saving potential is in improving the steam distribution system. The common pay back period for this typical housekeeping procedure is less than one year. Expected effect of efficiency improvement of steam mains in this refinery could be up to 10%.

5.1.1.2 Medium Cost Investments

5.1.1.2.1 Low Pressure Steam For Tank Heating Changed For Hot Water Circuit

The main reason for the low condensate recovery is, of course the fear for returning condensate with oil contamination to the boilers. Therefore, the condensate recovery is non-existing from the processes. If, however, a protective circuit is introduced, i. e. the tank and other heatings are changed for heating with hot water, which in turn is heated by the low pressure steam, the condensate from the water heating can be recovered safely.

The financial gains from such a measure are quite big as listed below. They are built upon the following assumptions: the condensate is recovered at 95 °C, which results in an energy saving of 335 MJ/tonne. If only 50 tonnes per hour condensate is recovered, about 1/3 of the process consumption, the savings will be 144 TJ annually. The water cost given by the staff, US$ 0.3 per tonne is used, even if it seems very low considering that the boiler is operating at 45 bar and with turbine operation.

energy savings	590 000	US$/year
reduced water costs	120 000	US$/year
TOTAL	**710 000**	**US$/year**

The change of the system from low pressure steam to hot water does not imply very big reconstruction. However, a separate study would need to be made in order to determine the precise scope and costs. The investments mainly consist of a heat exchanger, pump station and rearranging the existing piping system. Additional operation costs mainly consists of pumping electricity and maintenance. The payback can safely be estimated to less than a year.

5.1.1.2.2 Recuperation Of Flare Gas

The system is not operative due to operational problems, mainly related to the compressor and control system as described in section 4.2.1.5.

The problems, as described for us, do, however, not seem to be too difficult to solve. The uneven load on the compressor and the backward rotation at stops should be possible to solve with a combination of better control system and a check valve after the compressor. This since the compressor is fitted with speed control. Possibly, this should be completed by increased buffer capacity in the low pressure storage tank before the compressor. The cheapest way is probably to increase the pressure to e. g. 1 bar(g) in the tank by means of an insensitive low pressure compressor, in that way doubling the capacity. If the problem also lies in the gas recipient processes, an additional high pressure buffer tank after the compressor could help. The rest of the problems seem mainly to be process improvements. This would have to be studied in more detail to give precise measures and costs.

The amount of gas to flare is, however, quite high, maximum 3,750 kg/hour, and therefore, if the average flow is only half of that, and the recovery unit is rehabilitated to recover 80 % of the gas the energy savings from such a system would be 480 TJ/year. In monetary terms, that would correspond to US$ 2 million per year, if valued as LPG. The refinery management has unspecified plans for a project to rectify this situation. We strongly support and recommend such a project for determining what measures are required, and thereafter implementing it without delay.

5.1.1.2.3 Hydrogen Rich Gas From Process Sold Instead Of Fired

At present, a surplus of hydrogen from the platforming is mixed into the fuel gas. Since hydrogen is quite expensive to manufacture, this is a waste. The hydrogen rich gas from platforming and HDS units amounts to 90 tonnes per day and consists of 75 % hydrogen. According to the management, there are plans to install another hydrogen desulphurisation (HDS) unit within the next few years, which would use the surplus hydrogen. However, this would probably not be realised until the Claus problems are solved, see section 4.2.1.4, since the hydrogen sulphide must be utilised. Anyhow, it would probably be possible to find use for the hydrogen in a way that would pay back in short time, so the money would be recovered long before the HDS unit could be erected. Tentative ideas for use would be to sell it to the ammonia plant at HIP Petrohemija, which would require a separate study for determining if and how this could be done, or to sell it to the nearby company Tehnogasa. The requirements and terms for such a delivery would also have to be studied separately.

5.1.1.3 Long Term Recommendations

5.1.1.3.1 New Boiler And Steam Turbine System

The steam boiler capacity is at present fully utilised and no margins exist for breakdowns etc. Furthermore, an earlier energy study rightly pointed out that much of the high pressure steam is utilised in low efficiency drive turbines for compressors, pumps and fans. Considerable savings could be achieved if those drive turbines were replaced with electric motors, the electricity for which would be generated in a single, efficient turbine adapted to present needs of steam and power. An investment in a new 120 tonnes steam per hour boiler and a 12 MW turbine is therefore planned within the near future. A preliminary study of the steam balance for the refinery does, however, indicate that the savings would be big enough to consider postponing the investment in the new boiler and start with only the turbine. See Appendix 5.1.

The financial calculation indicates following investments in cogeneration equipment:

New steam turbine with generator & installation:	3 800 000 US$
Motors for pumps and mechanical drive:	500 000 US$
New pumps:	100 000 US$
New piping for LP Process steam:	100 000 US$
TOTAL	**4 500 000 US$**

Savings/year: 17,700 kW$_{el}$, with a value of: US$/year 2,100,000 million.

5.1.1.3.2 Spent Acid Unit

As described in section 4.2.1.3, the alkylation unit is out of operation since the spent catalyst acid cannot be disposed of. Normal practise is to send it for regeneration off-site. This option is, however, not available in this case. The management therefore has considered installing a small regeneration unit for only this plant. The plans, see Appendix 4.4, have been reviewed and there is little doubt that the investment would be financially viable from a company point of view, even though costs for recommissioning the alkylation unit should be added to the cost side. Note that costs and benefit figures not have been verified within this study but accepted as given.

Another, and, in our opinion, even more beneficial solution is presented below in section 5.2.1.3.3.

5.1.1.3.3 WSA Unit Replacing Claus Unit And Spent Acid Regeneration

An idea for saving money and solving two problems in one could be to install a unit for production of fresh sulphuric acid from both the spent alkylation catalyst and from the hydrogen sulphide form the amine wash, when the amount of sulphur is too low for running the Claus process.

The amount of spent acid produced is 24 tonnes per day, and the present Claus unit is designed for maximum 60 and minimum 15 tonnes sulphur per day. This means that two options exist. Either the existing Claus unit is shut down and all sulphur streams are used in the new unit, or the new unit will mainly be used for regeneration of the spent acid and only take hydrogen sulphide when the minimum requirement for operation of the Claus unit is not met. In the latter case, the operation and production of sulphuric acid will be more uneven. The sulphuric acid degeneration is, however, enough for the operation of the unit so lower limit for H_2S supply apply.

Haldor Topsøe in Denmark markets a process, called wet gas sulphuric acid (WSA), which could combine the two problems into one solution, see Appendix 5.2.

A prerequisite for this solution would, naturally, be that a market for the surplus sulphuric acid can be found. Since sulphuric acid is a widely used chemical, it should, however, not pose a major problem.

The investment calculation is made as an incremental cost for a complete changeover to the WSA process, compared to the above suggestion to invest in separate Claus and spent acid recovery units. Operation costs are assumed to be unchanged. The prices for Spent acid and Claus units are NIS' own, whereas the price for the WSA process is a rough estimation from Haldor Topsøe. For the calculation, an average alternative sulphur production in the old Claus unit of 30 tonnes per day has been assumed. The WSA unit is, however, dimensioned for maximum 60 tonnes sulphur from hydrogen sulphide per day, just as the existing Claus unit, to ensure full capacity.

Investment	WSA process	15.0	US$ million
	installation, civil works	5.0	US$ million
- Avoided investment	Spent acid	5.0	US$ million
	Claus unit	5.0	US$ million
NET INVESTMENT		**10.0**	**US$ million**
Incremental incomes	sulphuric acid sold	6.0	US$ million/year
- Incremental costs	lost income sulphur	1.0	US$ million/year
ANNUAL NET INCOME		**5.0**	**US$ million/year**

The payback therefore would be 2 years. If the WSA unit only is supposed regenerate sulphuric acid and to use hydrogen sulphide only when the content is too low for the old Claus unit, the unit can be built smaller and the costs will be as follows. For the calculation, an average alternative sulphur production of 5 tonnes per day has been assumed for the new Claus unit, but the WSA unit is dimensioned for maximum 15 tonnes per day sulphur from hydrogen sulphide to make up for peak loads, which gives it a low utilisation.

Investment	WSA process	8.5	US$ million
	installation, civil works	3.5	US$ million
- Avoided investment	Spent acid	5.0	US$ million
	Claus unit	5.0	US$ million
NET INVESTMENT		**2.0**	**US$ million**
Incremental incomes	sulphuric acid sold	1.0	US$ million/year
- Incremental costs	lost income sulphur	0.2	US$ million/year
ANNUAL NET INCOME		**0.8**	**US$ million/year**

The incremental payback in this case therefore would be 2.5 years.

5.1.1.4 Other Measures Considered

5.1.1.4.1 Change Steam Ejectors To Vacuum Pumps In Vacuum Distillation

A very promising measure to save steam is to replace vacuum steam jets in the vacuum tower with vacuum pumps. Unfortunately, we could not get enough data for determining the feasibility and putting figures on the savings and investments. A further study is, however, recommended.

5.1.1.4.2 District Heating

A plant of this complexity and size has considerable amounts of waste heat. Simplified speaking, if the low grade heat in the condensate can be used, one tonne of condensate is produced for every tonne of steam produced in the plant. Since the refinery has a very low level of condensate recovery out of fear for oil contamination, the prospect is very good. Contamination of oil in the water for district heating would not have the same consequences since the condensate will be heat exchanged to the system. The measure has, however, been rejected in favour of measure 5.2.1.2.1, which is considered more beneficial.

5.1.1.4.3 Co-Generation In Furnaces

Since several of the refinery processes are heated by furnaces, it has been considered to use the heat demand as basis for gas turbine generation of electricity. This has, however been ruled out due to too confined space and the low electricity price. At a higher electricity price, this idea might, however, be revived.

5.1.1.4.4 Heat Integration

Heat integration of the various processes is a very rewarding measure in a complex like this, where each process has been built independently from the others, without optimisation of the overall energy consumption. This has however already been studied in 1989 in more detail than could be incorporated in this study, and the first steps on the way to implementation have been taken by the management.

5.1.1.4.5 Change Of Column Internals

An increased mass transfer efficiency, and a reduced pressure drop of column internals would save considerable amounts of energy. Also this has, however, already been studied and is planned for implementation. It was therefore not considered in this study.

5.1.2 Environment

5.1.2.1 Lo cost / No cost measures

5.1.2.1.1 Waste Treatment And Disposal Of Solid Sludge From Concrete Basin

The final disposal of solid waste, now stored in a concrete basin, has not been solved yet, but a project is planned. In the study "Treatment, removal and recycling of refinery solid wastes", this project is described. The technologies enalling the recycling of the outlet streams are; oil is introduced in the processing unit, water is sent to water treatment unit and solids, without heavy metals, are removed to dumping or treated by the fixation method where the inorganic hazardous waste is converted to non-hazardous waste.

In Sweden most oil spills at this type of plants are collected and reused at the plants themselves, either directly in the boilers or in special waste incinerators. In some cases, where the plants not have the possibility to take care of the waste, it is sent away for destruction (incineration) or deposition.

It is possible to incinerate most waste containing oil in special furnaces. Higher temperatures and more controlled combustion are normally required in order to reach satisfactory destruction. It can be possible to incinerate waste containing oil in cement kilns.

Oil contaminated soil and sludge can also be treated biologically by adding certain micro-organisms which increase the normal detoriation rate. However, this method must be considered to still be in the development stage but will probably be a widespread treatment method in the future.

An example of waste which cannot be incinerated or treated microbiologically is metal hydroxide sludge from precipitation processes. This kind of waste has to be deposited under controlled conditions.

A simple design of a controlled deposit is shown in the figure below.

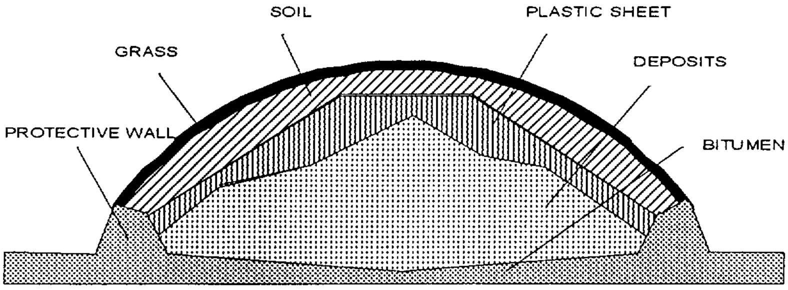


Figure. Design of a controlled deposit.

In order to avoid metal containing leachate to contaminate the surroundings the deposit has a compact asphalt plate in the bottom. Waste and sludge is deposited on top of the asphalt and when the deposit is filled it is covered with reinforced plastic foil to protect the waste from rainwater. Finally the waste deposit is covered with sand and soil. During the waste filling period which may take up to several years the waste must be protected from rain by a roof or a temporary watertight covering.

The preparation costs for such a deposit with a size of 150 m² mainly comprise the costs for the asphalt and the plastic covering.

	US$
Ground work	1,000
Asphalting (SEK 200/m²)	5,000
Plastic covering (15·20 m²)	2,500
Local labour costs (½ man-month)	1,000
Unforeseen costs (15%)	1,500
Total	11,000

Then, when the deposit is full and should be covered with sand or soil this will cost:

	US$
Sand	1,500
Local labour costs (1 week)	500
Unforeseen costs (15%)	500
Total	2,500

The best would be to locate the deposit as close as possible to the plant.

5.1.2.2 Medium cost investments

5.1.2.2.1 Reduction Of SO_2 Emissions

The measures at the Swedish refinery, used as an example, for minimising the sulphur emissions are:

- General energy efficiency measures.
- Run all fuel gas absorbers with optimal flow of amine in order to decrease the content of H_2S in the fuel gas as much as possible. Newly installed analysis equipment for the fuel gases from the FCC is used to optimise the process.

For Pancevo one important measure is to upgrade the existing Claus unit for full-load production. The suggestion, from the plant personnel, to install a smaller Claus unit, would decrease the SO_2 emissions. For further reduction of SO_2 emissions, the Claus units can be complemented by a third stage. An, in our opinion better alternative in this case would be to install a WSA unit as described in section 5.1.1.3.3.

Another way to reduce the total SO_2 emissions is of course by installing desulphurisation equipment for the flue gases, however, not realistic here.

In a long run a change from oil to gas is recommended since emissions of SO_2, dust, soot and particles would decrease drastically without installation of cleaning equipment. Even emissions of CO_2 would decrease and a reduction of SO_2 would be easier to achieve.

5.1.2.2.2 Reduction of NO_x

Reduction of NOx is especially important in this type of plant where it is combined with emissions of hydrocarbons to form photochemical smog. To achieve a substantial reduction of the NO_x emissions there are in principle two alternatives:

1. Change to gas as the only fuel and installation of lox NO_x-burners.
2. Installation of selective catalytic reduction (SCR) in one or several chimneys.

Alternative 1

A change from oil to gas normally results in a reduction of the NO_x emissions of 30-50 %. An installation of low-NO_x burners would further reduce the emissions. The reducing capacity of low-NO_x burners increases if gas is used as fuel compared to oil and if steam injection is installed together with the burners. The estimated cost for installation and start up work for one medium size low-NO_x burner, inclusive steam injection, is 16,000 - 19,000 US$. Between 55 and 65 % reduction is possible to achieve if the low-NO_x burners are combined with steam injection. If the fuel is changed to gas a total reduction of 55-80 % can be accomplished.

Alternative 2

The installation of SCR results in a reduction of the NO_x emissions of 70-90 % but is also increasing the handling and, of course, emissions of ammonia. However, the emitted ammonia is very limited compared to the NO_x emissions. It is not economical to equip chimneys with lower flue gas flows than 30,000 Nm^3/h. The investment for SCR is very difficult to estimate and vary depending on the design of the plant. The following cost can be used for reference: an investment cost of 65,000 US$/MW and an operation cost of 2.5 US$/MWh, calculated on supplied thermal effect and energy respectively.

Other measures for smaller reduction on NO_x emissions are:

- trimming of existing burners
- education
- steam-injection
- NSCR in FCC
- recirculation of flue gases into the combustion air

5.1.2.2.3 Continuous Environment Monitoring System

A system developed in Sweden uses DOAS-technique, a light-beam is sent through the air and by spectral analysis the average value of several different emissions are measured. This continuos system is installed in e.g. England, Denmark and Chile with the aim at a safe and stable operation. It also work as a warning system. The cost is from 75,000 up to 180,000 US$, depending on the complexity.

There are many measures to reduce the emissions of hydrocarbons:
- Search for leakages and tightening of the leakages.
- Exchange of equipment, supplementing or modification of existing equipment to achieve tighter equipment.
- Install equipment to decrease the emissions from individual major sources of emission.
- Improve the tightening on storage.
- Recirculation of hydrocarbons at un-loading and loading of boats, cars and train.
- Continuos measuring- and control system, regarding VOC.
- Measures at existing water treatment plants.

Conduct all safety-vents, with hydrocarbons, to flare.

5.1.2.3 Long term recommendations

5.1.2.3.1 Regeneration Of Spent Sulphuric Acid

The refinery has a plan to invest in a regeneration unit of their own, approximate investment 5 MUS$. In this investment the cost of restoring the alkylation unit has not been included but considering a several year long stop of the unit, there will most likely be a need of restoring the unit. Still the investment will pay back in a short time and we support the investment fully.

5.2 “HIP Petrohemija” petrochemical complex

5.2.1 Energy

In this Chapter only the following measures will be discussed:

Housekeeping and Operational Improvements;
Combustion, Steam and Condensate System Improvements;
Waste Heat Recovery and Reuse;

Only after analysis and/or implementation of proposed measures prescribed by these three measures, one can have reliable entering data for further consideration of energy efficiency improvements.

Total expected energy savings in boiler house and steam and condensate system could be estimated in the range of 20-30% with pay back period about 2 years.

5.2.1.1 Lo Cost / No Cost Measures

Concerning this plant the following n/l cost measures has to be implemented without delay because it can result in 15-20% energy savings. This analyses concerns the boiler house and the steam and condensate systems.

5.2.1.1.1 Boiler Efficiency and Boiler Control Systems

Monitoring will not of itself lead to energy savings unless the data is analysed and put in context within the company or establishment.

Monitoring system in this factory is not reliable and complete and it is not used for energy analysis. It is used only for running the process. Instrumentation used is not in such a good condition. For illustration of this statement the boiler efficiency calculation in Chapter 1.4 can be used.

Measuring systems of steam, feed water and fuel for each boilers have to be re-calibrate or replaced. The ratio of steam to fuel is the main measure of efficiency of the boiler and it should be measured and maintained at a high level, compatible with good practice.

Continuously log boiler performance has to be done so that signs of deterioration soon become evident, enabling corrective maintenance to be carried out.

It is highly recommended to improve monitoring system and to use these data for running the boiler house in optimal way. The next step is to introduce automatic boiler control system. Inadequate or incorrect application of boiler control can easily add 15% to fuel consumption compared with a well-controlled system. In particular, control of multiple boilers is generally poorly understood, as a consequence of which many existing systems are misconfigured and some cases uncontrollable. The main aim of a boiler control should be to reduce avoidable wastage to a minimum whilst providing the necessary output as required.

This boiler house must be examined thoroughly and a detailed plan for its retrofitting must be prepared. This action could be expensive and takes time. Because of that some n/l cost measures have to be done in the meantime.

1. The measuring of the content of combustion products are not significantly different from the expected values, which shows that the process is well conducted. Unfortunately, the process conducted manually, and it is understandable that the higher efficiency can be expected once the automatic combustion process control is installed. The factory experts created some suggestions concerning automatic control of the boiler house. This study proposed control system worth 1,000,000 US$.

Suggested actions are to:

a) Repair or replace the vital parts of the burners;
b) Improve combustion control by installing the control system for fuel-to-air ratio by measuring CO_2 or O_2.
c) Clean the heat transfer surfaces and control the flue gas temperature history. Any increase of flue gas temperature will be recognised and proper action could be taken.

2. The metering system for feed water supplying, steam production and distribution to the main consumers has to be repaired or installed.

3. The temperatures of the boiler surfaces are higher than it is normal. At some points it was more than 100 °C. The insulation of the boiler has to be checked and repaired. It could get a decrease in the radiation losses for about 1.0%.

4. The boiler efficiencies are (for boilers No.1 and No.2) as follows:

Flue gas loses	17.0 - 19.6%
Radiation losses	3%
Blowdown loss and desalination	4%
	Total: 73.4 - 76.0%

By performing the suggested actions in items 3.1-3.3, there could be an increase in the boiler efficiency for approximately 10%. The pay back period for this is normally less then one year.

Example 1.

The boiler constructions are old, with high temperatures of combustion products (180 °C). In the exploitation those temperatures are even higher (200 °C). The heat of the combustion products can be used for preheating of the water for supplementing in the system which would lead to a higher degree of use of the boilers. The investment for the construction of these heaters with additional equipment for all three boilers is as follows:

equipment	330,000	US$
unforeseen 15%	30,000	US$
TOTAL	**380,000**	**US$**

With using the waste heat of the combustion products, it will be possible to save energy in amount of 128,000 GJ/year, which is 522,000 US$ per year. The pay back period is 9 months.

Example 2.

The high temperature of the boiler walls (at some points even 100 °C) stresses the necessity of the insulation reparation. The investment for the replacement of two boilers insulation is as follows:

material and construction	82,000	US$
unforeseen 15%	12,000	US$
TOTAL	**95,000**	**US$**

The boiler insulation reparation would decrease the losses through the boiler surface. The estimated saving is 32,000 GJ/year, which is 130,000 US$ per year. The pay back time is 9 months.

Example 3.

The water heat from desalination and blow down is only partly used. Before it is thrown away, this water could be used for heating the water to supplement the system. The investment for construction of heat exchanger with accompanying equipment is as follows:

equipment	190,000	US$
unforeseen 10%	20,000	US$
TOTAL	**210,000**	**US$**

By using the desalination and blow down water heat it would be possible to save 81,000 GJ/year, which is 331,000 US$ per year. The pay back period is 8 months.

Example 4.

Existing measuring and process control system in the boiler room are not reliable enough for the plant working balance. When the system for measuring, control and regulating of the working process of boilers is changed and completed, it will be possible to widen the control parameters and to start with the work in all plants in an energy efficient and safe way. The investments required are as follows:

monitoring equipment	600,000	US$
unforeseen 15%	90,000	US$
TOTAL	**690,000**	**US$**

By changing and completing the existing system for measuring and working parameters it is possible to save 128,000 GJ/year, which is 522,000 US$ per year. This investment would pay back on 16 months.

Example 5.

The current way of calculation of the energy consumption distribution in the plants is not energetically stimulating enough. Actually, these are internal calculations without real economic outcomes in the production units. With installing the energy consumption control system in every technologically important and closed production units, it will be possible to control and lower the energy consumption. The investment for the measuring equipment is as follows:

measuring equipment	130,000	US$
unforeseen costs 15%	20,000	US$
TOTAL	**150,000**	**US$**

With this energy consumption control equipment and the adequate calculating mechanisms, it will be possible to lower the consumption for 80,000 GJ/year, which is 326,000 US$ per year. The pay back period is 6 months

5.2.1.1.2 Steam Trap, Insulation, Leakage and Metering Survey

Existing housekeeping procedure is not effective which also means that it is not efficient. A lot of leakages were found in steam and condensate distribution system. There are hundreds of steam traps and only a small number of them operate properly. A flash steam allowed to blow to waste (condensate tanks). There are some points for condensate collection before it is wasted. There are a lot of contaminated condensate which can be recovered by using heat exchangers, but it is wasted now. However, even the clean condensate used for heating the tanks and premises is not returned.

Some analysis performed by authorized personnel in boiler house have shown that the mass flow rate of lost condensate could be about 70 m^3/h. The price of waste condensate is estimated on the level of 3 DEM/m^3, which means that the hourly lost is 210 DEM/h. Calculation of this lost per year (8,000 working hours) it results in 1,680,000 DEM. The mentioned analysis shows the environmental effects as well, and the pay back period was estimated to about 3 years.

About 5-10% of all steam and condensate pipelines are not insulated. Some pipes are damaged by corrosion and produce other leakages. There are a lot non insulated valves and flanges. Many important steam leaks are hidden such as: a) leaking or stuck traps or by-pass valves discharging to sewer or condensate system; b) leaking valves leading to idle equipment; and c) leaks in heater or other equipment connected to the steam system.

Housekeeping includes measures to reduce energy use that can readily be taken by plant engineer or plant operator at little or no cost and in a short time. Examples of simple housekeeping are inspecting combustion equipment, adjusting burners, and inspecting and repairing steam traps - preferably on a routine basis. At a slightly more advanced level, the operation of process equipment can be rescheduled to avoid frequent start-ups and shutdowns -generally, continuous operation is more energy efficient than intermittent operation - or equipment can be adjusted to operate at the lowest economical temperature. Improvement of insulation becomes part of housekeeping if materials costs are low and the payback period is shorter than a year. For example, if the surface temperature of currently insulated steam lines or liquid piping exceeds 40 C, the insulation should be upgraded. Damaged insulation can result in much heat loss, so regular inspection of distribution lines is desirable. Combustion efficiency is major area of potential operational savings, as 1 - 5% of fuel used can be saved by regular tune-up of the air-to-fuel ratio. Modern technology enables fuel-to-air ratios to be maintained at recommended levels at all times, insuring consistent combustion efficiency. Microprocessor controlled servo motors fitted to fuel valves and air dampers replace the traditional methods of control, providing a programmable system which will automatically select and maintain the fuel-to-air ratio specific to a particular fuel.

The flue gas temperatures of the boilers were in range from 165 to 210 °C. This temperature is in a range of the designed one (180 °C). However, it has to be controlled on a regularly basis because of the rule which says that an increase of around 20 °C above that temperature for a clean boiler, means that the tubes must be cleaned. A rise of 17 °C causes a decrease in efficiency of 1 %.

Any discussion on energy conservation in Petrochemical has to start with housekeeping procedures.

1. The steam distribution system is in a very poor condition. It means that a detailed reparation of the system must be done. All steam traps and valves have to be checked, repaired or replaced. Insulation must be checked as well and put on the uninsulated pipelines, valves and flanges. Corroded pipelines have to be replaced.

Just to illustrate the effect of a leak consider the following:

Steam pressure 7 bar
Hole size 0.8 mm

Produces the loss equivalent to 1,200 nm^3 of natural gas per year.

Or, to illustrate the loss through uninsulated surface and flanges, the following example could be used:

> A 3 m length of exposed 150 mm diameter piping carrying steam at a pressure of 7 bar can waste 2,400 nm^3 of natural gas per year.
> If there were five uninsulated flanges on the same 150 mm diameter pipe, heat losses would equate to another 2,400 nm^3 of natural gas being wasted in a year.

During the audit it was very difficult to count the number of leaks and uninsulated places. However, there is no doubt that a great energy saving potential is in improving the steam distribution system. The common pay back period for this typical housekeeping procedure is less than one year. Expected effect of efficiency improvement of steam mains in this petrochemical could be up to 10%.

2. As it has been mentioned, the condensate from the processes is wasted. There is no good excuse for this. The problem of pollution of the condensate could be overcome by heat exchanger or by measuring the concentration of pollutant in the condensate and automatic relief condensate if it happens that the concentration is too high.

Possible practical boiler fuel saving by returning the condensate in this plant is up to 10%.

Example 1.

The reparation of damaged and ruined parts of the steam line and their insulation is a necessary measure. The investment for the replacement of ruined parts and damaged or ruined insulation's is as follows:

equipment	295,000	US$
unforeseen 10%	30,000	US$
TOTAL	**325,000**	**US$**

With this the waste of energy in the distributional system will be lowered, which would lead to saving of 128,000 GJ/year, which is 522,000 US$ per year. The pay back period is 7 months.

Example 2.

The reparation of valve seals, replacement of the old ones, and valve insulation are the measures which the maintenance department should always takes care of. The investment for mending these things is as follows:

material and works	79,000	US$
unforeseen 10%	9,000	US$
TOTAL	**88,000**	**US$**

This will lower the waste of energy in the distributional system which will save 64,000 GJ/year, ie. 261,000 US$ per year. The pay back period is 4 months.

Example 3.

The replacement of damaged steam trap should be a permanent task of the maintenance department. In the present conditions this has been partly neglected. Investment for this is as follows:

equipment and construction	76,000	US$
unforeseen 10%	9,000	US$
TOTAL	**85,000**	**US$**

With a regular replacement of steam traps, it would be possible to save 48,000 GJ/year, compared to the present situation. It amounts to 196,000 US$ per year. The pay back period is 5 months.

5.2.1.1.3 Economiser

There is no air preheater in this boiler house, but there is an economiser for preheating the make up water up to 80 C, because, as it was mentioned, there is no returned condensate. Each boiler is supplied with such economiser.

The boilers use the natural gas as a fuel which contains minimal sulphur and it is possible for the flue gas exit temperatures to be below the water dew point temperature without causing significant corrosion problems. Considerable improvements in efficiency can be obtained if the water vapour in the flue gas is condensed by further cooling. The maximum increase in energy obtained is approximately equal to the difference between Gross Calorific Value and Net one. However, again it has to be stressed that the real potential of energy saving from waste flue gases can be determined after performing all prescribed housekeeping measures. Only after attaining the maximal energy efficiencies of all consumers within the factory, realising the efficient distribution steam system and effective returning the condensate in the boiler house, and maximal energy efficiency of boilers, one can estimate and realise real potential of waste energy usage.

1. The next step in improving the total efficiency of the boiler house could be analysis of possibility to use flue gases for preheating the make-up by using the *condensing* economiser. Efficiency improvements of about 5% are common for economiser units installed, often producing pay back period of 1-2 years.

5.2.1.1.4 Condensate Recovery

If the feed water temperature is low, the cause should be discovered. It could be due to:

a low rate of condensate return;
the lack of insulation on the condensate return pipes;
losses from the feed water, either as heat through the walls or as overflow.

As much condensate as it is economically possible should be returned from sources where there is no likelihood of contamination. This will save heat, make-up water and chemicals used in water treatment, as well as reduce blowdown losses. The possible fuel savings resulting from increased condensate return are shown in Figure 3. The make-up water in this case is 15 °C and assumed temperature of returned condensate is 90 °C. The boiler fuel saved is calculated by using the basic consumption when there is no condensate returned.

Example 1.

In the present circumstances, the condensate is returned and used only from the boiler room. The condensate from the process is being thrown away in fear of its yielding and pollution. There is a possibility of constructing a system for accumulating and using it without any danger for boilers. The investment for the construction of the system for accumulating and returning the condensate, with accompanying equipment is as follows:

equipment and construction	500,000	US$
unforeseen 20%	125,000	US$
TOTAL	**625,000**	**US$**

By using the condensate heat it will be possible to lower the energy waste in the system which would save 224,000 GJ/year. It amounts to 914,000 US$. The pay back period is 8 months.

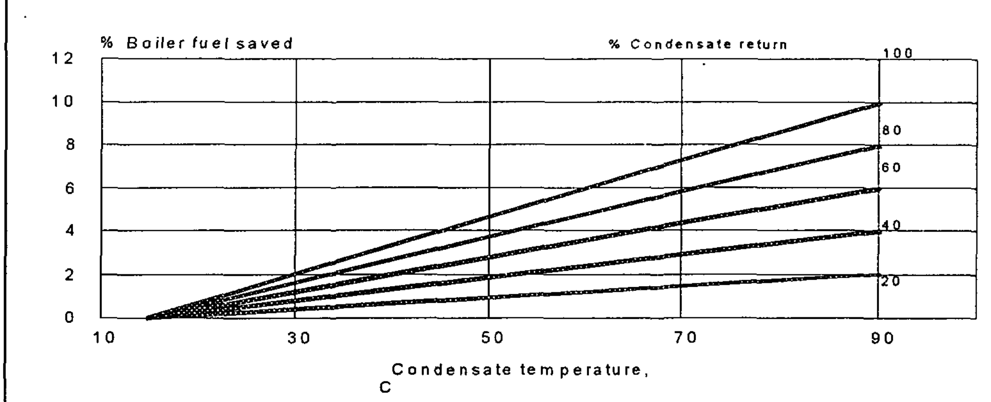


Figure 3: Fuel saved by condensate return

The condensate is wasted. Returning the condensate directly into the boiler or, if it is contaminated, by using the heat exchanger or automatic dumping by measuring the conductivity, it is possible to save fuel from 5% for 50% returned condensate to 9% for 90% returned condensate.

5.2.1.2 Medium Cost Investments

5.2.1.2.1 Replacing Dechlorinator Jets With Vacuum Pumps

The existing dechlorinator jets provide the vacuum necessary for brine dechlorination by two conventional single stage steam jet ejectors. One is operated and one is spare. Due to the corrosive media, they are equipped with titanium nozzles. The design figures are:

flow:	140.7 kg/h equivalent air
Cl_2 content:	98 $\%_w$
Suction pressure	252 mmHg (a)
Suction temperature	43 °C
Discharge pressure	810 mmHg (a)
Steam requirement	517 kg/h
Steam pressure	7 bar (g)

Since the vacuum is rather low, there would be no problems to replace the jets with a vacuum pump. It must, however, be made in titanium due to the corrosiveness of the humid chlorine. The investment for a vacuum pump to replace the inefficient steam jets would be:

vacuum pump	30,000	US$
unforeseen, 15%	5,000	US$
TOTAL	**35,000**	**US$**

Changing one of the steam jet ejectors for a vacuum pump would save 500 kg/hour or 4,000 tonnes/year steam. This corresponds to 11 TJ steam per year, or in monetary units, US$ 84,000 per year. The reserve vacuum source would then be kept as steam jet ejector. With an investment of 35,000 US$, the payback would be less than two years.

5.2.1.2.2 Installation of capacitor banks for correction of power factor

The transformation all the way down to 4 V for the electrolysis means that a lot of reactive power is generated. This has a quite high cost, even though it does not increase the actual power consumption, as it increases the current in the transmission lines and therefore the transmission losses. The power companies therefore apply penalties for low power factor.

In HIP petrochemical plant, the average reactive effect, above the allowed power factor 0.95, is 10 MVAR at a price of 5.06 US$/MVARh during high tariff. This means a total annual cost US$ 200,000. The maximum reactive power is estimated at approximately 13 MVAR. Correction of the power factor at, say, 6 kV would cost 15 US$/kVAR. This is a total price including installation and regulation

Capacitors	200,000	US$
unforeseen	30,000	US$
TOTAL	**230,000**	**US$**

The payout would thus be just over a year. If the power factor is improved at a lower tension level, some energy can be saved in the transformer too, but the cost will be higher.

5.2.1.2.3 Evaporation of chlorine for hydrochloric acid with cooling water or brine cooling water

The chlorine evaporation is dimensioned for making up for a total production loss in the chlor-alkali plant so that the VCM plant can operate independently. The design capacity therefore is 8,335 kg chlorine per hour, which is evaporated at 7.5 bar (a) and 23.3°C. It is then superheated to 35 °C. During continuous operation, the chlorine evaporation station operate at reduced load, since only chlorine for the hydrochloric acid plant is evaporated continuously. The evaporation for this purpose is 300 - 400 kg/hour. The heating media for the chlorine evaporation is low pressure steam, which is heat exchanged to a circulating water circuit at 88 °C.

The design heat duty of the evaporation is 700 kW and the losses from the steam header to the evaporation may amount to 10 % of that, or 70 kW.

Close to the evaporation, there is a cooling water return pipe. The cooling water is returned at approximately 35°C and is cooled to approximately 20°C in the cooling towers. Since only approximately 5 % of the designed heat duty of the heat exchanger is utilised, it should be possible to use this cooling water to evaporate the chlorine. lowering the cooling water from 35 to 30°C would give an average temperature difference across the heat exchanger of approximately 10°C, requiring some 5 tonnes per hour of cooling water. In this way, the benefit is double, cooling the cooling water at the same time as the heat is utilised.

For a higher heat duty and higher temperatures, the nearby brine cooling water could be used instead. During normal operation, the brine is cooled from 76°C to 60°C, with a heat duty of 10 MW_{th}. Both the temperature and the energy content are rather high. However, the brine preparation cannot always be relied upon, since it will not work for a long time once the chlorine production stops. Therefore it is unsuitable for e. g. chlorine evaporation for the purpose of making up for lost produciton, since it will stop at just the occasions when it is needed.

The savings when heating with cooling water, calculating only with the steam savings, would be 1 GWh per year, or, in monetary terms, US$ 27,000 per year. The payback would be under one year. The required equipment is a pump, piping and 3-way valve for switching heating media. The existing heat exchanger can then be used.

The above measure is a typical example of how steam can be replaced by low grade heat. A more comprehensive study of heat integration possibilities like this would be highly recommended, organising, prioritising and optimising the potentials for low grade heat utilisation. An overall energy saving of 10-20% can be expected, in addition to the savings from normal housekeeping, which must be implemented first.

5.2.1.2.4 Condensate recovery

A plant of this complexity and size has considerable amounts of waste heat. Simplified speaking, if the low grade heat in the condensate can be used, one tonne of condensate is produced for every tonne of steam produced in the plant. Since the HIP petrochemical plant has a very low level of condensate recovery, the prospect for improvement is very good.

Since the condensate recovery system is non existing or in bad condition, and since some steam is lost or recovered already today, the additional financially viable potential in terms of tonnes condensate is conservatively estimated to a quarter of the amount of steam produced. This would mean that 75 tonnes per hour can be utilised. The energy content is estimated by assuming that the condensate is delivered at the condensation temperature 139°C at 3.5 bar, implying a pressurised and insulated condensate system. The actual savings therefore may be slightly lower if a simpler solution is chosen.

$$(584 - 63)\ \text{MJ/tonne} \times 75\ \text{tonnes/hour} / 3{,}600\ \text{MJ/MWh}_{th} = 11\ \text{MW}_{th}$$

With an operation time of 8,000 hours per year, this would amount to 310 TJ, or in monetary terms, US$ 2 million per year for the energy alone. For the water, another US$ 2 million per year can be added, calculated with the internal price for boiler water at 3.4 US$ per tonne. The total saving would then be US$ 4 million per year for such a simple measure.

No investment calculation is done for this measure as a separate study would need to be made in order to determine the precise scope and costs. The payback time will, however, be considerable shorter that one year, even if safety equipment, by means of a conductivity meter and a fast operating automatic valve for dumping the condensate if it is contaminated, is included.

If the condensate, with these safety precautions, is still not trusted to be taken back into the boilers, it can be used for preheating the make-up water. This would mean additional investment in a heat exchanger. Furthermore the energy savings would decrease slightly, to 10 MW_{th}, and the water savings would not be realised. The monetary savings would therefore decrease to US$ 1.8 million.

5.2.1.3 Long Term Recommendations

5.2.1.3.1 Change To Membrane Method

The single most important measure in this project, from an environment point of view, would be to replace the chlor-alkali plant to a new one, using the membrane technology and thus avoiding mercury entirely. This is further described under section 5.2.2.3.2. From energy point of view, it would have a beneficial effect, however not of the dimension that could bear the costs for a conversion alone.

The design electricity consumption for a new membrane technology chlor-alkali plant would be approximately 2,860 kWh/tonne Cl_2, which compared to today's actual consumption of 3,394 kWh/tonne would save some 534 kWh/tonne. This amounts to 40 GWh electricity calculating on the 1990 production. With the current electricity price, the contribution from electricity saving in monetary terms would be approximately US$ 450,000 per year. However, if speculating in normalisation of the conditions and in the Yugoslavian electricity price adapting to the ones in e. g. Germany, the savings would be substantially higher. With the current international electricity price it would amount to more than US$ 1.4 million annually.

Other sources of contribution would come from reduced maintenance and avoided replacement of worn-out parts of the process, e. g. the cell bottoms, which are leaking mercury and due for replacement within the next couple of years. Presently, the time efficiency is low and affecting both the downstream production of VCM and PVC and the peak to average power ratio when trying to regain lost production. Also worker safety and morale will be improved by a abandoning of mercury in their working environment.

Furthermore, the change will have to come soon anyway. Markets are very sensitive to environmental issues and eco-labelling is a powerful sales tool stressing that not only direct producers, but their subsuppliers too are using eco-friendly production methods. In addition, the European Union has banned all chlor-alkali production in mercury cells after the year 2010, and will certainly not import any products from this method after that.

5.2.1.4 Other Measures Considered

5.2.1.4.1 Coupling Of 6 Cells To Power The 7th

Since the amalgam decomposer works as a short-circuited battery with a tension of approximately 0.8 V and slightly lower current than in the electrolysis, it would be feasible to connect 6 decomposers to power the electrolysis cell of the 7th. It would result in a saving of approximately 15 % electricity. It does, however mean quite big and expensive reconstruction, and the idea was rejected due to too many faulty cells, there is a too big risk that the system will not work properly.

5.2.1.4.2 Insulation Of Cells And Recovery Of Hot Water / Steam Generation

It would be possible to insulate the cells and coolers for e. g. sodium hydroxide solution and to recover low grade heat from them. However, since the plant has waste amounts of unused waste heat already, and since the status of the cells is not very good, it would not be practical to recover the heat at this stage.

5.2.1.4.3 District Heating

Investigations of the possibilities for export to the nearby settlements in the outskirts of Pancevo have been initiated. The nearest district heating boiler house is situated in Sodara, 6 km from the HIP plant. The maximum capacity there is 26 MW_{th}, heating a living area of 86,000 square meters. The consumption during a normal winter season is approximately 25 GWh, which gives an average consumption of 6 MW_{th}, calculating on heating season 4,000 hours, or 60 W/m^2. Calculating with experience values from other similar systems, a value of 150 W/m^2 is normal, giving an average effect of 13 MW_{th} and a peak around 20 MW_{th}, which seems more realistic considering the size of the boiler house. As a thumb rule, 25 % of the average consumption is for tap water heating.

Since the condensate recovery system is non existing or in bad condition, and since some steam is lost or recovered already today, the financially viable potential in terms of tonnes condensate is conservatively estimated to a quarter of the amount of steam produced. This would mean that 75 tonnes per hour can be utilised. The energy content is estimated by assuming that the condensate is delivered at the condensation temperature 139°C at 3.5 bar, and returned at 80°C which is 10°C above the district heating return temperature.

$$(584-335)\ \text{MJ/tonne} \times 75\ \text{ton/hour} / 3{,}600\ \text{MJ/MWh}_{th} = 5\ \text{MW}_{th}$$

In order to increase the amount of heat delivered, it would be possible to add unused low pressure steam to the system. A separate study must be made to establish the exact scope and limitations for a financially viable system.

The incomes from this sale would, of course, be very much depending on the sales price. Operating as base load and thus delivering hot tap water all year round, the energy delivered could amount to 94 TJ or 2,500 tonnes of saved oil equivalent per year. This is calculated with a load of 5 MW_{th} during the heating season and 1.5 MW_{th}, for hot water production, during the rest of the year. Assuming a heat price corresponding to the avoided fuel cost only, would mean incomes of US$/year 590,000. The savings will, of course, be even bigger as the operation costs for one or more boilers can be avoided.

The investment would be approximately 200 US$ per meter of pipe, including all, or totally US$ 1.2 million. To this comes pumps and heat exchanger.

pipes	1 200 000	US$
heat exchanger	150 000	US$
pumps	150 000	US$
unforeseen 15 %	225 000	US$
TOTAL	**1 725 000**	**US$**

The payback period for this project would therefore be around 3 years.

The above calculation assumes that the condensate is not taken back but dumped at the boiler house. If the condensate can be reclaimed, It is better to take it directly back to the boiler feed water instead of using it for district heating.

In order to increase the heat delivered, it could also be possible to install a heat pump, cooling the condensate further. For extracting the condensate heat down to, say 65°C, the additional investment would amount to:

heat pump	250 000	US$
installation	150 000	US$
unforeseen 15 %	60 000	US$
TOTAL	**460 000**	**US$**

The additional heating capacity would be 1.25 MW_{th}, which, calculating with only the heating season 4,000 hours per year, would add 5 GWh_{th} to the delivered energy. In monetary terms that would amount to US$110,000. The payback would thus be over 4 years.

The above measures on district heating could be combined with delivery of district heat from the fertiliser plant also, increasing the heating capacity further.

5.2.2 Environment

The major environmental problem in a chlor-alkali plant is mercury emissions. Mercury is a toxic, heavy metal and should as far as possible be avoided. The environmental situation in Pancevo is very serious with unacceptable large emissions of mercury to water and air and production of too much hazardous waste. In the future, this method will be prohibited and therefore no measures should be done without considering this. Our strongest recommendation is a change of method as soon as possible.

5.2.2.1 Low Cost / No Cost Measures

A number of good house-keeping measures have to be implemented to reduce the emissions. Thereafter the most important way to reduce the emissions is to secure a well functioning working system for maintenance.
Since the environmental impact is very high, there is a good potential to improve the environmental situation at the plant by low-cost measures.

The emissions of mercury from the plant can be reduced considerably by tightening of all leakage, avoiding spillage, regular maintenance and continuous improvements of the process.

5.2.2.1.1 The Vacuum System

The vacuum system is not in operation and need to be rehabilitated immediately.

5.2.2.1.2 Mercury Deposition Method

Sludge, containing mercury, should be avoided. Instead, all sludge produced should be treated by dewatering and destillation and thereafter be re-used in the process.

5.2.2.2 Medium Cost Investments

5.2.2.2.1 Mercury Recovery System

It is very important to immediately rehabilitate the retort unit so mercury can be recovered. A study of this has been done by the plant and the estimated cost is 100,000 DM.

5.2.2.2.2 Oil Residue From Sludge

The oil residue from sludge is planned to be taken back to the refinery. This is not always done due to problem with acceptance at the refinery. These problems need to be solved at once so the oil can go back to the refinery. They ought to have the best possibilities to treat the oil properly.

5.2.2.2.3 Cooling Of Chlorine Without CFC

The cooling medium used at the plant, R12, is a CFC and has the highest "Ozone Depletion Potential", ODP, of freons. R12 will be abandoned in the future, it was abandoned in Sweden 1995, and it will have to be exchanged. One recommended alternative cooling media to R12 is R134a, a HCFC, for which the ODP is zero. The boiling point for R134a is a few degrees higher compared to R12, but the molecular weight is somewhat lower. The two freons have almost the same compression capacity, the heat transfer capacity is 10-20% better for R134a and the condensing pressure is 1-2 bar higher.

According to the Swedish regulations, the old system must not be rebuilt if the ODP for the cooling medium is zero. Since an indirect system is not necessary the investment for changing cooling medium will be low. The maximum allowed leakage from the system is 5%.

Before converting the system to R134a the following need to be done:
- documentation of the component of the system
- function analysis
- tightening of leakages and general maintenance
- control of the compatibility of the component and the material with the new cooling medium, for R134a, ester oil is used and its elastomer is more aggressive than for R12.
- cleaning

After these preparation a maximum residue of 200 ppm of R12 is allowed in the system.

To check the compatibility with another medium the following data are needed:
- type of compressor and oil, viscosity, amount of oil, elastomer
- type of drier
- elastomers in gaskets and components
- amount of cooling medium
- working conditions, normal and extreme
- temperature of; evaporisation, super heating, condensing, super cooling and pressure pipes

Experience show that conversion in normal cases give equivalent performances. A new oil is needed for unchanged lubrication and oil return. Problems can occur if residues of mineral oil and chlorine are in the unit.

An estimated cost for conversion is US$ 150,000-200,000, excluding the destruction cost.

Other compounds that can be used as alternative to R12 are ammonia and butane, both produced within Pancevo. The conversion to these compounds will need more changes in the system.

With too old compressors, more than ten years, the normal recommendation is to rebuild the system instead of conversion. Rebuilding today is normally done by using the indirect system. With this system only 10% of the total amount of cooling medium is needed, compared to the direct system.

In the letter from Pancevo, dated 31 st of October, 1996, a method with absorption in CCl_4 and destillation, is mentioned. In our opinion CCl_4 should not be considered since it is a CFC and also carcinogenic.

5.2.2.2.4 Reduction Of Chlorine Losses

Plans exist to expand the chlorine detection system, from 8 to 16 detecting points. This systems serves as an emergency system.

5.2.2.2.5 Working Environment

One additional measure to reduce the negative effects on the workers' health is to distribute selenium-tablets. Selenium reduces the damage that mercury can cause.

5.2.2.3 Long Term Recommendations

5.2.2.3.1 Change Of Cell Bottoms

There is an urgent need for rehabilitation of many of the cell bottoms. The plans are to change a few at a time. A total change at one time is too expensive and not practically possible. Since the measure of changing the cell bottoms need very high investments, our recommendation is to consider a change of method in the near future and concentrate the investment on this measure instead.

5.2.2.3.2 Change To Membrane Method

Because of the status of the chlor-alkali plant in Pancevo, our recommendation is that the whole method should be changed as soon as possible. A change of method has already been studied by the plant and the estimated cost, presented in a tender from German UHDE, 1991, was US$ 47 million.

Due to financial reasons, the change of method is not realistic as an immediate measure. Meanwhile, a number of measures need to be implemented at once in order to reduce the very high environmentally impact caused by the mercury emissions.

5.3 "HIP - Azotara" fertilizer complex

5.3.1 Energy

In this Chapter only the following measures will be discussed:

Housekeeping and Operational Improvements;
Combustion, Steam and Condensate System Improvements;
Waste Heat Recovery and Reuse;

Only after analysis and/or implementation of proposed measures prescribed by these three measures, one can have reliable entering data for further consideration of energy efficiency improvements.

Total expected energy savings in boiler house and steam and condensate system could be estimated in the range of 20-30% with pay back period around 2 years.

5.3.1.1 Lo Cost / No Cost Measures

Concerning this plant the following n/l cost measures has to be implemented without delay because it can result in 15-20% energy savings. This analyses concerns the boiler house and the steam and condensate systems.

5.3.1.1.1 Boiler Efficiency and Boiler Control Systems

Monitoring will not of itself lead to energy savings unless the data is analysed and put in context within the company or establishment.

Monitoring system in this fertilizer is not reliable and complete and it is not used for energy analysis. It is used only for running the process. Instrumentation used is not in such a good condition. For illustration of this statement let us analyse the following example:

The efficiency of boiler house can be calculated using the total steam production (1,268 t/day) and the natural gas consumption (121,700 nm^3/day) metered by staff of the factory by using their instrumentation. As the net calorific value is 35,068 kJ/nm^3, the boiler house efficiency is:

$$\eta_{BH} = \frac{1268 \cdot 10^3 \cdot (3{,}048 - 63.5)}{121700 \cdot 35{,}068} = 0.887$$

As there is no returned condensate it is assumed that the make-up water has the temperature 15 °C.

Calculated value is higher that it could be expected. Combustion efficiency (Table 1) measured two days later are lower than this one and, as it is well known, combustion efficiency is only a part of total efficiency of boiler house. Measured mass flow rate of natural gas is used for payment and it is exact. Possibly the mass flow rate of produced steam is not reliable. This metering system must be checked. It is not clear does the internal steam usage is calculated as internal or external one! All this items must be clarified.

Measuring system of steam from boilers has to be re-calibrate or replaced. The natural gas consumption metering system has to be installed for each boiler. The ratio of steam to fuel is the main measure of efficiency of the boiler and it should be measured and maintained at a high level, compatible with good practice.

The measured steam pressures of the superheated steam from each boiler are higher than it is designed (measured: 35.4, 35.4 and 35.0 barg; designed and necessary pressure in process: 33 barg). That is another unnecessary increase of fuel consumption.

Continuously log boiler performance has to be done so that signs of deterioration soon become evident, enabling corrective maintenance to be carried out.

Feed water meter has to be re-calibrated or replaced.

For air preheating the heat wheels are used for each boiler. However, there is no explanation why are the flue gas temperatures for each boiler higher than the designed ones. They vary from 291 to 336 °C (Table 1), and design temperature is 180 °C. With the heat wheels these temperatures are lower (without measuring) and the preheat air reaches the temperatures of 140 °C before entering the burners (Table 2).

This boiler house must be examined thoroughly and a detailed plan for its retrofitting must be prepared. This action could be expensive and takes a time. Because of that some n/l cost measures have to be done in the meantime.

1. Flue gas analysis shows that the tested boilers operate with lower content of carbon dioxide: 7.6 to 9.3 for Boiler No.1,; around 10% for No.2; and around 8% for No. 3. Actually, CO_2 for Boiler No.2 could be good. The normal content of carbon dioxide for the natural gas as a fuel is 10 - 9%. Of course, the burner producer must be consulted for proper values. Generally, the performed flue gas analysis shows that boilers do not operate uniformly.

The measured flue gas temperatures are much higher than design one (180 °C), which only shows that the heat transfer surfaces has to be cleaned. This temperature will be even higher if the excess air is reduced to the normal value (for Boiler No.1 and No. 3).

Suggestion actions are to:

a) Repair or replace the vital parts of the burners;
b) Improve combustion control by installing the control system for fuel-to-air ratio by measuring CO_2 or O_2.
c) Clean of heat transfer surfaces and control the flue gas temperature history. Any increase of flue gas temperature will be recognised and proper action could be done.

2. The following actions can be performed as well:

   - Improve and repair the metering system for feed water supplying, steam production and distribution to the main consumers.

   - Control of the make up water has to be improved. The quality of make-up water is good (blowdown is performed every three days). However, there is no reason for such a high steam consumption for desalination process (4-6% of total steam production). Metering of waste condensate quality must be checked.

3. The temperatures of the boiler surfaces are higher than it is normal. On some spots it was about 120 °C. The insulation of the boiler has to be checked and repair. It could decrease the radiation losses for about 1.0-1.5%.

4. A big mass flow rate used for continuous process of desalination could be reuse by installing the heat exchanger for preheating the make-up water. Temperature of this condensate is 180 C, which means that a huge amount of flash steam is lost. For reuse of flash steam, which is of a very good quality, there is no need even to install heat exchanger.

5. The boiler efficiency is (for all boilers) as follows:

Flue gas loses (without wheel heat exchanger)	23 - 26%
Radiation losses	4%
Blowdown loss and desalination	4 - 6%
Total:	64 - 69%

By performing the suggested actions in items 1-4, there could be an increase in the boiler efficiency for approximately 10%. The pay back period for this is normally less then one year.

Example 1.

The boiler constructions are old, with high temperatures of combustion products (180 °C). In the exploitation those temperatures are even higher (300 °C). The heat of the combustion products can be used for preheating of the water for supplementing in the system which would lead to a higher degree of use of the boilers. The investment for the construction of these heaters with additional equipment for all three boilers is as follows:

equipment	210,000	US$
unforeseen 15%	30,000	US$
TOTAL	**240,000**	**US$**

With using the waste heat of the combustion products, it will be possible to save energy in amount of 67,000 GJ/year, which is US$ 273,000 per year. The pay back period is 11 months.

Example 2.

The high temperature of the boiler walls (at some points even 120 °C) stresses the necessity of the insulation reparation. This goes for all three boilers. The investment for the replacement of boiler insulation is as follows:

material and construction	100,000	US$
unforeseen 15%	15,000	US$
TOTAL	**115,000**	**US$**

The boiler insulation reparation would decrease the losses through the boiler surface. The estimated saving is 20,000 GJ/year, which is 82,000 US$ per year. The pay back time is 17 months.

Example 3.

The water heat from desalination and blow down is only partly used. Before it is thrown away, this water could be used for heating the water to supplement the system. The investment for construction of heat exchanger with accompanying equipment is as follows:

equipment	135,000	US$
unforeseen 10%	15,000	US$
TOTAL	**150,000**	**US$**

By using the desalination and blow down water heat it would be possible to save 33,000 GJ/year, which is US$ 135,000 per year. The pay back period is 13 months.

Example 4.

Existing measuring and process control system in the boiler house are not reliable enough for the plant working balance. When the system for measuring, control and regulating of the working process of boilers is changed and completed, it will be possible to widen the control parameters and to start with the work in all plants in an energy efficient and safe way. The investments required are as follows:

monitoring equipment	590,000	US$
unforeseen 15%	90,000	US$
TOTAL	**680,000**	**US$**

By changing and completing the existing system for measuring and working parameters it is possible to save 80,000 GJ/year, which is US$ 326,000 per year. This investment would pay back on 25 months.

Example 5.

The current way of calculation of the energy consumption distribution in the plants is not energetically stimulating enough. Actually, these are internal calculations without real economic outcomes in the production units. With installing the energy consumption control system in every technologically important and closed production units, it will be possible to control and lower the energy consumption. The investment for the measuring equipment is as follows:

measuring equipment	100,000	US$
unforeseen costs 15%	20,000	US$
TOTAL	**120,000**	**US$**

With this energy consumption control equipment and the adequate calculating mechanisms, it will be possible to lower the consumption for 33,000 GJ/year, which is US$ 135,000 per year. The pay back period is 11 months.

5.3.1.1.2 Steam Trap, Insulation, Leak And Metering Survey

Existing housekeeping procedure is not effective which also means that it is not efficient. A lot of leakages were found in steam and condensate distribution system. There are hundreds of steam traps and only a small number of them operate properly. A flash steam allowed to blow to waste (condensate tanks). There are some points for condensate collection before it is wasted. There are a lot of contaminated condensate which can be recovered by using heat exchangers, but now it is wasted. However, even the clean condensate use for heating the tanks and premises is not returned.

For example, if the mentioned daily production is analysed, one can calculate that 5.2 MW is lost with waste condensate. For that day (November 12, 1996) the steam production was 1,268 tonnes or an average of 52.8 t/h. If the waste condensate is at temperature of 100 °C and make-up water of temperature of 15 C, it means that:

$$\frac{52,833}{3,600} \cdot 4.186 \cdot (100 - 15) = 5,222 \text{ kW} \approx 5.2 \text{ MW}$$

or, using the efficiency of boiler of 0.8, which means that for heating the necessary make-up water has to be spent:

$$\frac{5,222 \cdot 3,600}{35,086 \cdot 0.8} = 670 \text{ nm}^3/\text{h}$$

or, 16,080 nm^3/day. As the daily natural gas consumption was 121,700 nm^3/day, it is possible to save:

$$\frac{16,080}{121,700} \cdot 100\% = 13.2\ \%$$

of natural gas. If the heat exchangers are used because of polluted condensate, the possible savings will be lower but still sensible and acceptable.

About 5-10% of all steam and condensate pipelines are not insulated. Some pipes are damaged by corrosion and produce other leakages. There are a lot non insulated valves and flanges. Many important steam leaks are hidden such as: a) leaking or stuck traps or by-pass valves discharging to sewer or condensate system; b) leaking valves leading to idle equipment; and c) leaks in heater or other equipment connected to the steam system. It is estimated by some experts in the factory, that there is about 10 km of pipelines with diameter over 50 mm.

Housekeeping includes measures to reduce energy use that can readily be taken by plant engineer or plant operator at little or no cost and in a short time. Examples of simple housekeeping are shutting of standby furnaces, inspecting combustion equipment, adjusting burners, and inspecting and repairing steam traps - preferably on a routine basis. At a slightly more advanced level, the operation of process equipment can be rescheduled to avoid frequent start-ups and shutdowns - generally, continuous operation is more energy efficient than intermittent operation - or equipment can be adjusted to operate at the lowest economical temperature. Improvement of insulation becomes part of housekeeping if materials costs are low and the payback period is shorter than a year. For example, if the surface temperature of currently insulated steam lines or liquid piping exceeds 40 °C, the insulation should be upgraded. Damaged insulation can result in much heat loss, so regular inspection of distribution lines is desirable. Combustion efficiency is major area of potential operational savings, as 1 - 5% of fuel used can be saved by regular tune-up of the air-to-fuel ratio. Modern technology enables fuel-to-air ratios to be maintained at recommended levels at all times, insuring consistent combustion efficiency. Microprocessor controlled servo motors fitted to fuel valves and air dampers replace the traditional methods of control, providing a programmable system which will automatically select and maintain the fuel-to-air ratio specific to a particular fuel.

The flue gas temperatures of the boilers were in range from 291 to 336 °C. This temperature is higher then the designed one (180 °C). This shows that it is possible that boiler tubes become fouled by soot and deposits and the amount of heat transferred from the hot flue gases to the water is reduced. There is a rule which says that an increase of around 20 °C above that temperature for a clean boiler, means that the tubes must be cleaned. A rise of 17 °C causes a decrease in efficiency of 1 %.

Any discussion on energy conservation in this Fertilizer has to start with housekeeping procedures.

1. The next step of improving the total efficiency of the boiler house could be analysis of possibility to use flue gases for preheating the make-up by using the condensing economiser. Efficiency improvements of about 5% are common for economiser units installed, often producing pay back period of 1-2 years.

2. The steam distribution system is in a very poor condition. It means that a detailed reparation of the system must be done. All steam traps and valves have to be checked, repaired or replaced. Insulation must be checked as well and put on the uninsulated pipelines, valves and flanges. Corroded pipelines have to be replaced.

   Just to illustrate the effect of a leak consider the following:
   Steam pressure 7 bar
   Hole size 0.8 mm

   Produces the loss equivalent to 1,200 nm^3 of natural gas per year.

   Or, to illustrate the loss through uninsulated surface and flanges, the following example could be used:

   A 3 m length of exposed 150 mm diameter piping carrying steam at a pressure of 7 bar can waste 2,400 nm^3 of natural gas per year.
   If there were five uninsulated flanges on the same 150 mm diameter pipe, heat losses would equate to another 2,400 nm^3 of natural gas being wasted in a year.

During the audit it was very difficult to count the number of leaks and uninsulated places. However, there is no doubt that a great energy saving potential is in improving the steam distribution system. The common pay back period for this typical housekeeping procedure is less than one year. Expected effect of efficiency improvement of steam mains in this fertilizer could be up to 10%.

Example 1.

The reparation of damaged and ruined parts of the steam line and their insulation is a necessary measure. The investment for the replacement of ruined parts and damaged or ruined insulation's is as follows:

equipment	140,000	US$
unforeseen 10%	15,000	US$
TOTAL	**155,000**	**US$**

With this the waste of energy in the distributional system will be lowered, which would lead to saving of 93,000 GJ/year, which is US$ 379,000 per year. The pay back period is 5 months.

Example 2.

The reparation of valve seals, replacement of the old ones, and valve insulation are the measures which the maintenance department should always takes care of. The investment for mending these things is as follows:

material and works	43,000	US$
unforeseen 10%	5,000	US$
TOTAL	**48,000**	**US$**

This will lower the waste of energy in the distributional system which will save 33,000 GJ/year, ie. US$ 135,000 per year. The pay back period is 4 months.

Example 3.

The replacement of damaged steam trap should be a permanent task of the maintenance department. In the present conditions this has been partly neglected. Investment for this is as follows:

equipment and construction	31,000	US$
unforeseen 10%	4,000	US$
TOTAL	**35,000**	**US$**

With a regular replacement of steam traps, it would be possible to save 20,000 GJ/year, compared to the present situation. It amounts to US$ 82,000 per year. The pay back period is 5 months.

5.3.1.1.3 Condensate Recovery

If the feed water temperature is low, the cause should be discovered. It could be due to:

a low rate of condensate return;
the lack of insulation on the condensate return pipes;
losses from the feed water, either as heat through the walls or as overflow.

As much condensate as it is economically possible should be returned from sources where there is no likelihood of contamination. This will save heat, make-up water and chemicals used in water treatment, as well as reduce blowdown losses. The possible fuel savings resulting from increased condensate return are shown in Figure 3. The make-up water in this case is 15 °C and assumed temperature of returned condensate is 90 °C. The boiler fuel saved is calculated by using the basic consumption when there is no condensate returned.

1. As it has been mentioned, the condensate from the processes is wasted. There is no good excuse for this. The problem of pollution of the condensate could be overcome by heat exchanger or by measuring the concentration of pollutant in the condensate and automatic relief condensate if it happens that the concentration is too high.

   Possible practical boiler fuel saving by returning the condensate in this plant is up to 10%.

At the present circumstances, the condensate is returned and used only from the boiler room. The condensate from the process is being thrown away in fear of its yielding and pollution. There is a possibility of constructing a system for accumulating and using it without any danger for boilers. The investment for the construction of the system for accumulating and returning the condensate, with accompanying equipment is as follows:

equipment and construction	250,000	US$
unforeseen 20%	60,000	US$
TOTAL	**310,000**	**US$**

By using the condensate heat it will be possible to lower the energy waste in the system which would save 93,000 GJ/year. It amounts to US$ 379,000. The pay back period is 10 months.

5.3.1.1.4 Economiser

As it is already mentioned, the heat wheels are installed in this boiler house for pre heat the air. The temperature leaving the heat wheels are still high. As natural gas has minimal sulphur content (see Table 1), it is possible for the flue gas exit temperatures to be below the water dewpoint temperature without causing significant corrosion problems. Energy savings up to 10% are possible by using the recovered heat to pre-heat boiler make-up water. However, the analysis of the possibility to use Condensing Economiser must be followed by the general inspection of the boiler house and the housekeeping measures must be such to fit the real parameters to design ones.

1. As it has been mentioned, the condensate from the processes is wasted. There is no good excuse for this. The problem of pollution of the condensate could be overcome by heat exchanger or by measuring the concentration of pollutant in the condensate and automatic relief condensate if it happens that the concentration is too high.

Possible practical boiler fuel saving by returning the condensate in this plant is up to 10%.

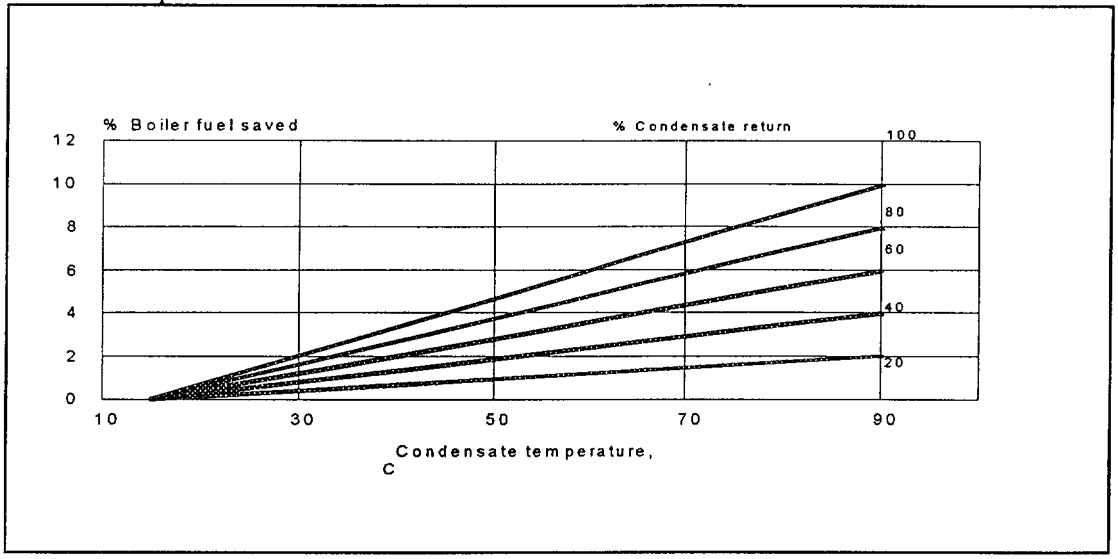


Figure 3: Fuel saved by condensate return

The condensate is wasted. Returning the condensate directly into the boiler or, if it is contaminated, by using the heat exchanger or automatic dumping by measuring the conductivity, it is possible to save fuel from 5% for 50% returned condensate to 9% for 90% returned condensate.

5.3.1.1.5 Decrease Steam-To-Carbon Ratio In The Ammonia Primary Reformer

Decrease steam-to-carbon ratio in the ammonia primary reformer from the present 3.8 to 3.3. With a gas consisting of almost pure methane the risk for carbon deposits on the catalyst is low.
Cost: Neglible, normal maintenance
Savings: Decrease in specific energy consumption with 1 GJ/tonne, equivalent to 3 Nm^3 gas at a cost of US$ 0.288. With a production 250 000 tonnes ammonia pro year 72 000 US$ pro year is saved. Payback less that a year

5.3.1.2 Medium Cost Investments

5.3.1.2.1 Use Spent Cooling Water For Evaporation Of Ammonia In Nitric Acid Plant.

In one of the nitric acid plants steam is used for evaporation of ammonia. In a nitric acid plant a lot of water at a temperature of 30 to 50 °C is available, that can replace steam at evaporation. For that a new evaporator with larger heat transfer area is necessary, at least if the plant operates at design capacity.
Estimated cost: US$ 0.2 million
Savings: Steam requirement for evaporation of one tonne ammonia is 0.55 tonne, that is, the steam consumption for ammonia evaporation is 0.17 tonne per tonne

HNO_3, giving a cost of US$ 2.2 per tonne HNO_3.
At design capacity, 150 000 tonnes pro year, US$ 320,000 in steam cost is saved.
An investment is paid in less than one year.

5.3.1.3 Long Term Recommendations

5.3.1.3.1 Replace Internals in the Ammonia Synthesis Reactor

Replace internals in the synthesis reactor with a new one with up-to-date radial design. The synthesis catalyst has to be changed anyway within the nearest future. Kellogg, who has originally designed the plant, has new interiors that are said to be giving 17 % NH_3 in the exit gas, which is double the present concentration. That will save compression energy and/or increase capacity. As a rough estimation the production will increase from 750 to 1000 tonnes per day and specific energy consumption decrease from 45 to 40 GJ/t.
Estimated cost: US $ 6 million.
Savings: With figures from appendix 2 this gives a net profit of more than US$ 14 million pro year. An investment is paid in less than one year.

5.3.1.3.2 Replacement Of Tubes In The Ammonia Primary Reformer

The tubes in the primary reformer will be replaced within some years. New material can make them thinner and give space for more catalyst. That will increase the capacity in the front end, which could have benefits if there is new internals in the synthesis reactor. However, in such a case, the whole process has to be recalculated.

5.3.2 Environment

5.3.2.1 Lo Cost / No Cost Measures

5.3.2.1.1 Regeneration of Ion Exchangers with Sulphuric Hydrochloric Acid instead of Nitric Acid.

Problems can occur with formation of calcium sulphate at the use of sulphuric acid. They are, however, normally easily overcome by using a more diluted acid, about 2 per cent, in the first phase at every regeneration and then go up to four per cent at the end of the cycle.
Sulphuric acid price: About US$ 100 per tonne. Total cost for sulphuric acid US$ 43 000 pro year.
Saving in nitric acid: US$ 48 000 per year
Costs for nitric acid and sulphuric acid are thus about equal.
Environmental saving: Decrease in emission to water is about 300 kg/d NO^3-N or 150 tonnes pro year calculated as ammonia.

5.3.2.2 Medium Cost Investments

5.3.2.2.1 Ammonia Removal from the Ammonia Plant Purge Gas

Remove the ammonia from the purge gas by water scrubbing before its burning in the primary reformer. The amount ammonia to be removed from the total purge gas flow of 5000 Nm^3/h with an ammonia content of 3.5 % is over three tonnes a day. As aqueous ammonia is produced and sold, this can give a financial contribution to the otherwise purely environmental investment.

Estimated cost:	US$ 2 million
Contribution:	US$ 0.18 million pro year from regained ammonia
Environmental saving:	2700 tonnes NOx as NO_2 pro year

5.3.2.2.2 Reduction of NOx from Nitric Acid Plants

Nitrous gases content in the tailgas was said to be 1500 ppm. That seems to be a high concentration for a process operating at 8.8 bar. With an absorption tower well designed and in a good condition, NOx concentration could be decreased considerably, down to under 500 ppm. First thing to do is to let an engineering company make calculations and maybe have the tower redesigned. It is better to put the money first on a good absorption and then, if necessary, install a catalytic NOx reduction, see section 5.3.2.3.2. A good absorption tower will increase production and decrease specific ammonia consumption. With a low concentration in the tail gases, an installation for catalytic reduction of NOx can be designed much smaller and cheaper.

5.3.2.2.3 NPK plant: Install efficient Water Circulation and pH Control with Nitric Acid addition to the Granulator Scrubber.

If a scrubber is used for air cleaning, the scrubber water must be returned to process. Otherwise, an air pollution problem has been transferred to a water pollution problem only.

As the gas from the granulator contains so much ammonia, the scrubber liquid must be slightly acidic to catch the ammonia. By addition of nitric acid, controlled by pH, an ammonium nitrate solution is formed, that can be concentrated up 50% or more by a controlled addition of make-up water. The bleed from that solution can be added to the granulation.

Ammonium nitrate easily forms aerosol in a scrubber. This must therefore probably be equipped with a demister on the top.
Estimated cost: Instrumentation for about US$ 60,000 if the scrubber is made of acid proof material.
Savings: Total emission from the granulator is 2.6 tonnes a day ammonia, that has a value of US$ 150 000 pro year.
Investment is paid in less than a year.

5.3.2.2.4 Improve Venturi Scrubbers at NPK Plant

We have not studied the venturi scrubbers thoroughly enough to tell why they operate so poorly. As is the case for all scrubbers used for air cleaning, the scrubber water must be returned to process to prevent that an air pollution problem just is transferred to a water pollution problem.
Water must be circulated, so the liquid contains at least 50 % dissolved salts to be able to be taken back to process. As the gas also contains some ammonia, pH in the circulating liquid must be controlled by HNO3.

Insulate the cyclones to prevent failing operation due to moist dust. At every stop the cyclones shall be purged with a small stream of hot air or instrument air.

Estimated cost: US$ 60,000.
Savings: 1.3 tonnes nitrogen, equivalent to 1.6 tonne ammonia, is emitted from the dryers to air and water. The emissions have a value of US$ 90,000 pro year.
Environmental saving: From the NPK plant is totally emitted 3.9 tonnes nitrogen a day or about 1200 tonnes pro year. An elimination of that would reduce the emissions with 0.6 per cent of the total nitrogen turnover of the whole site.

As an alternative, it is possible to install bag filters instead of the cyclones and scrubbers for the air after the dryers. The scrubbers have a very low efficiency. Filters would give much lower emissions. Dust content in air from a bag filter is less than 10 mg/m3, giving an emission of less than 1.5 kg/h. The cyclones shall be removed before installation of bag filters, because the small and even particle distribution of the dust from cyclones easily clogs a filter.
Estimated cost: US$ 2 million.

5.3.2.3 Long Term Recommendations

5.3.2.3.1 Low NOx Burners In Primary Reformer And In Steam Boiler

5.3.2.3.2 Reduction Of NOx From Nitric Acid Plants

Catalytic reduction of the nitrous gases in the tail gas will eventually be a necessary condition for further production of nitric acid.
Cost: An internal investigation from 1988 gave a cost of 3,5 million US$ for tail gas cleaning in all nitric acid plants. That is about the double in today's value of money, US$ 7 million.
Running costs: For NOx reduction about 0.010 tonne NH^3 per tonne HNO^3 will be used, making US$ 520,000 pro year.
Savings: The tail gas heating up to 500 °C will not be necessary. Only a slight temperature increase from 200 °C after gas/gas heat exchanger up to the catalyst operating temperature of 270 °C is necessary. As the present natural gas cost for tail gas heating is US$ 580,000, the saved heating cost will balance the cost for ammonia for reduction.
Environmental saving: 2700 tonnes NOx as NO_2 pro year. See also 5.3.2.2.

5.3.3 Safety

5.3.3.1 Installation Of Bleaching Towers In The Nitric Acid Plants

The not bleached acid is a considerable safety risk when making ammonium nitrate out of the nitric acid. The nitrite content in the acid should be regularly checked by $KMnO_4$ titration.

Maybe there are some parts from the now closed down ammonia plant I, which can be used for the purpose.

Estimated cost: US$ 200,000.

5.3.3.2 Build A Flare With A Pilot Flame For Burning Ammonia Process Gases When Sent To Vent At Failures

Cost: US$ 0.2 million

The measure is seriously recommended since gas cloud explosions can be disastrous. Under certain meteorological conditions a cloud can drift long distances and the adjacent refinery has flares that can ignite it. It is true that the gas density is lower than that of air but that does not eliminate the probability for an accident, even if it will decrease it to some extent.

6. Priority list and implementation schedules

6.1 General

The measures considered to have the highest priority are:

- The ones that either are needed for efficiency monitoring, as this will give more data for the continuing improvement of the efficiency
- The simple and inexpensive housekeeping measures that show a good profitability
- The measures that show a very high profitability

In any energy and environment project, it is important to implement the measures and re-evaluate the situation in a structured way. It is very important that the simple, less glamorous, measures are taken care of before the more advanced investments are considered. This since it is better to attack losses at the source than to address the effects of it. As an example, reducing process losses by housekeeping will give a positive payback. The alternative is often to build a treatment plant which only results in investment and operation costs. If the investment is done before the simple measures, it is often discovered that the treatment plant is oversized since it was built to take care of the waste that could be avoided. The same is valid for steam system efficiency and boiler capacity. The below figure shows a logical sequence.

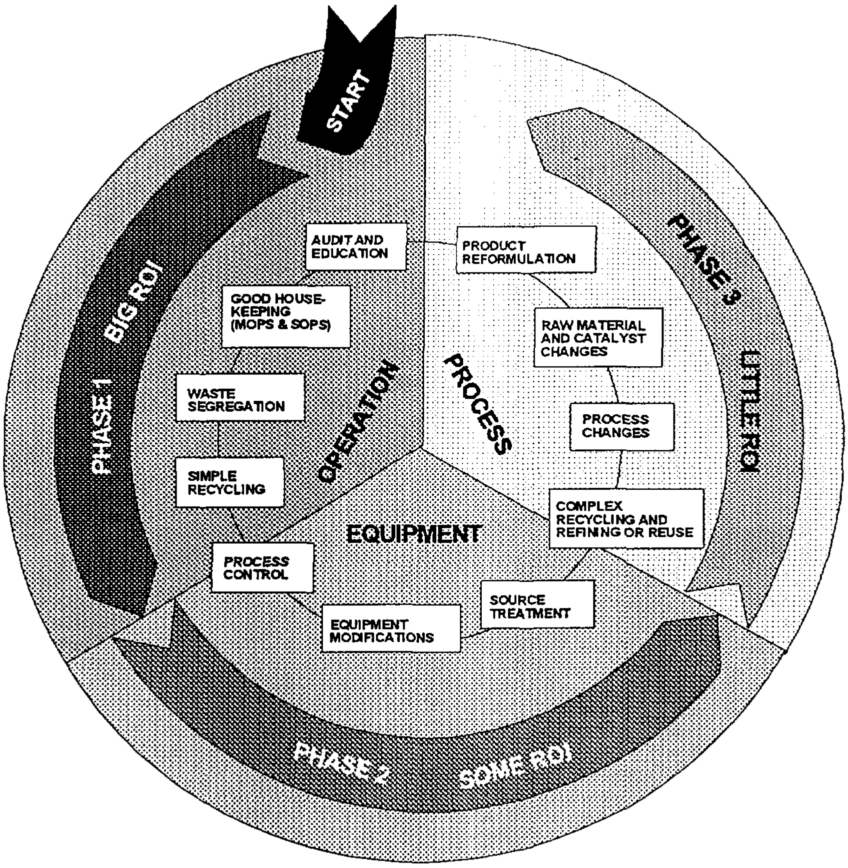


Fig 6.1 Phases of a energy/environment project. ROI = Return on Investment

In addition to the below listed measures, an energy management system is highly recommended, as described in section 7.

On the environmental side, the priorities are given to the emissions that are:

- toxic to humans and ecosystems, e. g. cyanides
- slowly acting, e. g. carcinogens
- irreversible, e. g. heavy metals
- slowly decomposing, e. g. dioxins
- global, e. g. CFCs
- no cost-low cost to rectify

The general order and method of addressing them, is however the same as described above, unless emergency actions are required.

6.2 "NIS - Refinerija Nafte Pancevo" refinery

Year 1

Section	Measure	Energy saving GJ/year	Cost saving MUS$/year	Investment MUS$
5.1.1.1	No/Lo cost measures			
5.1.1.1.1	Monitoring	260,000	1-1	1.1
5.1.1.1.2	Boiler improvements	300,000	1.2	1.0
5.1.1.1.4	Steam trap, insulation and metering survey	300,000	1.2	0.6
5.1.1.1.5	Condensate recovery	280,000	1.2	0.8
5.1.1.2.1	Hot water for tank heating	140,000	0.7	<0.7
5.1.1.2.2	Study recuperation of flare gas	-	-	-
5.1.1.3.3	WSA unit study	-	-	-
5.1.2.2.2	Oil sludge disposal study	-	-	-
5.1.2.2.3	Environment monitoring	(environm.)	-	0.2
	TOTAL	**1,300,000**	**5.4**	**4.4**

The overall payback for the measures year 1 is approximately 1 year.

Year 2

Section	Measure	Energy saving GJ/year	Cost saving MUS$/year	Investment MUS$
5.1.1.2.2	Recuperation of flare gas	480,000	2.0	<2.0
5.1.1.3.3	WSA unit	(environmental)	5.0[1]	10.0[1]
	TOTAL	**480,000**	**7.0**	**<12.0**

[1] incremental calculation

The overall payback period for the measures recommended for year 2 is therefore less than 2 years.

Year 3

Section	Measure	Energy saving GWh$_e$/year	Cost saving MUS$/year	Investment MUS$
5.1.1.3.1	turbine and electrical drives	140	2.1	4.5
	TOTAL	**140**	**2.1**	**4.5**

The overall payback period for year 3 is therefore just over 2 years

In total the measures for year 1-3 will cost 21 MUS $ and save 2,300 TJ or US $ 14 million annually. The overall payback will be less than 2 years.

In addition to the above, the measures planned from the earlier study are supported. This is, however, based on only the scarce information we have received. No in-depth analysis has been made.

6.3 "HIP Petrohemija" petrochemical complex

Year 1

Section	Measure	Energy saving GJ/year	Cost saving MUS$/year	Investment MUS$
5.2.1.1	No/Lo cost measures			
5.2.1.1.1	Boiler efficiency and boiler control system	695,000	1.6	1.5
5.2.1.1.2	Steam Trap, Insulation and Metering Survey	240,000	1.0	0.5
5.2.1.1.4	Condensate recovery	224,000	0.9	0.6
5.2.1.2.1	dechlorinator vacuum pumps	11,000	0.07	0.04
5.2.1.2.2	power factor correction	(indirect)	0.2	0.2
5.2.1.2.3	cooling water Cl_2 evaporation	3,600	0.03	0.03
5.2.2.2.1	Mercury recovery	(environm.)	-	0.7
5.2.2.2.3	CFC replacement	(environm.)	-	0.2
	TOTAL	**1,200,000**	**3.8**	**3.2**

The payback for measures year 1 is less than 1 year.

Year 2

Section	**Measure**	**Energy saving GJ/year**	**Cost saving MUS$/year**	**Investment MUS$**
5.2.2.3.2	Change to membrane method	(environmental)	-	50
	TOTAL		**-**	**50**

The long term measure for the chlor-alkali plant is environmental and strategic and does not have an immediate payback.

6.4 "HIP - Azotara" fertilizer complex

Year 1

Section	Measure	Energy saving GJ/year	Cost saving MUS$/year	Investment MUS$
5.3.1.1	no/Lo cost measures			
5.3.1.1.1	Boiler efficiency and boiler control system	330,000	0.7	1.3
5.3.1.1.2	Steam Trap, Insulation and Metering Survey	150,000	0.6	0.2
5.3.1.1.3	Condensate Recovery	90,000	0.4	0.3
5.3.1.1.5	steam to carbon ratio	250,000	0.07	0
5.3.1.2.1	cooling water ammonia evap.	230,000	0.3	0.2
5.3.2.1.1	change regeneration acid	(environmental)	0.05	0.05
5.3.2.2.3	NPK scrubber improvem.	(environmental)	0.15	0.06
5.3.2.2.4	NPK venturi improvem.	(environmental)	0.09	0.06
5.3.2.2.2	Nitric acid NOx red. study	(environmental)	-	-
5.3.3.2	Ammonia flare system	(safety)	0	0.2
5.3.3.1	Nitric acid bleaching	(safety)	0	0.2
	TOTAL	**1,000,000**	**2.4**	**2.6**

The measures suggested for year 1 therefore have an overall payback around 1 year.

Year 2

Section	**Measure**	**Energy saving GJ/year**	**Cost saving MUS$/year**	**Investment MUS$**
5.3.1.3.1	synthesis reactor internals	520,000	14.0	6.0
5.3.2.2.1	ammonia removal from purge	(environmental)	0.2	2.0
5.3.2.2.2	Reduce NOx from nitric acid	(environmental)	0.6	7.0
	TOTAL	**520,000**	**14.8**	**15.0**

The payback for the measures year 2 is thus one year.

Year 3

Section	**Measure**	**Energy saving GJ/year**	**Cost saving MUS$/year**	**Investment MUS$**
5.3.1.3.1	Nitric acid SCR NOx red	(environmental)	0	7.0
	TOTAL		**0**	**7.0**

The measure for year 3 is purely environmental, and does not have a payback.

In total, the measures for all three years have an investment cost of US$ 25 million, resulting in savings for 1.500 TJ per year or US$ 17 million per year. The overall payback is thus less than 2 years.

7. Energy management system

7.1 General

An energy management system is vital for the conservation of energy, with an energy manager at a sufficiently high organisational level to have influence on the maintenance and production departments, not only measure. Among his tasks will be to plan and co-ordinate the overall energy efficiency work, ensure that priorities and fundings are granted etc.

He will also have to ensure that all metering systems are calibrated and that the results of the work is communicated so that all the staff share the information. Among other tasks will be to follow up stop lists and present figures on the losses caused by faulty machinery and routines, not only in terms of production, but also in energy and environmental effects. He can then influence and motivate the management and staff to make sure that maintenance is kept up to a reasonable level.

A checklist for such work is presented in Appendix 7.1

7.2 Description of Present Energy Management In Factories

When organisation and management of all three factories are concerned, there are residues of the previous political system. This is understandable since these factories still belong to the state, and since the transformational processes in present day Yugoslavia are slow because of the difficult working condition, although their beginning was rather abrupt. The outcome of these facts is that all the responsibilities in the field of energetic are divided.

The factories have their central management's. Although each factory has its power plant, they are treated as production units in the same rank as any other production unit. The difference is that other production units produce their final product for the market and power plants produce energy fluids within the factory without any economic profit. Namely, there are some internal calculations which do not have any important effects or consequences. At the same time, every production unit has its energetically independence as much as the technology allows it. Also, there is a tendency for as much independence from the central power plant as possible. For that reason the situation when who is in charge for energy management comes into question is not clear.

This means that the authority over the instalments is also divided. The power plant is responsible for the energy part, housekeeping department takes care of the distribution network, and for the part of the system within the production units, the very production units are responsible.

Similar thing is repeated in the field of management. One of the responsibilities of the general manager of the production in the factory is energetics as a whole. At lower organisational levels, in production units, the authority is divided among power plant manager (within the energy production field) and the authorised managers of every production unit (within the field of energy consumption).

Besides, all three factories, and along with them the power plants are connected by mutual energy instalments. This is used only as a help when there are major damages and works on the principle of energy borrowing.

The department for development is responsible for environment protection. Management of these things represents one of the responsibilities of the development manager. At lower organisational levels (in the production units) this also belong to the group of responsibilities of the production manager it a particular unit.

This kind of organisational system in the field of energy and environment protection is fairly understandable. The residues of the past must be taken into consideration in the first place. In the previous period, power plants were independent and they were selling the energy to the consumers within the factories. This process was under control of general management, and also with certain independence in management and organisation within power plants own units. The changes which has happened in the organisation of factories lessened the influence of the power plant when rational energy consumption is concerned.

Another important factor is conditions for production in past five years. The changes occurred with the primary aim to keep the production in process, neglecting rationality and other consequences. All this also add to the negative influence of energy management.

From all what is said, it can be concluded that the changes in past couple of years have had negative influence on rational energy consumption with minimum environment pollution. The causes for such a condition are as follows:

- at high levels of organisation energetics represents one of the responsibilities of managers in charge (almost always production managers)
- at the production units level responsibilities are divided between energy producers, housekeeping department and energy consumers,
- energy consumers are primarily interested in the production (energy is at the second place)
- the power plant influence in the total of the factory management is insufficient.

At the moment, in all factories the preparations for reorganisation according to ISO regulations are in progress. Energetics and environmental protection will finally get appropriate and truly necessary treatment, also viewed in the light of rational energy consumption and environment protection among other things. The most important issue here, should be establishing the general authority in the field of energy consumption and environment protection. This includes separation of responsibilities from other jobs in the factory. Vertically, energetics and environment manager would be subordinate directly to the general manager; he/she would also unite all energy departments in the factory, from the production level, consumption in all organisational units.

The general conclusion is that many changes have to be done in all three factories. The fact is that there are many technically well prepared studies about how to decrease energy consumption and how to reduce pollution of environment. However, results are still very poor.

7.3 The Ways to improve Energy Management in Factories

Saving money by careful use of energy is an essential activity for any factory. The purpose of training employees in this area is clear enough. It is to ensure that they have the appropriate knowledge and skills to be aware of the energy saving decisions and opportunities which exist around them. This means a sound understanding of all energy using equipment which they may need, the conditions under which it should be operated and the standards of performance that can be obtained from it. These goals should be clearly defined in a company energy plan.

7.4 Attitudes to energy conservation

One of the prime functional tasks the energy manager faces is to change existing attitudes towards energy use particularly within the working environment. Conservation, and energy management generally, continues to be wrongly regarded by fart too many as a short term expedient. It is still being said that once the good housekeeping and other basic techniques have been put into effect, then the present limit has been reached. It is then up to technology to provide for the future.

7.5 The objectives of energy management

The main objectives of energy management could be put in following items:

1. Reduce costs by tariff negotiation;
2. Good housekeeping, by running existing plant in more effective way;
3. Improve plant performance by retro-fitting energy-savings measures;
4. New equipment and new process development with energy conservation in mind.

7.6 Reporting

The present and ever increasing importance of energy management ideally demands that the energy manager reports directly to the board or at least to a senior executive within the overall management structure.

As energy costs and usage involve every department or section of the organization, then in order to be effective, the status and set reporting procedure of the energy manager needs to be clearly defined.

7.7 Motivation and training

The most significant problem in achieving changes in the individual attitude towards energy is the need to change long standing, deep seated customs and practice. In attempting to change these attitudes it must be the aim to make energy conservation an integral part of the routine practice of the organisation by making everyone aware of the need to conserve. It is a vital part of our future way of life.

Another part of the energy manager's activities must be public relations and training, making people aware of what is happening, why it is happening and what they can do to help. If the organisation has an internal newspaper or P.R. department it should be used to the full. Seek the advice of the P.R. staff - after all communications and promotion are their business. Many concerns effectively use slogans, cartoon characters, posters, stickers and in-house competitions. Some even have a regular awards scheme. All promote the community spirit towards a common goal and even if there is only one winner of an award, others have tried, and each competitor makes an individual contribution towards the overall objectives.

But beware, a P.R. approach although necessary can be short lived and difficult to sustain. The ultimate target must be to remove the control of energy from many to a relatively small number of people. This is achieved by automatic control systems, which of course can adopt many forms covering many different applications. Automated systems can also waste energy if they are incorrectly adjusted or programmed then they are permanently wrong.

It is rightly said that money motivates. However, beware of any incentive scheme which incorporates payments for energy savings. The rising cost of energy, in spite of a vigorous conservation programme, can lead to a situation where no cash savings are realised even though energy is being saved. That situation will more than likely result in unhealthy mistrust and the possible collapse of the effort.

7.8 Policy

Success or failure will depend upon obtaining the commitment of top management, the union and the total work force. Employees can tell strait away when energy saving efforts are to succeed. Then management support requires much more than someone giving the nod to a conservation programme and assuming that each individual will just "fit this little job" into his already busy schedule. If the commitment is not there, everyone including the energy manager could well be wasting each other's time.

One of the first jobs must be to draw up a comprehensive proposal suggesting the pattern of involvement of everyone from the main board to the shop or office floor. The proposals must outline the financial benefits which are likely to occur in shorter and longer term. From these will emerge the objectives which the board will be asked to endorse as a matter of firm company policy. This is the main licence for the energy manager to proceed. Once approved, the policy and its objectives must be widely circulated so that everyone knows of its existence and purpose.

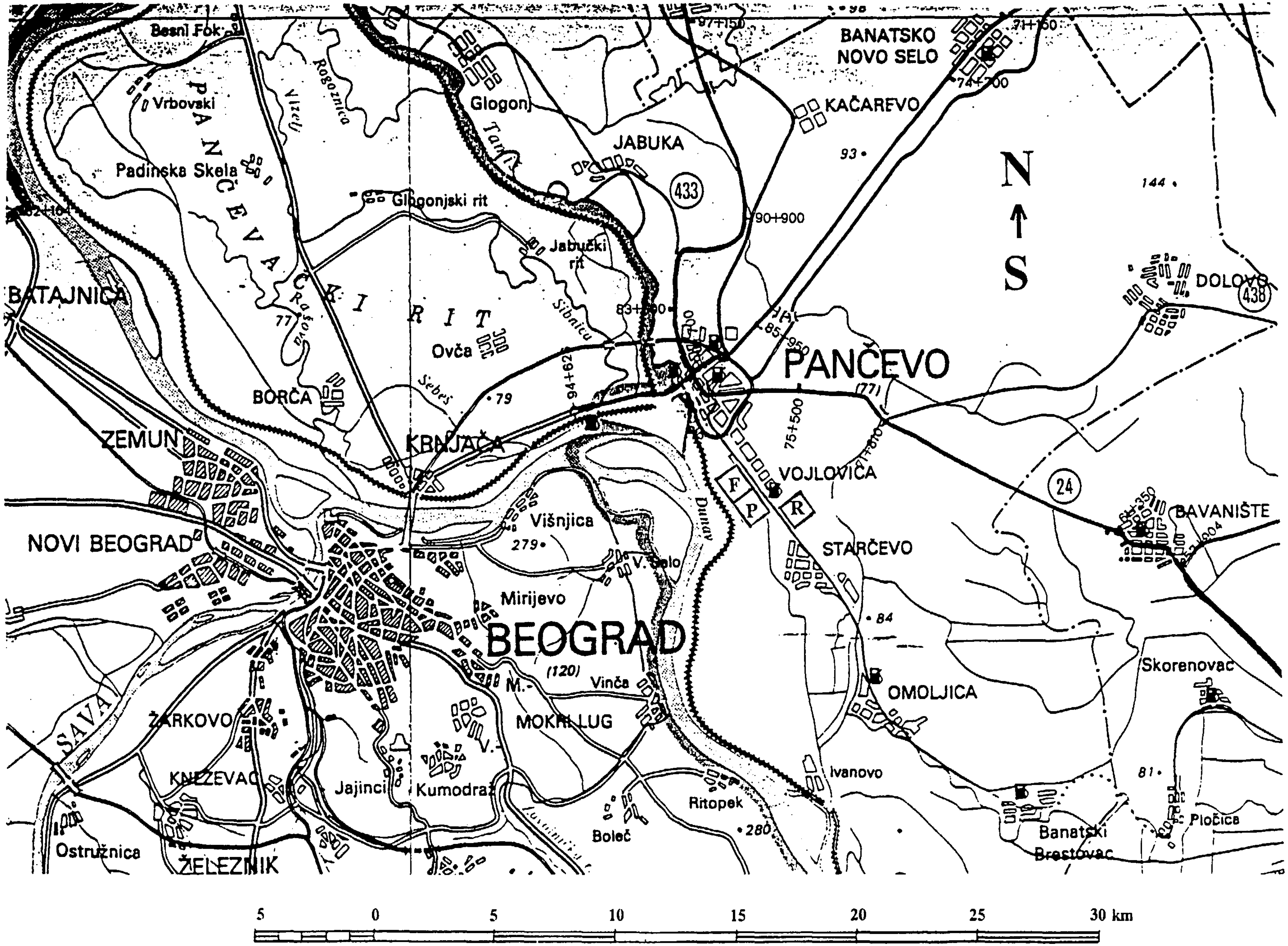
Top management support must go beyond the usual letters of intent and general platitudes. It also means making the manpower and money available to do the job.

7.9 Priorities and strategy

The best way for the newly appointed energy manager to establish himself is to concentrate on those areas likely to give the largest financial savings. The secondary, smaller savings can follow later. Ironic though it may seem one of the best weapons in the armoury will be increase in the price energy. The largest the increase the more aware everyone becomes of its value. The energy manager must be ready to take advantage of these situation immediately they arise.

The energy manager's main role is not to save energy himself but to organise, stimulate and encourage others. Success can be measured when the atmosphere has been created in which all have become energy managers.

Energy manager is a long term function of ever increasing importance. Perhaps the only certainty in this fast changing area is that those who take it up will find it a challenging and most rewarding task.


Besni Fok
97+150
BANATSKO NOVO SELO
71+150
74+700
Vrbovski
PANČEVACKI RIT
Rogoznica
Vizelj
Glogonj
Tamiš
KAČAREVO
JABUKA
93
Padinska Skela
433
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144
Glogonjski rit
90+900
Jabučki rit
BATAJNICA
Rače
77
Ovča
Sibnica
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PANČEVO
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BORČA
75+500
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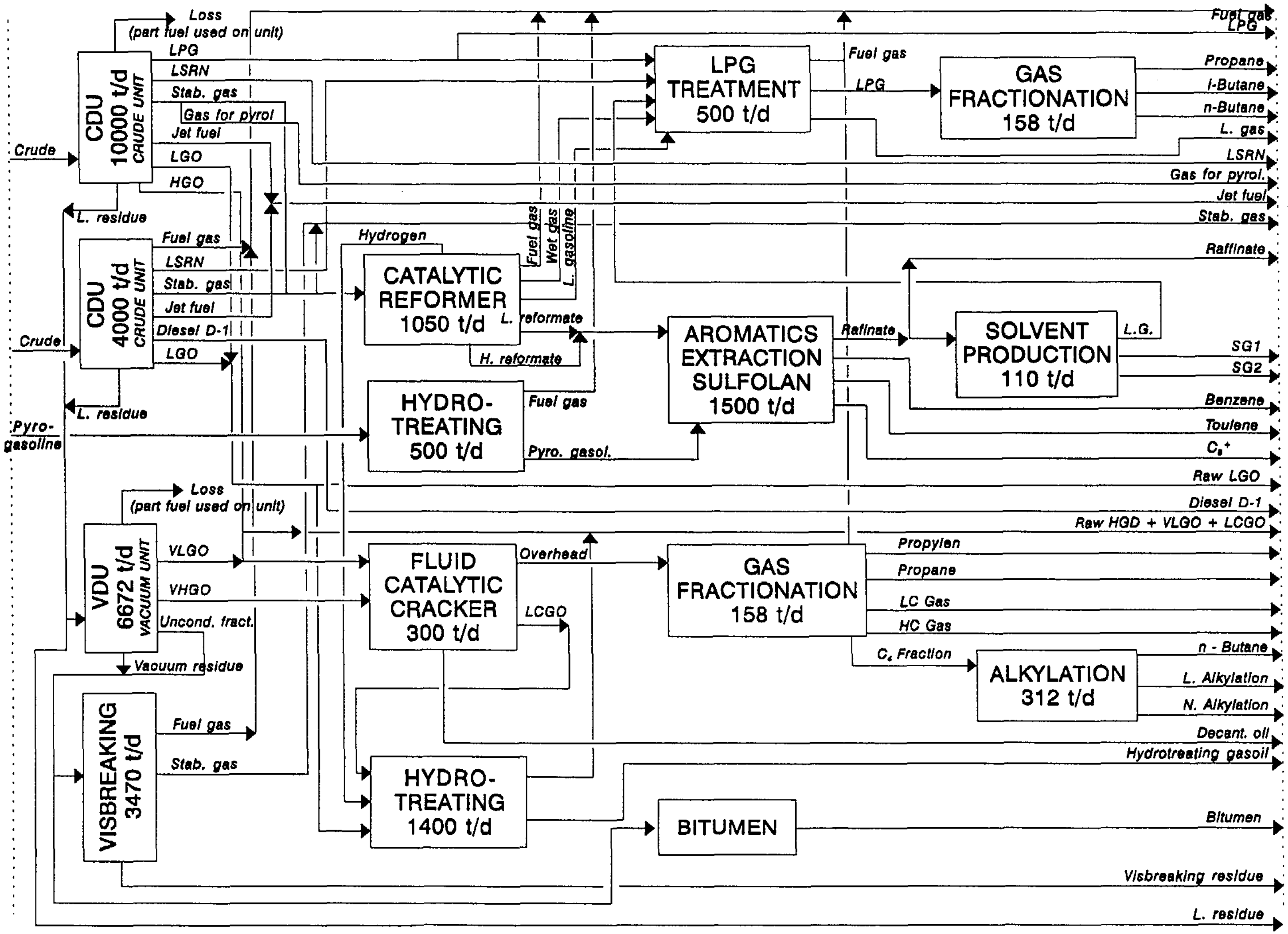
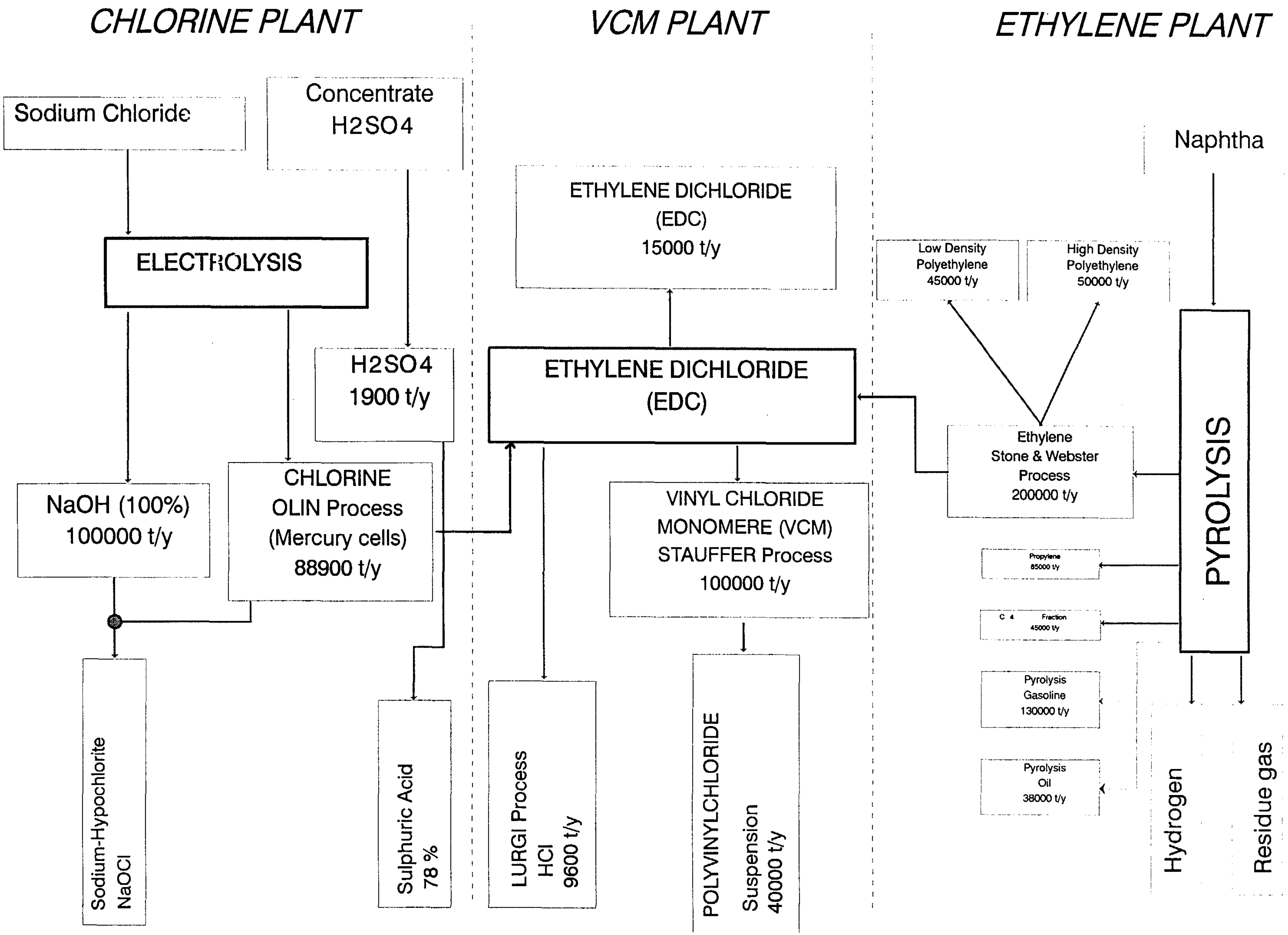
V. Selo
STARČEVO
Mirijevo
84
BEOGRAD
(120)
M.
Vinča
Skorenovac
OMOLJICA
SAVA
ŽARKOVO
MOKRI LUG
V.
KNEŽEVAC
Jajinci
Kumodraž
Ivanovo
81
Ritopek
Boleč
280
Pločica
Banatski Brestovac
Ostružnica
ŽELEZNIK
5
0
5
10
15
20
25
30 km

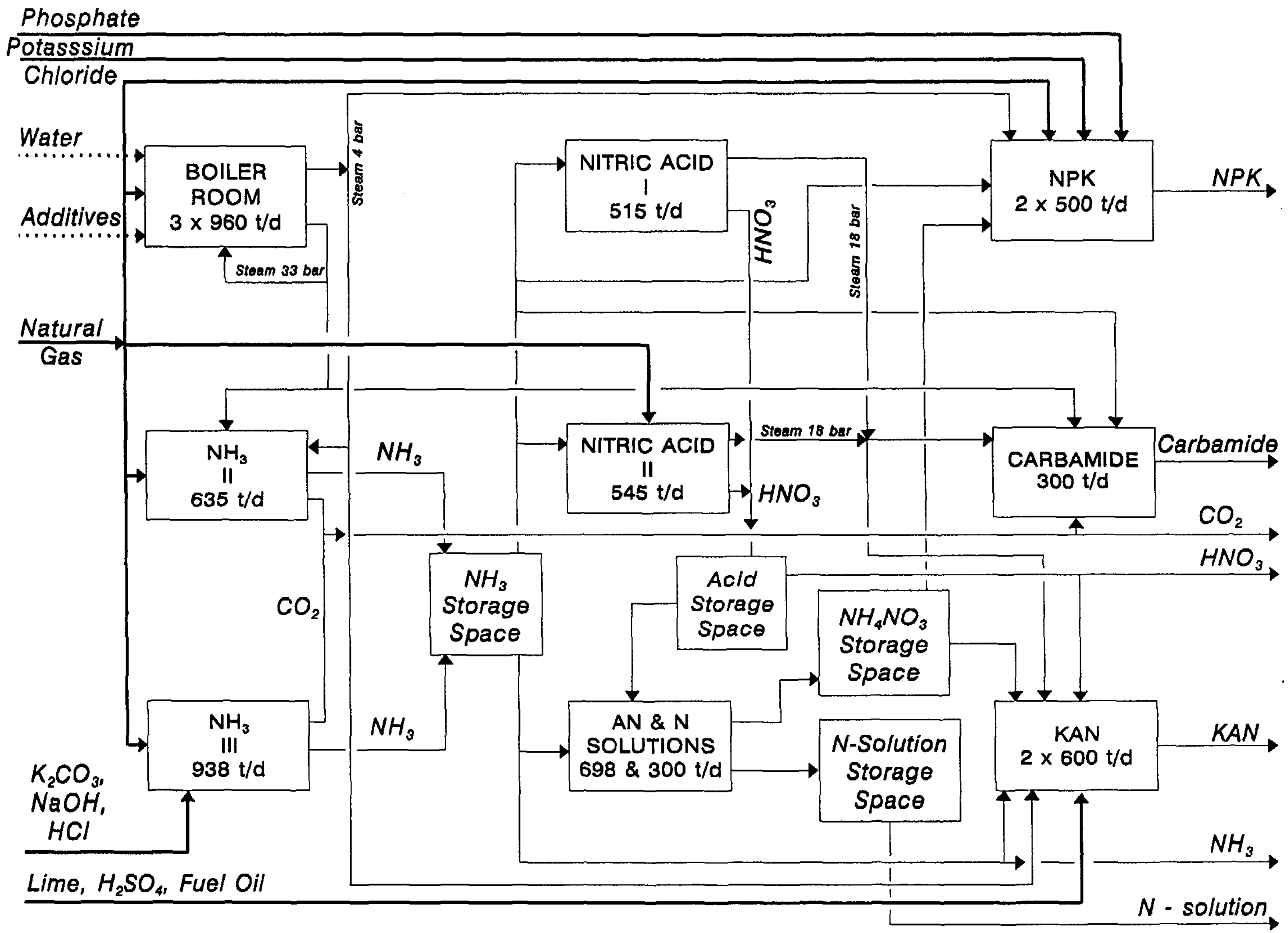
Appendix 1.1



Simplified Refinery Flowscheme


CHLORINE PLANT
VCM PLANT
ETHYLENE PLANT
Sodium Chloride
Concentrate H2SO4
ELECTROLYSIS
H2SO4 1900 t/y
NaOH (100%) 100000 t/y
CHLORINE OLIN Process (Mercury cells) 88900 t/y
Sodium-Hypochlorite NaOCl
Sulphuric Acid 78 %
ETHYLENE DICHLORIDE (EDC) 15000 t/y
ETHYLENE DICHLORIDE (EDC)
VINYL CHLORIDE MONOMERE (VCM) STAUFFER Process 100000 t/y
LURGI Process HCl 9600 t/y
POLYVINYLCHLORIDE Suspension 40000 t/y
Naphtha
Low Density Polyethylene 45000 t/y
High Density Polyethylene 50000 t/y
PYROLYSIS
Ethylene Stone & Webster Process 200000 t/y
Propylene 85000 t/y
C 4 Fraction 45000 t/y
Pyrolysis Gasoline 130000 t/y
Pyrolysis Oil 38000 t/y
Hydrogen
Residue gas

Appendix 1.3



Simplified Fertilizer Flowscheme

Appendix 3.1

EPS "Elektrovojvodina"
JP za distribuciju električne energije
Novi Sad

Breaking of electricity prices

CENOVNIK
za prodaju električne energije
od 01.08.1996 godine

100 Para = 1 din

TARIFNA GRUPA	Obračunska snaga (Para/kW)		Aktivna energija (Para/kWh)			Reaktivna energija (Para/kVArh)
	merena	nemerena	JT	VT	MT	VT
110 kV	2 373.67	-	-	5.57	2.79	2.94
35 kV	2 639.56	-	-	6.64	3.32	2.53
1-20 kV	2 668.22	-	-	7.34	3.67	2.81
Domaćinstvo	146.72	366.90	11.92	15.90	7.95	-
Dom. dalj.upr.potrošnja	146.72	366.90	-	-	4.82	-
Ostala potrošnja 0,4 kV I tar. stepen	1 868.71	-	-	10.94	5.47	2.75
Ostala potrošnja 0,4 kV II tar. stepen	241.75	604.37	18.38	23.00	11.50	-
Javna rasveta	-	-	20.05	-	-	-

Napomena: U Cenovniku (tarifnim stavovima) nije sadržan porez.

UKUPNA CENA (energija i snaga) ZA "DOMAĆINSTVO" SA 10% POREZA NA PROMET + 2% POSEBNOG POREZA ZA ŽELEZNICU

Jednotarifno	Dvotarifno		Mesečna naknada	Taksa na brojilo
	VT	MT		
(Para/kWh)			(Dinara/mesec)	
17.46	21.92	13.01	28.76	19.57

EPS "Elektrovojvodina"
JP za distribuciju električne energije
Novi Sad

6:00 - 14:00 } 12 h VT
17:00 - 21:00

REGULATORY REVIEW

1. Introduction

Energy Conservation and Environmental regulation in Yugoslavia are evolving rapidly. The State's overall ecological policy is to eliminate existing pollution sources and to prevent further pollution. When energy conservation is concerned, it is important to stress the fact that the Government of the Republic of Serbia has formed a Council for Rational Use of Energy (RUE) (*Official Gazette of the Republic of Serbia, No. 4/1995*). The objectives of the Council are as follows:

1. *Teaching about the importance of energy at preparatory school and elementary school levels, about the ways and economic effects of energy saving, and about the connection between RUE and the quality of living.*

2. *Permanent presence of advertisements about rational use of energy in the media, especially radio and television, conducted in methodological and illustrative way without campaigning elements, which is accessible to all education levels.*

3. *Stimulation in founding the centers for rational management of energy within universities, larger scientific institutions and specialised business organisations with the aim of creating special courses in updating the knowledge about the rational use of energy for consumers, maintenance stuff, producers, etc. and establishing the legal obligation to update and test the knowledge of this field from time to time.*

4. *Introduction of obligatory checking for new and reconstructed energy constructions before they start working in order to decide on their operational level, in separate parts and as a whole by authorised body of the Republic of Serbia, as well as putting bans on those objects whose operational levels are lower than those determined by a special regulation.*

5. *Introduction of tax exemptions for construction of apartments, offices and factories which are designed to use minimum of energy for heating and air conditioning.*

6. *Creating legal stimulations and conditions for larger engagement of private investments in so called "small energetics" in order to use smaller energy sources such as water currents, wind energy, solar energy, available geothermal energy, and biomass, because in that way there will be additional saving of solid, liquid and gaseous imported fuels, as well as domestic coal.*

In July 1995, the Council designed its operating plan which includes elaborate measures for its realisation. In the plan it has been suggested to create legal regulations in this field and to make additions to the existing one with the basic aim of increasing energy efficiency in every aspect of energy transformation. There are also suggestions for stimulations of some of the plans in industrial plants through lowering excise tax and income tax of the firms (which amounts to about 10% of the investments in the Project).

Current law regulation book in the field of energy deals primarily with the way in which the firms for production and distribution of energy are organised, with prices of energy sources, tariff system. This plan is the most all-inclusive document in the field of Energy Conservation so far.

2. Current law regulation on the energy field in the Republic of Serbia, concerning the Project: *High level advisory services on energy conservation and environment to the petrochemical industry "Panchevo"*

2.1 Law on Construction of the Industrial Facilities, *Official Gazette of the Republic of Serbia, No.44/1995.*

By this law constructing, technical and technological conditions before the start of previously mentioned work are determined, as well as creation of technical documents, the procedure for obtaining the construction works permit and the permit for use, construction of objects and other important questions concerning the construction and use of the object

This is the most important law for every investment and/or reconstruction in industry buildings.It gives the complete procedure for creation of documentation (Basic Design, Detailed Design, Feasibility Study, Inspection, Procedures for getting the permissions, and duties for using other regulations)

2.2 Law on Transportation, Distribution and Usage of Natural Gas, *Official Gazette of the Republic of Serbia, No. 66/1991.*

Transportation, distribution and usage of natural gas as a common good is regulated through this law and also through regulations which deal with natural gas transportation and distribution.

2.3 Law on national power engineering, *Official Gazette of the Republic of Serbia, No. 45/1995.*

The basic law for defining the scope of work, connection of electrical energy users to electrical energy grid, electrical energy distribution, tariff system, electrical energy balance, construction and protection of electrical energy facilities

2.4 Decision on establishing specialised organisations authorised for control of technical condition of combustion units which use liquid fuels and natural gas, *Official Gazette of the Republic of Serbia, No. 78/1992, No. 93/93, No. 12/1995.*

By this decision particular specialised organisations are authorised for obligatory supervision of control of combustion units' correctness or incorrectness in industries.

2.5 - Law on corporations' profit taxes, *Official Gazette of the Republic of Serbia, No.43/1994, No.53/1995, No.24/1996.*

- Law on excise taxes, *Official Gazette of the Republic of Serbia, No.43/1994, No.53/1995, No.24/1996.*

These laws are important for the project because they define how to stimulate investments in the field of rational use of energy through lowering of taxes and tax exeption from paying profit taxes. The laws also define the procedure for obtaining the agreement. It is possible to lower the total amount of investments for 10%.

3. Current law regulation on the environmental protection field in the Republic of Serbia, concerning the Project: *High level advisory services on energy conservation and environment to the petrochemical industry "Panchevo"*

3.1 Law on Environmental Protection, *Official Gazette of the Republic of Serbia, No.66/1991, No.83/1992, No.48/1994, No.53/1995.*

This law regulates the environmental protection and improvement system, the determination of protection measures, the procedure of putting under protection and management of the protected natural goods, measures and procedures for the protection from harmful influences of industry on environment, financing of protection and improvement of environment and organisation of protection activities and environment improvement.

Environment protection and improvement system includes a group of measures and conditions for: preservation and protection of natural and man-made values of environment; protection of population and environment from pollution; protection from harmful and dangerous materials, ionising and non-ionising radiation, noise and vibrations; protection of natural values from destruction and degradation; as well as measures and conditions for the improvement of environment qualities.

3.2 Regulation Book on Analysis of Influence of Constructions and Construction Works in the Environment, *Official Gazette of the Republic of Serbia, No.61, 1992.*

This Regulation Book determines the type of the constructions, i.e. construction works for which it is necessary to have an analysis of their influence on environment, as well as the content, methodology and verification of the analysis.

This analysis is required for the constructions in the field of: industry, mining, power plants, traffic, tourism, agriculture, forestry, waterpower engineering and public services, and also for all objects and construction works in the law-protected natural areas as well as protected areas of immobile cultural goods.

3.3 Decree on Establishing Air-Quality Control Program for 1994 and 1995, *Official Gazette of the Republic of Serbia, No.60/1994.*

The Government of the Republic of Serbia has passed this document which regulates the air-quality control with the aim of establishing the level of pollution, of estimating the influence of the polluted air on climate, health of population and environment in order to take appropriate protection measures.

3.4 **Regulation book on Methods for the Measuring of Emission, Criteria for Establishing of the Measuring Spots and Records, *Official Gazette of the Republic of Serbia, No.54/1992.***

It prescribes permitted values of emission, warning emission, sporadic air pollution, methods for systematic measuring of emission, the criteria for establishing the measuring spots and the way of data recording.

3.5 Regulation Book on Permitted Noise Level in Environment, *Official Gazette of the Republic of Serbia, No.54/1992.*

It determines the permitted noise level in an environment where people live, methods of measuring the noise, more detailed conditions which specialised organisations for noise measuring have to fulfil, and the content of the permit for noise sources.

3.6 Regulation book for the Criteria for Determining the Location and Organisation of the Disposal of Wastes, *Official Gazette of the Republic of Serbia, No.54/1992.*

It establishes the criteria for determining of locations for waste disposal places in order to protect the environment.

3.7 Regulation book on Danger Caused by Chemical Accident and Environment Pollution Estimation Methodology, Measures for Preparation and Measures for Overcoming of the Effects, *Official Gazette of the Republic of Serbia, No.60/1994.*

It determines the methodology for estimation of danger, i.e. of chemical accident risk and the danger of environmental pollution, measures in case of chemical accident and measures for dealing with the consequences of chemical accident, methods of classifying the types and amounts of dangerous materials in the processes of production, use, transport, trade, storing and keeping.

3.8 Regulation book on dealing with waste which has the properties of dangerous materials, *Official Gazette of the Republic of Serbia, No.12/1995.*

With this document, the Secretary of the Ministry of Environmental Protection determined the methods of dealing with waste which has the properties of dangerous materials, as well as of their production, use, transport, trade, storing and keeping.

3.9 Law on waters, *Official Gazette of the Republic of Serbia, No.464/1991.*

This law regulates the water protection, protection from harmful influence of water, use and management of water as natural goods, financing and management of waterpower engineering and supervision on implementation of this law.

It concerns on surface and underground water, geothermal and mineral water and drinking water.

3.10 Decree on defining of programme of protection from ionizing radiation in 1995, *Official Gazette of the Republic of Serbia, no. 15, 1995.*

This decree determines systematic analysis of outer radiation and the presence of radionuclide in the environment, measuring of technologically changed natural level of radiation, determining of the system of organization and intervention in case of accident, founding and maintenance of computerized databases, assessments of radiation with the professionally exposed persons and patients, removing of the sources of radiation from radioactive lighting rods, as well as storing of radioactive waste.

3.11 Law on dealing with waste materials, *Official Gazette of the Republic of Serbia, No.25/1996.*

This law deals with the collection and usage of waste as raw material, as well as the organization of dealing with waste and raw materials.

With the purpose of protecting the environment from damages caused by waste, as well as of purposeful exploitation and protection of natural resources, reduction of the amount of waste, control of quality of waste and safe storing of waste, this law determines the rights and duties of the institutions, companies, other legal subjects, individual entrepreneurs and other individuals in the collection and usage of waste.

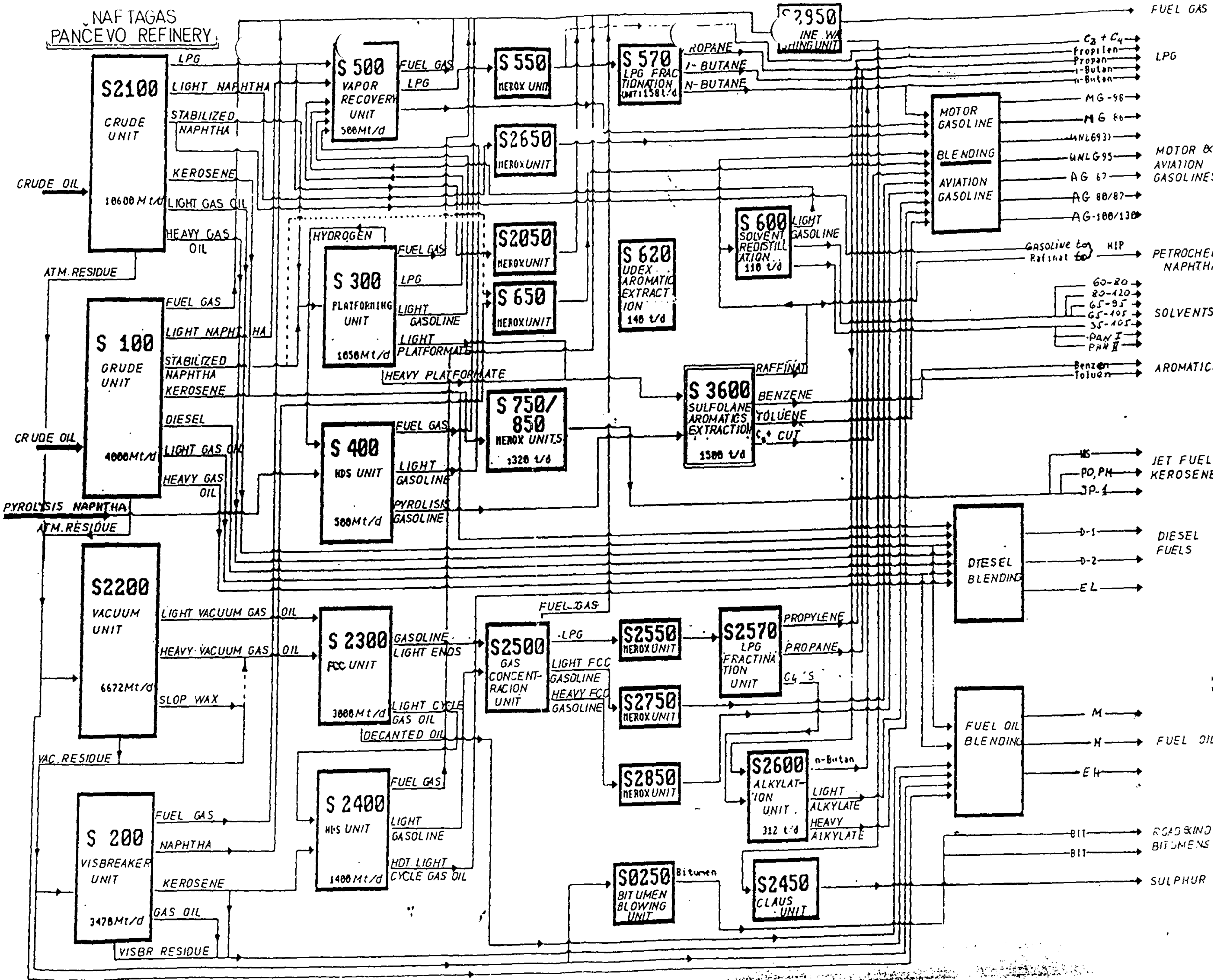
With regard to this law, waste includes all solid, liquid and gaseous materials made through the process of production and usage of goods. The types of waste are: 1) the waste that can be used as raw material without previous processing; 2) the waste that cannot be used as raw material without previous processing, and 3) the waste that cannot be used as raw material.

4. Comments

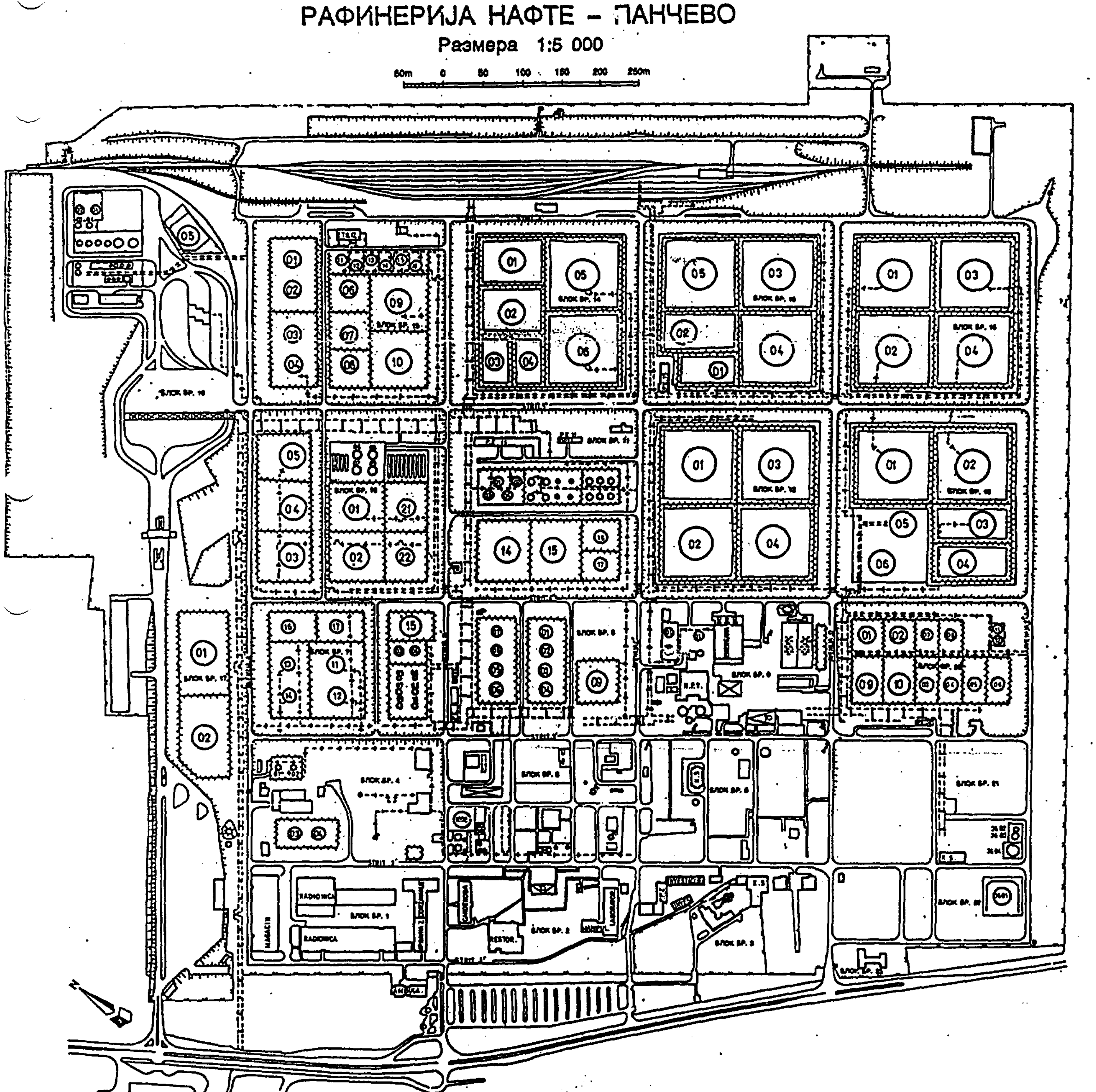
Majority of the laws, regulations and decrees mentioned are of comparatively recent date. Their further development will follow aiming towards more precise definitions of responsibilities, control of putting the law into effect, organising government institutions for conducting of these controls, forming the mechanisms for financial support of realisation of particular plans, etc.

There is a process of getting into work the carrying out of the law at the moment. Namely, because of the difficult time for production in the last few years and the lack even of basic raw materials and fuels, the realisation of these regulations was postponed. It was based mostly on carrying out basic duties, especially those concerning safety in the production plant.

At the same time, a reorganisation was at progress and along with that the change in responsibility of the inspections, which resulted in a certain degree of inconsistency in putting into effect the legal regulations covering this field. These processes are more or less completed, and it is expected that all the laws mentioned here will very soon be consistently put into effect.


NAFTAGAS
PANCEVO REFINERY
S2100 CRUDE UNIT 10600 Mt/d
CRUDE OIL
LPG
LIGHT NAPHTHA
STABILIZED NAPHTHA
KEROSENE
LIGHT GAS OIL
HEAVY GAS OIL
ATM. RESIDUE
S 100 CRUDE UNIT 4000 Mt/d
FUEL GAS
DIESEL
PYROLYSIS NAPHTHA
S2200 VACUUM UNIT 6672 Mt/d
LIGHT VACUUM GAS OIL
HEAVY VACUUM GAS OIL
SLOP WAX
VAC. RESIDUE
S 200 VISBREAKER UNIT 3470 Mt/d
NAPHTHA
GAS OIL
VISBR. RESIDUE
S 500 VAPOR RECOVERY UNIT 500 Mt/d
HYDROGEN
S 300 PLATFORMING UNIT 1650 Mt/d
LIGHT GASOLINE
LIGHT PLATFORMATE
HEAVY PLATFORMATE
S 400 HDS UNIT 500 Mt/d
PYROLISIS GASOLINE
S 2300 FCC UNIT 3000 Mt/d
GASOLINE LIGHT ENDS
LIGHT CYCLE GAS OIL
DECANTED OIL
S 2400 HDS UNIT 1400 Mt/d
HDT LIGHT CYCLE GAS OIL
S 550 MEROX UNIT
S2650 MEROX UNIT
S2050 MEROX UNIT
S 650 MEROX UNIT
S 750/850 MEROX UNITS 1320 t/d
S 570 LPG FRACTIONATION UNIT 150 t/d
PROPANE
I-BUTANE
N-BUTANE
S2950 INE WA DING UNIT
S 620 UDEX AROMATIC EXTRACTION 140 t/d
S 600 SOLVENT REDISTILLATION 110 t/d
S 3600 SULFOLANE AROMATICS EXTRACTION 1500 t/d
RAFFINAT
BENZENE
TOLUENE
C₉+ CUT
S2500 GAS CONCENTRACION UNIT
-LPG
LIGHT FCC GASOLINE
HEAVY FCC GASOLINE
S2550 MEROX UNIT
S2750 MEROX UNIT
S2850 MEROX UNIT
S2570 LPG FRACTINATION UNIT
PROPYLENE
PROPANE
C₄'S
S2600 ALKYLATION UNIT 312 t/d
n-Butan
LIGHT ALKYLATE
HEAVY ALKYLATE
S0250 BITUMEN BLOWING UNIT
Bitumen
S2450 CLAUS UNIT
MOTOR GASOLINE BLENDING
AVIATION GASOLINE
DIESEL BLENDING
FUEL OIL BLENDING
FUEL GAS
C₃ + C₄
Propilen
Propan
i-Butan
n-Butan
LPG
MG-98
MG 86
UNL 69(1)
UNL G 95
AG 67
AG 80/87
AG-100/130
MOTOR & AVIATION GASOLINES
Gasoline to HIP
Rafinat to
PETROCHEMICAL NAPHTHA
60-80
80-120
65-95
65-105
35-105
PAN I
PAN II
SOLVENTS
Benzen
Toluen
AROMATICS
MS
PO, PM
JP-1
JET FUEL KEROSENE
D-1
D-2
EL
DIESEL FUELS
M
H
EH
FUEL OIL
BIT
BIT
ROAD & IND. BITUMENS
SULPHUR

Map of refinery area



Appendix 4.4

NIS-RAFINERIJA NAFTE PANČEVO
RESEARCH AND DEVELOPMENT DEPARTMENT
DEVELOPMENT DIVISION

ALKYLATION SPENT SULPHURIC ACID RECOVERY UNIT AND PRODUCTION OF CONCENTRATED ACID (98,5 %)

Pančevo, October 1996.

CONTENTS

1. INTRODUCTION

1.1. The Short History of Pančevo Refinery

Pančevo Refinery is a part of the business system called Petroleum Industry of Serbia. The first units were completed in 1968. with crude unit having the capacity of 4.000 t/d or 1.320.000 t/y.

Within the second refiner expansion phase the alkylation unit was installed,the capacity of which is 321 t/d or 100.000 t/y of inlet feed. When producing alkylate,Pančevo Refinery is able to offer for sale the environmentally acceptable products having the properties of "reformulation" - unleaded motor gasoline and aviation gasoline.

1.2. Location

Pančevo Refinery is located in the southeast part of Pančevo. The geographical position of the town is as follows:

- Pančevo is located at the mouth of the river Tamiš into the Danube,and the town is developing on the left bank of the river Tamiš.
- Pančevo is about 13 kilometers far from Belgrade and the Refinery about 15 kilometers.

Pančevo Refinery is in the vicinity of the international road and railway lines: Belgrade-Pančevo-Vršac-Romanian border.

Refinery is also not far from the international navigable river DANUBE WHICH JOINS the Middle E/urope and the Black sea region. Refinery is in possession of the loading - unloading facilities on the Danube.

From the very beginning of the construction, refinery complex had the basic morphological division into the blocks defined as the areas between the avenues and the streets.

Alkylation Unit had been constructed as a part of FCC unit in the Block 6 during the second phase of refiner unit expansion.

Micro location of the spent acid recovery unit will not be defined in this study but through the analysis of sulphuric acid recovery unit influence on the environment in compliance with the Regulations (Official Gazette of RS, No.61 of 2. September 1992).

2. TECHNOLOGICAL PART

2.1. Sulphuric - Acid Alkylation

2.1.1. The Description of the Existing Unit

Sulphuric - acid alkylation unit has been designed by Foster Wheeler and under the licence of Stratford Engineering Corporation, through Edeleanu GMBH.
According to its basic design, this unit is capable of processing 22,5 m^3/h butenes, BUTANES ~~compound and the butane~~ obtained from FCC gasous products treatment, i.e.from GCU or the storage.

The unit can accept the feedstock from GCU depending on two FCC modes of operation (summer and winter).

On the winter mode of operation, the unit produces 14,1 m^3/h raw alkylate used for motor gasoline blending or 13,o m^3/h light alkylate for aviation gasoline based on 6o% conversion in FCC unit (maximum quantity of MIDDLE ~~medium~~ distillates).

On the summer mode of operation, the unit produces 13,6 m^3/h raw alkylate used for motor gasoline blending or 12,5 m^3/h light alkylate for aviation gasoline based on 8o% conversion (maximum quantity of gasoline). The unit is able to operate at 5o% capacity on both FCC modes of operation.

2.1.2. Sulphuric - Acid Consumption

Alkylation Unit in Pančevo Refinery is using the concentrated sulphuric acid as a catalyst. If fresh sulphuric acid is used, at the concentration of 98,5% m, without free SO_3, the average consumption will be 11,2 t/d ± 1o%.
For the initial start-up, 18o t sulphuric acid is required, for which 186 m^3 tank has been provided.

In case of feed pollution, the additional quantities of fresh acid are to be PROVIDED ~~envisaged~~, thus increasing the spent acid quantities on the basis of the following assumptions:

Components	Acid Consumption
Dienes	8 kg H_2SO_4/1 kg dienes
Sulphur	2o kg H_2SO_4/ 1 kg sulphur
Ethylene	2o kg H_2SO_4/1 kg ethylene

The total normative sulphuric acid consumption in Pančevo Rafinery alkylation unit, used as the catalyst and for "impurities" i.e. other components present in C_4 feedstock, being counted per 1,3 butadiene only, are the following:

TABLE 2

Type of consumption	Quantity	
	t/d	t/y
H_2SO_4 as a catalyst	11,2 ± 1o%	3,696 ± 1o%
$H_2S\ O_4$ per 1,3 butadiene	12,5	4,124
Total	23,7(+ 1,12)	7.82o (+ 369,6)

* Counted for 1o3,1o3 t C_4/y.

It means that, on the designed mode of operation, the unit will be producing approx. 24 t/d spent sulphuric acid, impured by water, soluble and insoluble organic substances, sulphonic acids, organic sulphates, sulphur dioxide, olefine polymer and carbon.

There is 186 m^3 tank available for storaging of spent sulphuric acid.

2.2. Technology for Regenerati~~ng~~ON Spent Sulphuric Acid

2.2.1. Spent H_2SO_4 Decomposition

H_2SO_4 is thermally decomposed into H_2O, SO_2 and O_2 in a special heater, as per chemical equation:

$$H_2SO_4 + \text{heat} \longrightarrow SO_2 + \frac{1}{2}\ O_2 + H_2O$$

All organic impurities are burnt to CO_2 and H_2O,whereas inorganic ones evaporate forming the ash.

2.2.2. Gas Purification and Cooling

In this part of the process, the gases,obtained by decomposition of H_2SO_4, are purified in the scrubbers and cooled with a view of condensing steam surplus and removing the unwanted impurities.

Damping of still hot gases, cooling for steam condensation and collecting of sour mist and particles are included into this part of the process.

2.2.3. Drying and Compressing the Gas

Wet gases from gas purification and cooling system, are passing through drier (tower) where almost the total quantity of steam is eliminated thus becoming a part of the acid produced.

Scrubbed, cooled and dried gases are then compressed in order to be removed through the remaining part of H_2SO_4 regeneration unit.

2.2.4. SO_2 Oxidation (Conversion)

Dry SO_2 is then oxidized to SO_3 as per the following equation:

$$SO_2 + \frac{1}{2} O_2 \xrightarrow{\text{Catalyst}} SO_3$$

Thus obtained SO_3 combines with water forming the acid. The oxidation takes place in a catalytic converter having a non-movable catalyst bed, usually 4 beds.

2.2.5. SO_3 Absorbtion

SO_3 absorbtion takes place per the following equation:

$$SO_3 + H_2O \xrightarrow[H_2\ SO_4]{} H_2SO_4$$

SO_3 obtained in the converter system, is completely absorbed when contacting 98% H_2SO_4 recycle stream in packed layer absorber.

Fig.1 shows process schema~~tic~~ of spent sulphuric acid regeneration unit.

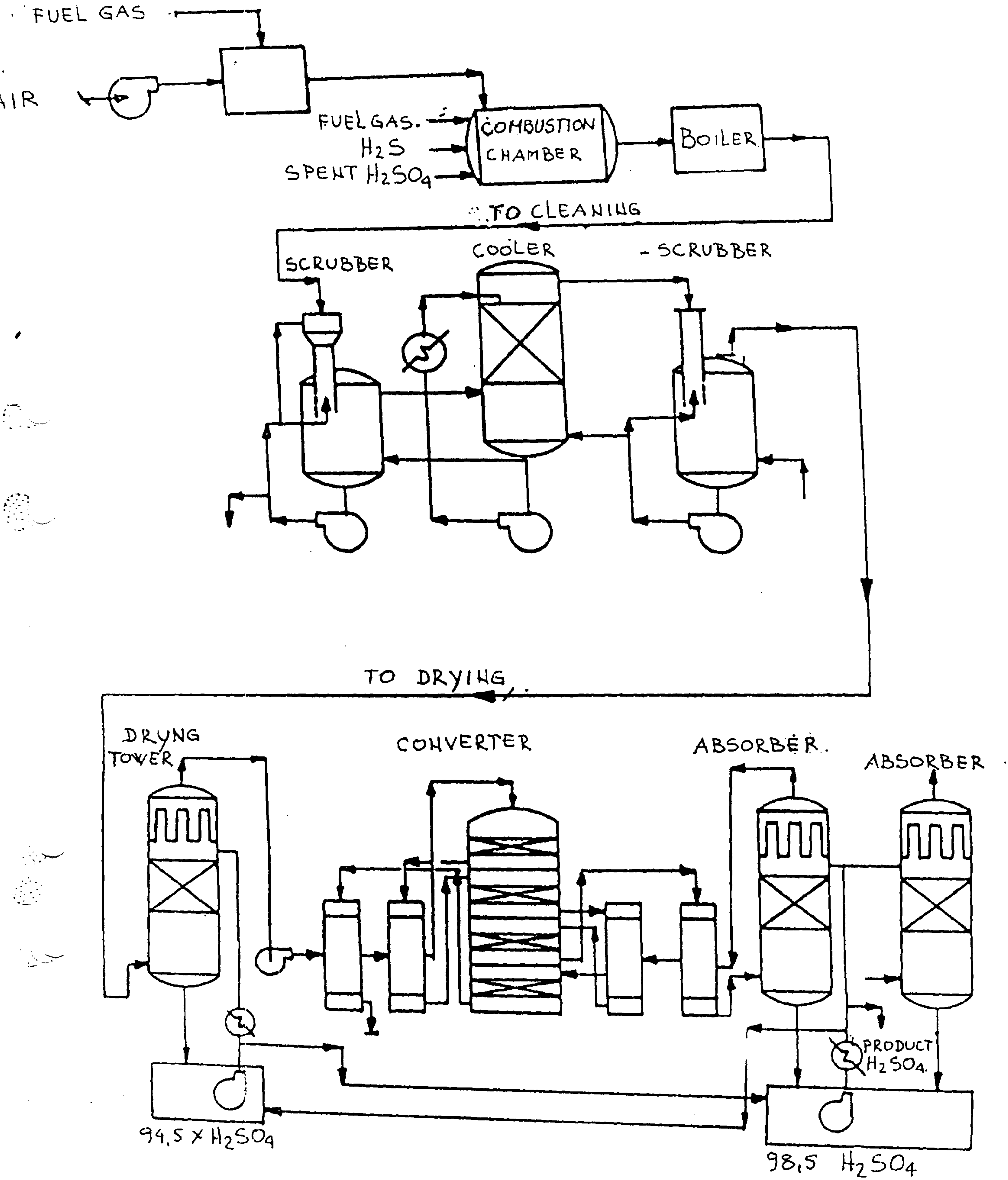


Fig. 1 PROCESS SCHEME OF SPENT H_2SO_4 REGENERATION UNIT

3. ENVIRONMENTAL PROTECTION

Spent sulphuric acid obtained in Alkylation unit of Pančevo Refinery is classified as the dangerous matter according to its properties and in compliance with the Regulation on the manner of treating the wastes having the properties of hazardous matter.

Chapter under the title Categories of Hazardous Wastes to be controlled, says that hazardous wastes are the matter containing sour solutions or acids in a solid state (item 2,16), and MATERIALS ~~matter~~ or wastes which, by their effects, cause serious damage when contacting tissue or in case of leakage they can damage material or even destroy other products or facilities and can be a source of other hazards (3.hazardous waste charasteristics: ass 8 code H8). Sulphonic acid content, polymerized olefins, organic sulphates being an organic part of spent acid, are the compounds polluting the environment. Spent sulphuric acid contains all these characteristics, so it has to be treated as hazardous matter.

LEGAL REGULATIONS DEALING WITH SPENT SULPURIC ACID TREATMENT AND ENVIRONMENTAL PROTECTION

Legal regulations concerning environmental protection being the basis of viability for construction of alkylation spent acid covery unit in RNP, are as follows:

1. Environmental Protection Law of the Republic of Serbia, Official gaz.RS No. 66, November 6, 1991.
2. Water Law, Official gaz.RS No.46, July 31, 1991.
3. Construction Law, Off.gaz.RS,No.44,October 27,1996.
4. Regulations on the analysis concerning building i.e.work influence on the enviroment, Off.gaz.RS No.61,September 2, 1992.
5. Regulations concerning the way of treating wastes having the properties of hazardous matter, Official gaz.RS,No.12,April 19,1995.
6. Decision on Air Protection against Pollution, OP No.21/1187, Official gaz.of Pančevo City Municipality, 25/11/1987.

4. INVESTMENT

According to the balance of sulphur acid consumption as the catalyst and for the impurities, the total quantity of the spent acid is 24 t/d, (7.92o t/y). Investment value of the complete spent sulphuric acid recovery Unit, having the capacity of 24 t/d amounts to 5.ooo.ooo US $.

The information taken from< ORONZIO DE NORA-MONSANTO; The price is on the basis of 1995.

PROCESS DESCRIPTION OF THE FLARE GAS RECOVERY PLANT REFINERY PANCEVO

The target of the Flare Gas Recovery System is the separation of the hydrocarbon compounds including inert gases by compression and subsequent condensation in gas- and liquid phase.

The occurring quantities of gasform and condensed hydrocarbons after the compression are dependent exclusively on the composition of the occurring flare gas and the cooling water temperature.

The gasform components will be deducted to the refinery heat gas net.

The liquid phase of the flare gas will be pumped to the plants S-5oo and S-25oo for purpose of further processing.

The following compositions show the vol. % and mass. % for the surrendered analyses of both flare gas systems FA-27oo and FA-17oo.

For the gas mixture of both flare gas quantities in the gasometer, 1/3 of FA-27oo and 1/3 of FA-17oo will be taken as a basis.

Flaregas - Analyses / RNP

Summary : vol %

Project No.: 86006

Component		FA-1700 (vol %)	FA-2700 (vol %)	mix (vol %)
Water	H2O	0,00	0,03	0,02
Hydrogen	H2	3,68	2,57	2,94
Hydrogen sulphide	H2S	0,71	4,36	3,17
Oxigen	O2	0,00	0,01	0,01
Nitrogen	N2	3,49	2,27	2,69
Carbon dioxide	CO2	0,26	0,86	0,66
Methane	C-1	16,27	7,10	10,08
Ethane	C-2	10,58	4,56	6,51
Ethylene	C-2=	0,14	3,37	2,32
Propane	C-3	19,51	20,16	19,94
Propene	C-3=	0,24	10,63	7,26
n - Butane	nC-4	14,43	12,44	13,08
i - Butane	iC-4	6,43	10,25	9,01
Butene	C-4=	0,46	7,20	5,01
n - Pentene	nC-5	4,94	4,15	4,40
i - Pentene	iC-5	5,35	6,54	6,15
Pentene	C-5=	0,67	0,33	0,44
Hexane	C-6	4,42	3,17	3,57
Hexene	C-6=	0,36	0,00	0,12
Benzene		0,17	0,00	0,06
Heptane	C-7	2,82	0,00	0,91
Heptene	C-7=	0,31	0,00	0,10
Toluene		0,34	0,00	0,11
Octane	C-8	1,66	0,00	0,54
Octene	C-8=	0,17	0,00	0,06
E - Benzene		0,54	0,00	0,18
	C-9+	2,05	0,00	0,66
		100,00	100,00	100,00

(mix = 2/3 quantity of FA-2700 + 1/3 quantity of FA-1700)

Flaregas - Analyses / RNP

Summary : mass %

Project No.: 86006

Component		FA-1700 (mass %)	FA-2700 (mass %)	mix (mass %)
Water	H_2O	0,001	0,01	0,007
Hydrogen	H_2	0,151	0,11	0,124
Hydrogen Sulphide	H_2S	0,490	3,14	2,257
Oxigen	O_2	0,000	0,01	0,007
Nitrogen	N_2	1,998	1,36	1,573
Carbon dioxide	CO_2	0,231	0,80	0,610
Methane	C-1	5,304	2,41	3,375
Ethane	C-2	6,469	2,90	4,090
Ethylene	C-2=	0,077	2,00	1,359
Propane	C-3	17,484	18,80	18,361
Propene	C-3=	0,207	9,46	6,376
n - Butane	nC-4	17,054	15,29	15,878
i - Butane	iC-4	7,592	12,60	10,931
Butene	C-4=	0,530	8,54	5,870
n - Pentene	nC-5	7,245	6,33	6,635
i - Pentene	iC-5	7,844	9,98	9,268
Pentene	C-5=	0,960	0,49	0,647
Hexane	C-6	7,735	5,77	6,425
Hexene	C-6=	0,609	0,00	0,203
Benzene		0,269	0,00	0,090
Heptane	C-7	5,739	0,00	1,913
Heptene	C-7=	0,615	0,00	0,205
Toluene		0,638	0,00	0,213
Octane	C-8	3,846	0,00	1,282
Octene	C-8=	0,395	0,00	0,132
E - Benzene		1,168	0,00	0,389
	C-9+	5,349	0,00	1,780
		100,000	100,00	100,000

(mix = 2/3 quantity of FA-2700 + 1/3 quantity of FA-1700)

For the quantitative dimensioning of the compressors of 9o t/d of flare gas, the following basic data for both gas analyses and their mixture (6o t/d FA-27oo; 3o t/d FA-17oo) do result:

Table 1

Analysis	FA-27oo	FA-17oo	Mix
Mol. Weight	47,27 kg/kmol	49,19/kg/kmol	47,89 kg/kmol
Gas Density	2,11 kg/Nm³	2,2o kg/Nm³	2,14 kg/Nm³
Gas Quantity	2.5oo kg/h	1.25o kg/h	3.75o kg/h
	1.185 Nm³/h	57o Nm³/h	1.755 Nm³/h

Furthermore, the part of the unsaturated hydrocarbons which do polymerize can be seen from the both gas analyses.

The quantity of unsaturated hydrocarbons is composed of the sum C_2= to C_8=.

The following table shows the material data of the unsaturated hydrocarbons.

Table 2

Analysis	FA-27oo	FA-17oo	Mix
Mol. Weight	7o,95 kg/kmol	45,o kg/kmol	46,3 kg/kmol
Gas Density	3,17 kg/Nm³	2,o1 kg/Nm³	2,o7 kg/Nm³
Gas Quantity	42,41 kg/h	512,25 kg/h	554,66 kg/h
	13,35 Nm³/h	254,99 Nm³/h	268,34 Nm³/h
	3,4 mass. %	2o,5 mass. %	14,8 mass. %

The unsaturated hydrocarbons will be absorbed into the jet gas washer by a wash fluid (heavy benzine, reformer benzine).

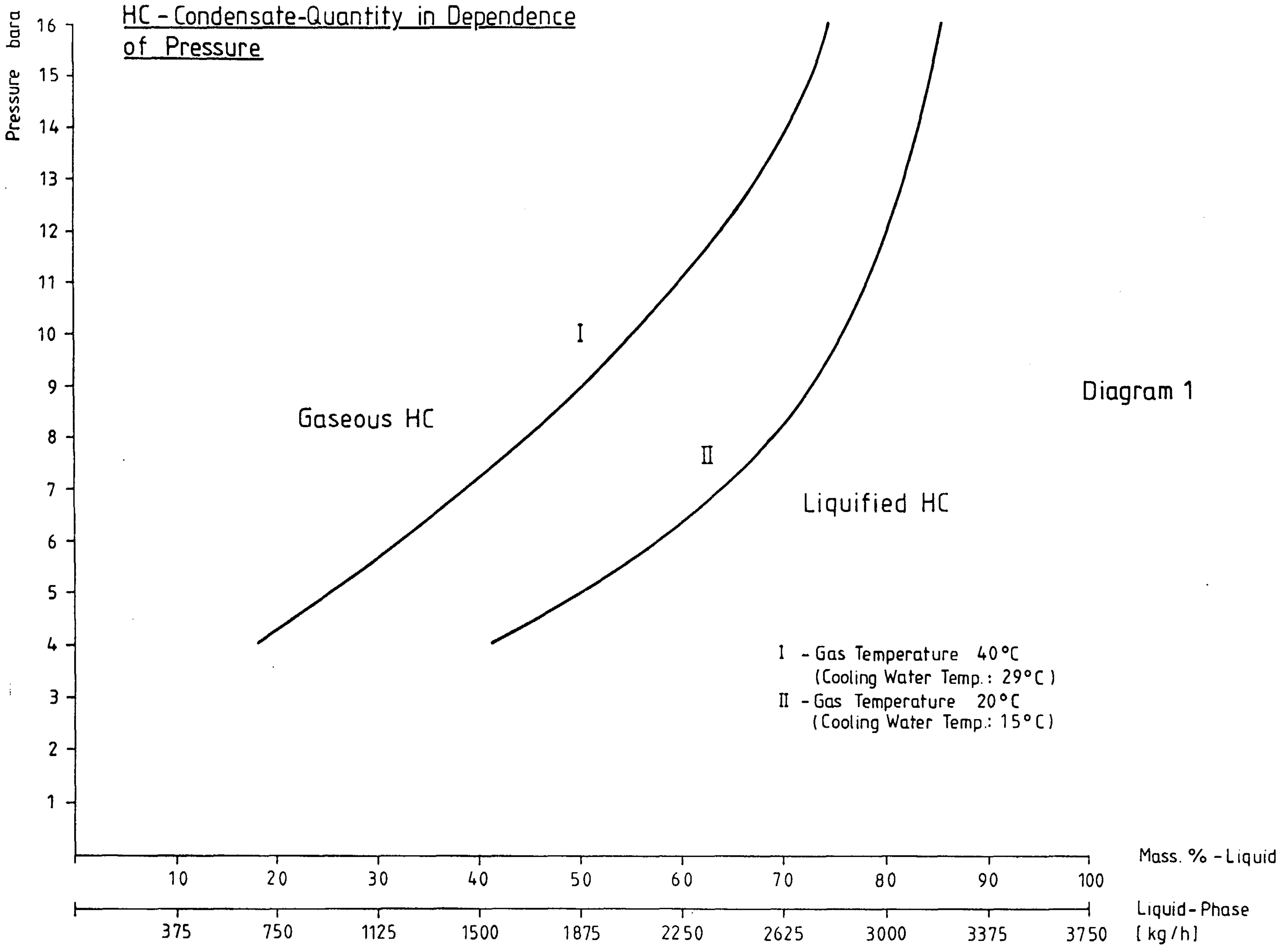
In diagram 1, the liquid recovery rate for the practically present gas mixture dependent on the compressor end pressure and the gas temperature after end cooler is shown.

Curve I shows the quantity liquid phase for the gas temperature 4o °C (cooling water summer temperature: 29 °C) and curve II for the gas temperature 2o °C (cooling water winter temperature: 15 °C).

An economic recovery results at a compression to 16 bar a.

The liquid phase recovery rate mathematically is for:

-	Gas temperature 2o °C	85 mass. %
-	Gas temperature 4o °C	74 mass. %



HC - Condensate-Quantity in Dependence of Pressure

Diagram 1

Plant Description of the Flare Gas Recovery Plant Refinery Pancevo

1. General Plant Description

The Flare Gas Recovery Plant shall be erected in block 5.

The plant consists of a gasometer as buffer vessel and a 2-stroke compressor unit. The compressor unit contains as main aggregate a 2-step screw compressor with controllable electrical motor drive. Jet gas washers are arranged before and behind the first compressor step. Behind the second compressor step, there is one end cooler and one separator per stroke. HC-condensate collecting vessels and condensate pumps complete the plant.

The 2-stroke compressor unit of the flare gas recovery is designed for 9o t/d of flare gas per stroke.

Depending on the occurring quantities of flare gas, both strokes can also be run in parallel manner.

The plant is planned as a dead-man-station, that is, there will be no staff at location. The plant will be run and supervised by remote control from a central station.

2. Tie-in Points at existing Flare Gas System

At both existing flare systems, fitting pieces for the recovery plant will be installed, in the field between knock-out-drum and water-seal-vessel. The delivery tubes will be welded without operation interruption at both existing flare pipes, pierced and equipped with a check valve.

The new pipes will be ducted from both tie-in points to the gasometer.

3. Low Pressure Gasholder (Gasometer)

The gasometer serves as buffer for both arriving flare gas streams and has been dimensioned for a volume of 3.ooo m³ and a pressure of 2oo mm WC. The operating range shall be in the sector between 8oo and 1.ooo m³ so that a buffer volume of ca. 2.ooo m³ is at disposal. In case a screw compressor runs with minimum speed and no flare gas streams into the gasometer, a compressor is able to run ca. 1 h until the min. fill level is reached.

LOW PRESSURE GASHOLDER (GASOMETER)

Technical Data Sheet

1. General

Foundation site:	Rafinerija Nafte Pancevo
Equipment No.:	FAT - 1oo1
Medium:	Flare Gas
Pieces:	1
Type:	Expandable liquid-seal gasholder
Producer:	....

2. Short Description

The gasholder shall be used for the temporary storage of flare gas containing H_2S at a constant overpressure of 2oo mm WC.

The volume shall be variable by moving up and down of a single stroke cylinder (bell), closed cupola-shaped above, in a water-filled steel basin, dependent on the feeding and draining quantities.

Basin and bell shall be welded together by their single components.

Purchaser to mark X in info - column where data required in vendor's proposal

Rev. Nr.	Orig.	1	2	3	4	5	6	7	8	9
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Date										

3. Dimension data

Operating volume: 3.ooo m^3

Outside diameter: max. 2o.ooo mm

Operating pressure: 2oo mm WC

Operating temperature: 2o - 4o °C

4. Climatic conditions

Max. air temperature: 4o °C

Min. air temperature: - 28 °C

Max. barometer pressure: 1,o3 bar

Min. barometric pressure: o,97 bar

Influence of wind to be considered:

- for constructions o - 1o m high: 7o kg/m^2
- for constructions 1o - 3o m high: 9o kg/m^2

Max. snowload: 75 kg/m^2

Remarks:

The area is within seismic zone according to Mercalli-Cancani-Sieberg scale, zone VI.

Purchaser to mark X in info - column where data required in vendor's proposal

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Date										

Dimension of Gasometer

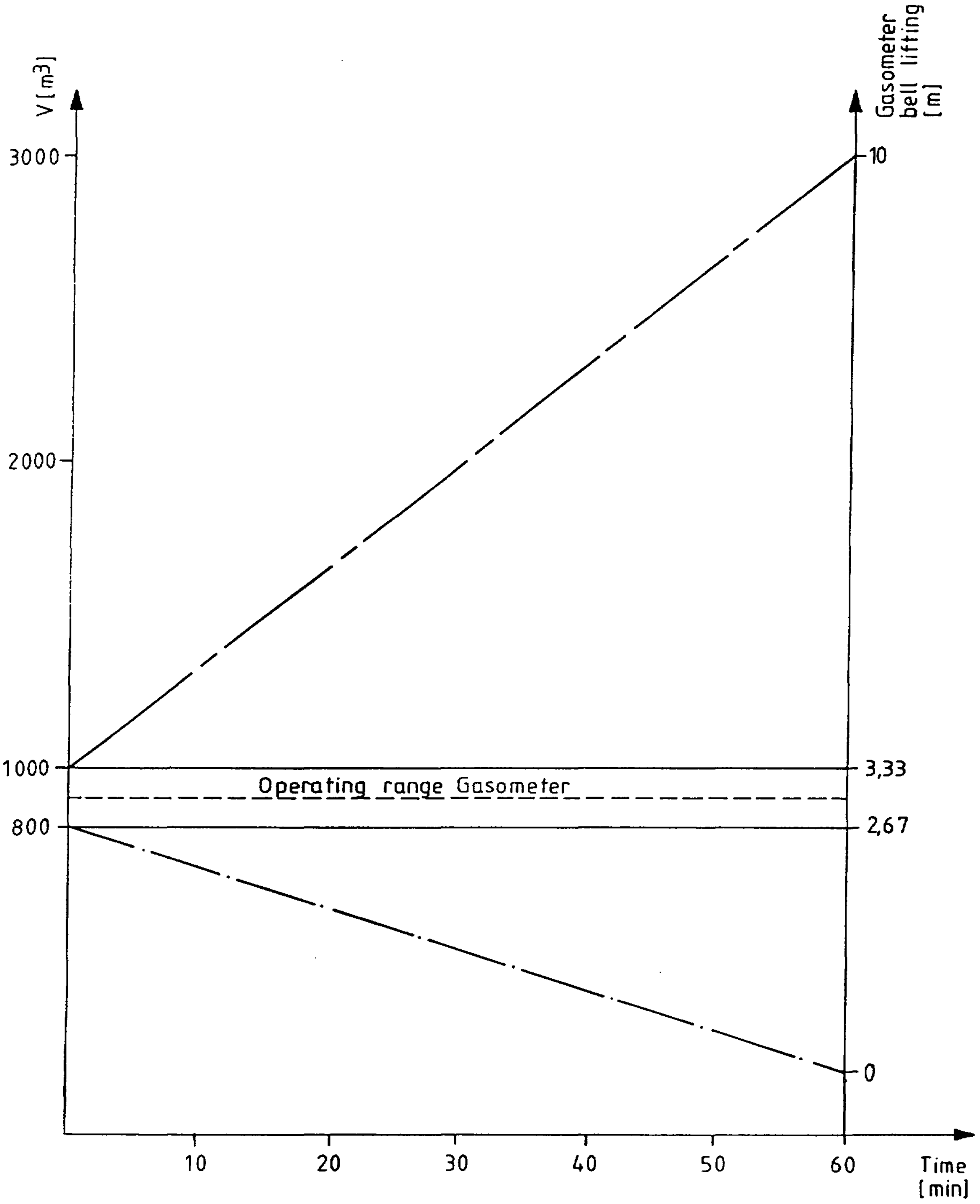

Diagram 2

Flare gas according to gas analysis, page 5, shall be compressed by a 2-step screw compressor.

To the scope of delivery of the screw compressor unit belongs one jet gas washer, respectively before and behind the first step where heavy benzine or reformer benzine will be used as wash liquid and the end cooler with separator after the second compressor step.

A speed controlled electrical motor drive, Type B3 also belongs to the scope of delivery of the compressor. Screw compressor and electrical motor have to be delivered skid mounted. A separate specification exists for the jet gas washers and the electrical motor.

The compressors have to be planned for a dead-man-station, that is, there will be no staff at location. The plant will be controlled and supervised by a central station. At location, there is a control switchboard.

The whole plant is in the ex-zone-sector.

Purchaser to mark X in info - column where data required in vendor's proposal

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4. Compressor System

The 2-stroke flare gas compressor plant consists of the following equipment components per stroke:

- Gas washer 1 (jet washer) with petrol wash liquid
- Screw compressor 1. step with possibility of petrol injection
- Gas washer 2 (jet washer) with petrol wash liquid
- Screw compressor 2. step with possibility of petrol injection
- Gas cooler
- Separator
- Integrated control system with speed controlled motor

The dimensioning is effected for a flare gas quantity of 2.ooo Nm³/h and a compressor end pressure of 16 bar a.

The 2-step screw compressor fulfills the demand to reach an optimal recovery of the condensed HC-components as well by feeding in the flare gas with 7 bar a into the fuel gas system as by a 16 bar a compressor end pressure.

By the speed control of the screw compressors in the sector between loo % and 5o %, a control of the quantity in the sector between loo % and 4o % is possible.

The compressor speed control will be effected by increase of the gasometer bell.

Below a gas quantity of 4o %, the screw compressor pumps the flare gas by means of a bypass back to the gasometer.

Both screw compressors will be equipped with an ever moving equipment and each compressor step gets the possibility of petrol injection for cooling and prevention of incrustation.

In order to remove the unsaturated HC-components from the flare gas by gas washers, ca. 1 m³/h of petrol wash liquid per washer is required.

All mentioned equipment components of the compressor system belong to the scope of delivery of the srew compressor producer.

7								
8			Operating point nr.	☒ = norm. oper point	☒	☐	☐	☐
9			Process stage		1 | 2	1 | 2	1 | 2	1 | 2
10			Model designation					
11			Gas designation (see data sheet 202)					
12			Designation of operating point		100% speed	100% speed	50% speed	50% speed
13			Guarantee point		☒	☐	☐	☐
14			Nr. of units for service					
15			Nr. of stand-by units					
16			Inlet mass-flow capacity	☐ kg/s ☒ kg/h	4.300	4.300	1700	1700
17			Discharge mass-flow capacity	Nm³/h	2.000	2.000	800	800
18				☐ kg/s ☐ kg/h				
19			Mass-flow capacity tolerance	%				
20			Inlet-volume capacity	☐ m³/s ☒ m³/h	2.300	2.300	900	900
21			Inlet-volume capacity tolerance	%	+/- 0			
22			Inlet-vol. cap. at surge limit	☐ m³/s ☐ m³/h				
23			Inlet absolute total press.	bar a	1,01 | 4,5	1,01 | 3,8	1,01 | 4,5	1,01 | 3,8
24			Inlet total temperature	°C	40 | 40	40 | 40	40 | 40	40 | 40
25		X	k (= cp/cv for ideal gases only) 1)					
26		X	Z (= p·v/R·T)					
27			Discharge absolute total press.	bar	4,6 | 16	3,9 | 7	4,6 | 16	3,9 | 7
28		X	Discharge total temperature	°C				
29			k (= cp/cv for ideal gases only) 1)					
30			Z (= p·v/R·T)					
31			Absolute backpress. on relief valve	bar				
32			Shaft input power	kW				
33			Specific power consumption	J/m³				
34			Specific power tolerance	%				
35		X	Compressor shaft speed	☐ s⁻¹ ☒ min.⁻¹				
36			Driver coupling power	kW				
37		X	Combined driver coupling power (with gear)	kW				
38		X	Recommended driver power	kW				
39			Driver shaft speed	☐ s⁻¹ ☒ min.⁻¹	~ 3.000			
40			Type of driver	☒ electric motor	☐ steam turbine		☐ gas turbine	
41				☐ diesel engine	☐ gas engine		☐ expander	
42				☒ other: variable speed motor driver recommended				
43			Manufacturer of driver: ____				Supplier: ○ P ☒ V	
44		X	Inlet point	☐ standard (see code § 1.4.4)				
45				☐ other: ____				
46		X	Discharge point	☐ standard (see code § 1.4.4)				
47				☐ other: ____				
48		X	Attendance interval:	☐ 1 hour	☐ 4 hours		☐ 8 hours	☐ 24 hours
49				☐ no routine attendance				
50		X	Service	☐ 3 shifts	☐ 1 shift		☐ intermittent	☐ other: ____
51								
52			1) $p \cdot V^{k_i}$ = const. for isentropic change of state					
53								
54			Purchaser to mark X in info - column where data required in vendor's proposal					

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5. HC-Condensate Collecting vessel and HC-Condensate Pumps

The HC-condensate and the petrol wash liquid from the jet washers before and behind the first compressor step will be pumped into collecting vessels, from there into a separation vessel where the liquified hydrocarbons will be separated by water. From the separation vessel, the liquid phase will be pumped to the plants S-5oo and S-25oo for purpose of further processing.

All HC-condensate collecting and separation vessels will be equipped with a lift gas connection.

The HC-condensate pumps will be equipped with an axial face seal and a quench oil system.

6. MSR-Equipment

The MSR-equipment consists of:

- Flare supervision with camera and monitor
- Pressure-, quantity-, temperature and niveau transmitter
- Control valves with actuator
- Microprocessor-controlled, decentral MSR-system (central station, colour video system, colour monitor, record printer)

Appendix 4.6

INVESTMENT ACTIVITIES IN PANČEVO PETROLEUM REFINERY

1. Fluidized Catalytic Cracking Unit (FCC) reconstruction

This reconstruction shall include the following:
- Replacement of double, bent risers with vertical riser
- Installing of Texaco feed injectors
- Installing of close-coupled cyclones in reactor and regenerator vessels
- Installing of regenerator air dispersion grid
- Modification of wet gas compressor
- Modification of air compressor

This project shall be completed in 3 phases.
Total Investments:
US $ 15.400.000

2. Vacuum Distillation Unit Reconstruction

The reconstruction shall include:
- Replacement of vacuum column internals
- Replacement of ejector system
- Replacement of heater control system
- Replacement of vacuum column control system

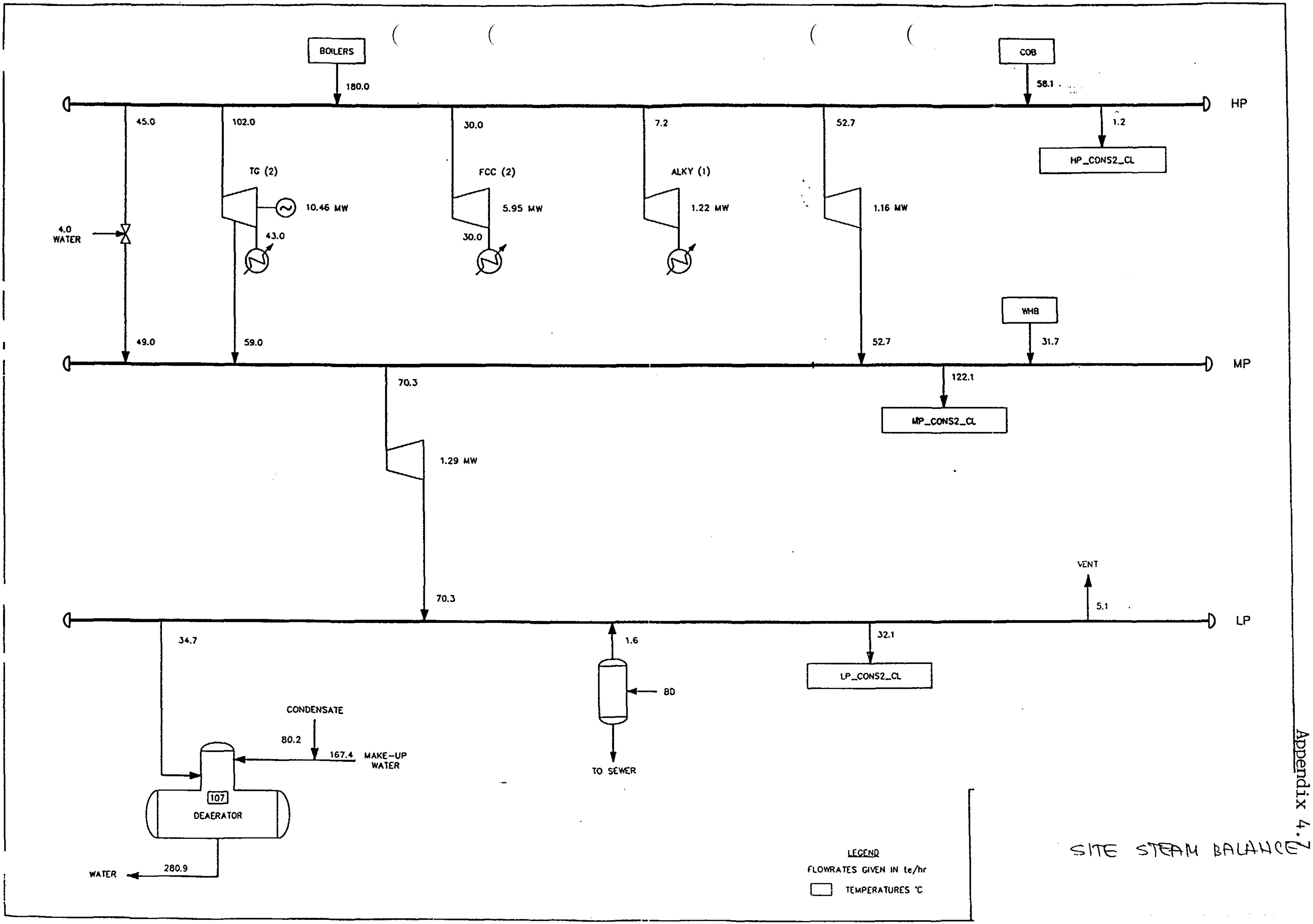
Preliminary project is being prepared.
Total investments:
US $ 3.600.000

3. Thermal integration of Crude Unit, Vacuum Unit and Visbreaking Unit

- Integration of these three units is aimed at optimum available heat exchange and fuel oil consuption decrease.
- Hot vacuum unit supply and heater inlet temperature increase by 85 °C
- Hot visbreaking unit supply and heater feed inlet temperature increase by 33 °C
- Increase of heater crude inlet temperature by 20 °C
- Installation of computer control system for all three units.

Feasibility Study is being prepared.
Total investments:
US $ 1.500.000

Appendix 4.7



SITE STEAM BALANCE

OIL REFINERY - BOILER HOUSE

1. Design Data and Present Case

1.1 Boiler House

Schematic description of boiler house is shown in Figure 1. Three boilers are installed in the boiler house. The boilers are fired typically with heavy fuel oil with 2.5 - 3.0% of sulphur (burner designed value of sulphur is up to 5%) and the oil is preheated to proper temperature for kinematic viscosity of 25 cS (centi Stocks). Usual temperature of oil is about 110-130 °C before entering the burners. The oil from the supplier is pumped into service tanks and the oil is preheated of steam. Alternatively the boilers could be run by gasoline (occasionally and during the start up procedure).

Each boiler is equipped with four pressure-jet atomizing oil burner made by HAMWORTHY, UK, and the maximum capacity of each burner is 1,320 kg/h for heavy fuel oil and 1,272 kg/h for gasoline.

Boiler design data of all three boilers are as follows:

Type:	Integral water tube boiler
Manufacturer:	John Thompson, UK
Installed:	1968
Steam Pressure:	45.5 barg
Steam Temperature:	412 °C
Feed Water Temperature:	108 °C
Capacity:	70.8 t/h
Design flue gas temperature:	177 °C

During the audit an efficient tests of boiler No.2 and No.3 were made. Boiler No.1 was out of operation during the audit. The results are presented in Table 1 for boiler No.2 and Table 2 for boiler No.3.

The surface temperatures of these two boilers were from 75 to 105 °C, which means that the radiation losses were 4-5%, which is over normal values.

Battery limit for performed audit is shown in Figure 2. All desired measuring points are shown as well. However, there were no possibilities to made all necessary measurements. The possible measurements using existing instrumentations are shown in Table 3 (boiler No.2) and Table 4 (boiler No.3).

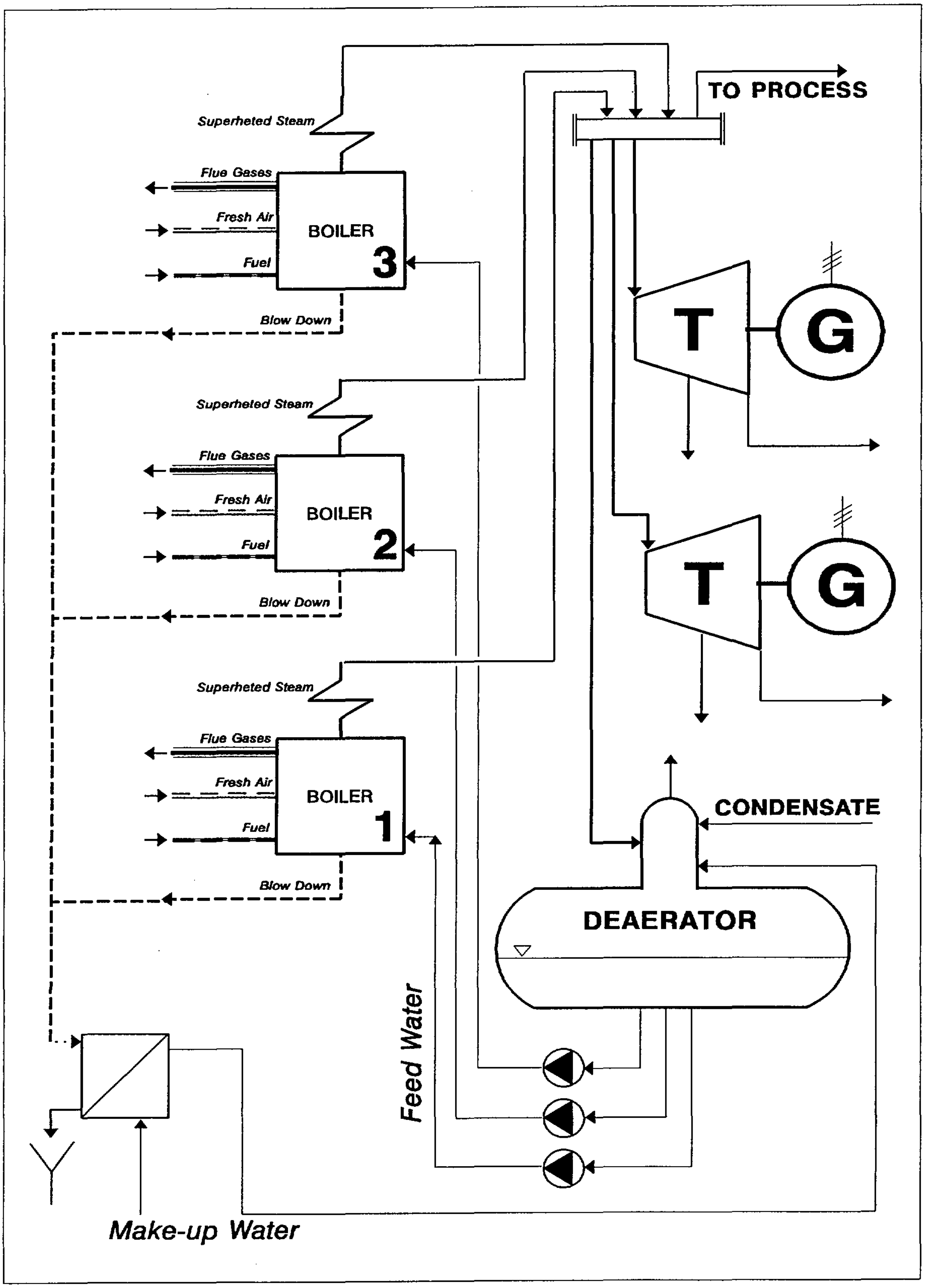


Figure 1: Schematic description of the boiler house

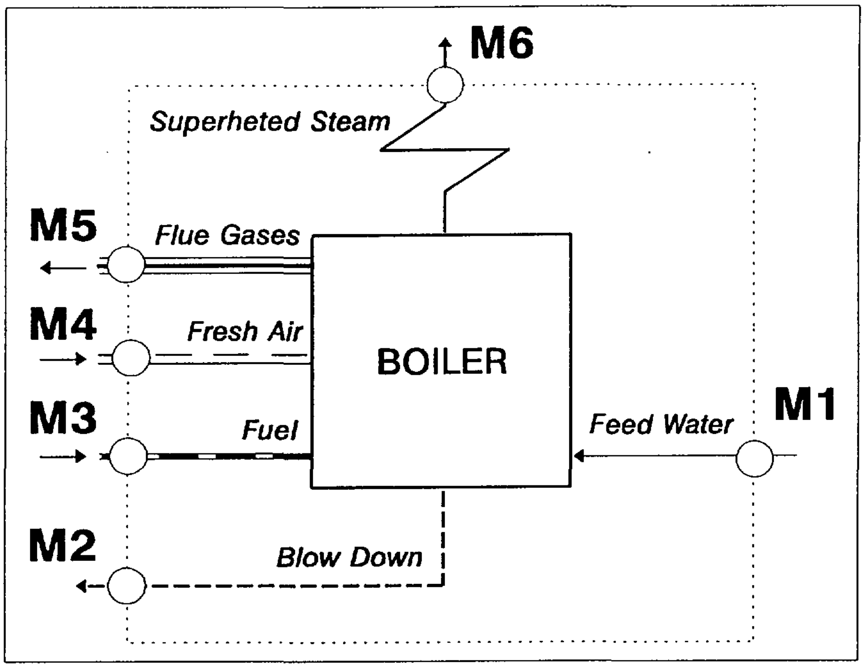


Figure 2: Battery limit of the boiler

Table 1: Flue gas analysis for boiler No.2

Company:	Oil Refinery, Panchevo
Location:	Boiler House, BOILER No. 2
Date and Time:	October 30, 1996 (10:55 - 11:49)
Fuel:	Heavy Fuel Oil
Net Calorific Value:	41,181 kJ/kg (this is value measured on the day of the audit)
Sulphur content in a fuel oil:	1.33%

Measured value	Units	Measurements (5-10 min intervals)							Average value
		1	2	3	4	5	6	7	
Ambient temperature	°C	26	27	28	29	29	30	31	28.57
Flue gas temperature	°C	199	198	196	200	197	197	200	198.14
Flue gas contents	CO_2	11.3	11.7	11.5	11.6	11.2	11.3	11.2	11.40
	O_2	6.1	5.6	5.8	5.7	6.2	6.1	6.3	5.97
	CO	147	215	236	252	260	250	244	229.14
	NO_x	410	419	426	427	419	435	467	429.00
	SO_2	421	451	459	480	468	484	482	463.57
C. Efficiency	%	91.1	91.5	91.4	91.4	91.2	91.4	91.2	91.31
Excess air	-	1.41	1.37	1.38	1.37	1.42	1.41	1.43	1.40

Table 2: Flue gas analysis for boiler No.3

Company:	Oil Refinery, Panchevo
Location:	Boiler House, BOILER No. 3
Date and Time:	October 30, 1996 (12:04 - 12:27)
Fuel:	Heavy Fuel Oil
Net Calorific Value:	41,181 kJ/kg (this is value measured on the day of the audit)
Sulphur content in a fuel oil:	1.33%

Measured value	Units	Measurements (5-10 min intervals)							Average value
		1	2	3	4	5	6	7	
Ambient temperature	°C	31	31	31	-	-	-	-	31.00
Flue gas temperature	°C	200	200	202	-	-	-	-	200.67
Flue gas contents	CO_2	10.5	10.2	10.5	-	-	-	-	10.40
	O_2	7.2	7.5	7.2	-	-	-	-	7.30
	CO	165	178	178	-	-	-	-	173.67
	NO_x	386	407	413	-	-	-	-	402.00
	SO_2	428	415	411	-	-	-	-	418.00
C. Efficiency	%	90.6	90.3	90.5	-	-	-	-	90.47
Excess air	-	1.52	1.55	1.52	-	-	-	-	1.53

Table 3: Measuring data from the existing instrumentations (boiler No.2)

Measuring point	Measured value	Time				Average value
		11:20	11:40	11:55	12:20	
M1	t_1 [°C]	110	110	110	110	110.00
	p_1 [bar]	67	67	67	68	67.25
M2	m_2 [t/h]					
	t_2 [°C]					
M3	m_3 [t/h]	4.5	4.5	4.2	4.2	4.35
	t_3 [°C]	130	130	130	130	130.00
M4	t_4 [°C]	22	22	23	23	22.50
M5	t_5 [°C]	190	190	-	189	189.67
M6	m_6 [t/h]	67	67	64	65	65.75
	t_6 [°C]	45	46	46	46.5	45.88
	p_6 [bar]	410	410	410	410	410.00

Table 4: Measuring data from the existing instrumentations (boiler No.3)

Measuring point	Measured value	Time				Average value
		11:25	11:45	12:00	12:20	
M1	t_1 [°C]	110	110	110	110	110.00
	p_1 [bar]	67	67	68	68	67.50
M2	m_2 [t/h]					
	t_2 [°C]					
M3	m_3 [t/h]	4.5	4.35	4.35	4.3	4.38
	t_3 [°C]	130	130	130	130	130.00
M4	t_4 [°C]	23	23	24	24	23.50
M5	t_5 [°C]	199	199	200	200	199.50
M6	m_6 [t/h]	58	54	54	52.5	54.63
	t_6 [°C]	45	46	47	46	46.00
	p_6 [bar]	390	385	385	386	386.50

1.2 Feed Water System

The feed water tank is located under the roof and is insulated. The return condensate has a temperature of 36 °C from turbines condenser and from 80 to 90 °C from some processes in boiler house. All condensate from processes in the Refinery is wasted! The feed water to boilers is about 108-110 °C.

There is a continuous process of desalination in the boiler drum which uses 3-4% of the total steam production. About 40% of produced condensate during the desalination is recovered in the form of flush steam and the rest is used for preheating the make-up water in a heat exchanger.

The blowdown at the boiler are performed three times per day. The blowdown operation is performed manually.

1.3 Turbines and Generators for Electricity Production

To condensate turbines for electricity production are in use. Turbine design data are as follows:

Type: Condensate
Manufacturer: The English Electric Company, UK
Installed: 1968
Steam Mass Flow Rate (high pressure): 51.0 t/h
Steam Pressure (high): 44.5 barg
Steam Temperature: 400 °C
Steam Extraction: 16.5 barg
Steam Temperature (at extraction point): 280-300 °C
Condensation vacuum: 710 mmHg

Generator design data are as follows:

Manufacturer:	The English Electric Company, UK
Installed:	1968
Voltage:	6,000 V
Power:	6.0 MW

1.4 Steam and Condensate System

The steam is distributed at a pressures of: 1) 45.5 barg, 412 °C, 70.8 t/h to the turbines for electricity production and to the process; 2) reduced by throttling and/or extracting from turbines up to 16.5 barg and is used in the process; and, 3) reduced to 4 bar for processes (heating of the tanks, premises, etc.). Condensate from turbines at 36 °C is returned to the boilers.

Steam and condensate leakages are huge and the steam traps are in a very poor condition. Some condensate is polluted and it is wasted although it has a rather high temperature. Because of that a small amount of condensate is returned to the boiler house (min 10% and max 50%, depending on the electricity production). That means that a lot of make-up water is used and a lot of energy and chemicals are used for its preparation.

1.5 Daily Production Report of Boiler House

A typical daily production report in boiler house contains only temperatures and pressures in different point of the plant and very restricted number of flows of steam and water and some power values concerning electrical production. That means that there is no possibilities to make energy balance of the plant either in total or some insulated part of plant.

2. Energy Conservation Measures and Discussion of Collecting Data

Energy conservation measures can be grouped into six categories:

- Housekeeping and operational Improvements;
- Combustion and Steam System Improvements;
- Waste heat recovery and reuse;
- Electric system improvements;
- Process modification;
- Cogeneration.

In this Chapter only the possibility of implementation of first three categories will be discussed. Only after implementation of proposed measures prescribed by this three categories one can have reliable entering data for further consideration of last two categories. The forth category is not the first priority one at the moment.

A walk-through energy audit cannot result in either an energy balance or evaluated energy conservation measures. What can be done and what has been the aim of this walk-through audit is to get a general view of the energy situation at the plant and to find out in which energy system possible and feasible energy conservation measures exist.

Concerning this refinery, the following n/l cost measures have to be implemented without delay because it can result in 15-20% energy savings. This analyses deals with the boiler house and the steam and condensate distribution systems.

2.1 Housekeeping Procedure

Existing housekeeping procedure is not effective and, which means that it is not efficient as well. A lot of leakages were found in the steam and condensate distribution system. There are hundreds of steam traps and only a small number of them operate properly. A flash steam is allowed to blow to waste (condensate tanks). There are a lot contaminated condensate which can be recovered by using heat exchangers, but now they are wasted.

About 5-10% of all steam and condensate pipelines are not insulated. Some pipes are damaged by corrosion and produce other leakages. There are a lot of non insulated valves and flanges. Many important steam leaks are hidden such as: a) leaking or stuck traps or by-pass valves discharging to sewer or condensate system; b) leaking valves leading to idle equipment; and c) leaks in heater or other equipment connected to the steam system.

Housekeeping includes measures to reduce energy use that can readily be taken by plant engineer or plant operator at little or no cost and in a short time. Examples of simple housekeeping are shutting of standby furnaces, inspecting combustion equipment, adjusting burners, and inspecting and repairing steam traps - preferably on a routine basis. At a slightly more advanced level, the operation of process equipment can be rescheduled to avoid frequent startups and shutdowns - generally, continuous operation is energetically more efficient than intermittent operation - or equipment can be adjusted to operate at the lowest economical temperature. Improving insulation becomes part of housekeeping if materials costs are low and the payback period is shorter than a year. For example, if the surface temperature of currently insulated steam lines or liquid piping exceeds 40 °C, the insulation should be upgraded. Damaged insulation can result in much heat loss, so regular inspection of distribution lines is desirable. Combustion efficiency is major area of potential operational savings, as 1 - 5% of fuel used can be saved by regular tune-up of the air-to-fuel ratio. Modern technology enables fuel-to-air ratios to be maintained at recommended levels at all times, ensuring consistent combustion efficiency. Microprocessor controlled servo motors fitted to fuel valves and air dampers replace the traditional methods of control, providing a programmable system which will automatically select and maintain the fuel-to-air ratio specific to a particular fuel.

The flue gas temperature of the boiler was about 200 °C at both boilers. This temperature is higher then designed one (177 °C). This suggest that it is possible that boiler tubes become fouled by soot and deposits and the amount of heat transferred from the hot flue gases to the water is reduced. There is a rule which says that an increase of around 20 °C above that temperature for a clean boiler means that the tubes must be cleaned. A rise of 17 °C causes a decrease in efficiency of 1 %.

Any discussion on energy conservation in this Refinery has to start with housekeeping procedures.

2.2 Monitoring

Monitoring itself will not lead to energy savings unless the data is analyzed and put in the context within the company or establishment.

Monitoring system in this refinery is not reliable and complete and it is not used for energy analysis. It is used only for running the process. Instrumentation used are not in such a good condition. For example, output mass flow rate of steam of boiler No.3 is *greater* than the mass flow rate of feed water at the same boiler! The difference is about 10%. Or, using the measuring data (Table 3 and 4) one can calculate that the boiler efficiency is greater than 1.0 (cca 1.02 - 1.03).

Boiler efficiency measurements (Table 1 and 2) indicates that the CO content in flue gases is high. That means that incombustible fuel exists in flue gases. The reason could be inefficient atomization in the burner. The excess air is higher than it is normal. There is no O_2 (or CO_2) control system. The NO_x and SO_2 contents are to high. Burners has to be checked and/or repaired.

Measuring system of steam from boilers has to be re-calibrate or replaced. The same has to be done with fuel consumption metering system. The ratio of steam to fuel is the main measure of efficiency of the boiler and it should be measured and maintained at a high level, compatible with good practice.

The blow-down is performed manually. An automatic system has to be implemented.

Continuously log boiler performance has to be done so that signs of deterioration soon become evident, enabling corrective maintenance to be carried out.

Meter feed water has to be re-calibrated or replaced.

2.3 Air Preheating

There is no air preheaters in subject boiler house. The air is sucked from the bottom of the boiler room. The temperature in that part of the room during the audit was 21 °C and under the roof of the room it was 35 °C. The thermal efficiency of a boiler plant could be increased by 1% if the combustion air temperature was raised a further 20%. In the case of this refinery it means that only simple reconstruction of air intake (from bottom to the roof) could increase the boiler efficiency for about 0.5%.

2.4 Economizer

There is no economizer in boiler house. Economizer for preheating boiler feed water is generally a very attractive investment. But, in this case any discussion on feed water preheating must be followed after performing the improvement of steam and condensate distribution system. After this, it is possible to calculate the real size of the economizer.

2.5 Condensate Recovery

If the feed water temperature is low, the cause should be discovered. It should be due to:

- a low rate of condensate return;
- the lack of insulation on the condensate return pipes;
- losses from the feed water either as heat through the walls or as overflow.

As much condensate as is economically possible should be returned from sources where there is no likelihood of contamination. This will save heat, make-up water and chemicals used in water treatment, as well as reduce blowdown losses. The possible fuel savings resulting from increased condensate return are shown in Figure 3. The make-up water in this case is 15 °C and assumed temperature of returned condensate is 90 °C. The boiler fuel saved is calculated using the basic consumption when there is no condensate returned.

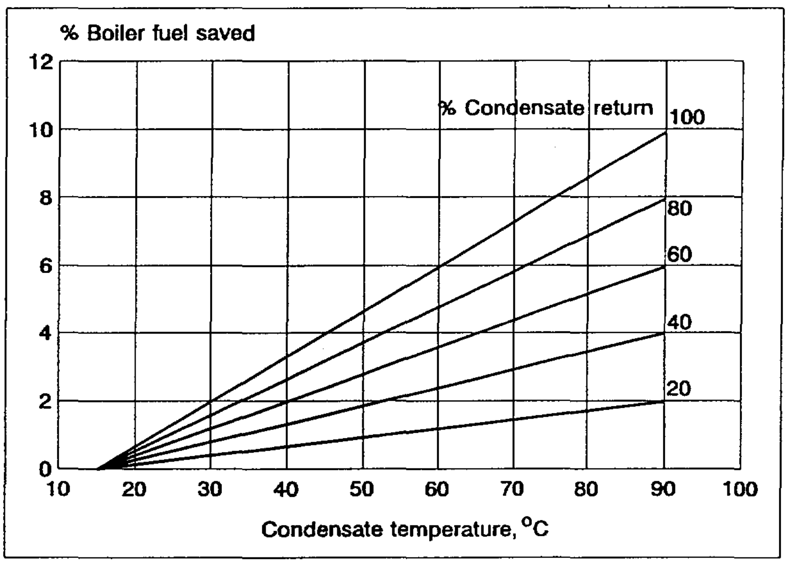


Figure 3: Fuel saved by condensate return

The case of this refinery only the condensate from condensing turbines is returned. The rest of the condensate is wasted. Returning the condensate directly into the boiler or, if it is contaminated, by using the heat exchanger or by automatic dumping by measuring the conductivity, it is possible to save fuel from 5% for 50% returned condensate to 9% for 90% returned condensate.

3. Conclusion and Recommendation

3.1 Flue gas analysis shows that the tested boilers operate with lower content of carbon dioxide: 11.40% for Boiler No.2 and 10.40% for Boiler No.3. The normal content of carbon dioxide for the heavy fuel oil is minimum 13%. Consequently the content of the oxygen is higher than it is normal (4%). Oil burners should be able to operate down to 1.15 excess air with upper limit of about 1.20. That means that in refinery case boilers operate with higher excess air (1.40 and 1.53). The content of CO is a little bit higher than it is normal, but having in mind that the excess air is higher it means that incombustible fuel is in flue gas.

The measured flue gas temperatures are higher than designed one (177 °C), which pointed out that the heat transfer surfaces has to be cleaned. This temperature would be much higher if the excess air is reduced to the normal value.

Suggestion actions are to:

a) Repair or replace the nozzles of the burners and check the pressure before the burners.

b) Improve combustion control by installing the control system for fuel-to-air ratio by measuring CO_2 or O_2.

By improving the combustion system the level of SO_2 and NO_x will be reduced as well.

c) Cleanliness of heat transfer surfaces and control the flue gas temperature history. Any increase of flue gas temperature will be recognised and proper action can be done.

3.2 Improve the metering system for feed water supplying, steam production and distribution to the main consumers. Establish the metering system for condensate returning.

Control of the make up water has to be improved. If the quality of water treatment is improved and the proportion of returned condensate is increased, this should reduce the amount of blowdown necessary.

3.3 The temperatures of the boiler surfaces are higher than it is normal. At some points it was about 130 °C. The insulation of the boiler has to be checked and repaired. It could decrease the radiation losses for about 1.0-1.5%.

3.4 The boiler efficiency is (both boilers):

Flue gas loses	14.2-14.8%
Radiation losses	4%
Blow down loss	3%

Total: 78.2 - 78.8%

By performing the suggested action in items 3.1-3.3 the boiler efficiency could be increased for 5-6%. The pay back period for this is normally less then one year.

3.5 The next step of improving the total efficiency of the boiler house could be the analysis of possibility to use flue gases for preheating the make up water or combustion air. Both options are feasible. Efficiency improvements of about 5% are common for economizer units installed, often producing pay back period of 1-2 years. the installation of the air preheater is more expensive and the pay back period is longer.

3.6 The steam distribution system is in a very bad situation. That means that detailed reparation of the system must be done. All steam traps and valves have to be checked, repaired or replaced. Insulation must be checked as well and put on the uninsulated pipelines, valves and flanges. Corroded pipelines have to be replaced.

Just to illustrate the effect of a leak consider the following:

Steam pressure 7 bar and hole size 0.8 mm produce the loss equivalent up to 1,500 litres of oil per year.

Or, to illustrate the loss through uninsulated surface and flanges, the following example could be used:

- A 3 m length of exposed 150 mm diameter piping carrying steam at a pressure of 7 bar can waste 3,000 litres of oil per year.
- If there were five uninsulated flanges on the same 150 mm diameter pipe, heat losses would equate to another 3,000 litres of oil being wasted a year.

During the audit it was very difficult to count the number of leaks and uninsulated places. However, there is no doubt that a great energy saving potential is in improving the steam distribution system. The common pay back period for this typical housekeeping procedure is less than one year. Expected effect of efficiency improvement of steam mains in this refinery could be up to 10%.

3.7 As it was mentioned, the condensate from the processes are wasted. Only the turbine condensate is returned to the boilers. That means that only 10 to 50% is returned, depending of electricity production. At the moment there is no economical reasons for increasing the electricity production because of low electricity prices.

Possible boiler fuel saving by returning the condensate is from 5 to 9%.

3.8 Total expected energy savings in boiler house and steam and condensate system could be estimated in the range of 15-20% with pay back period about 2 years.

Appendix 4.9

Furnace efficiency improvement.

During the audit the measurement of combustion efficiency of the baggiest furnace in refinery installed in the New Crude Unit was performed. The results are shown in Table 1.

Table 1: Flue gas analysis for furnace in New Crude Unit

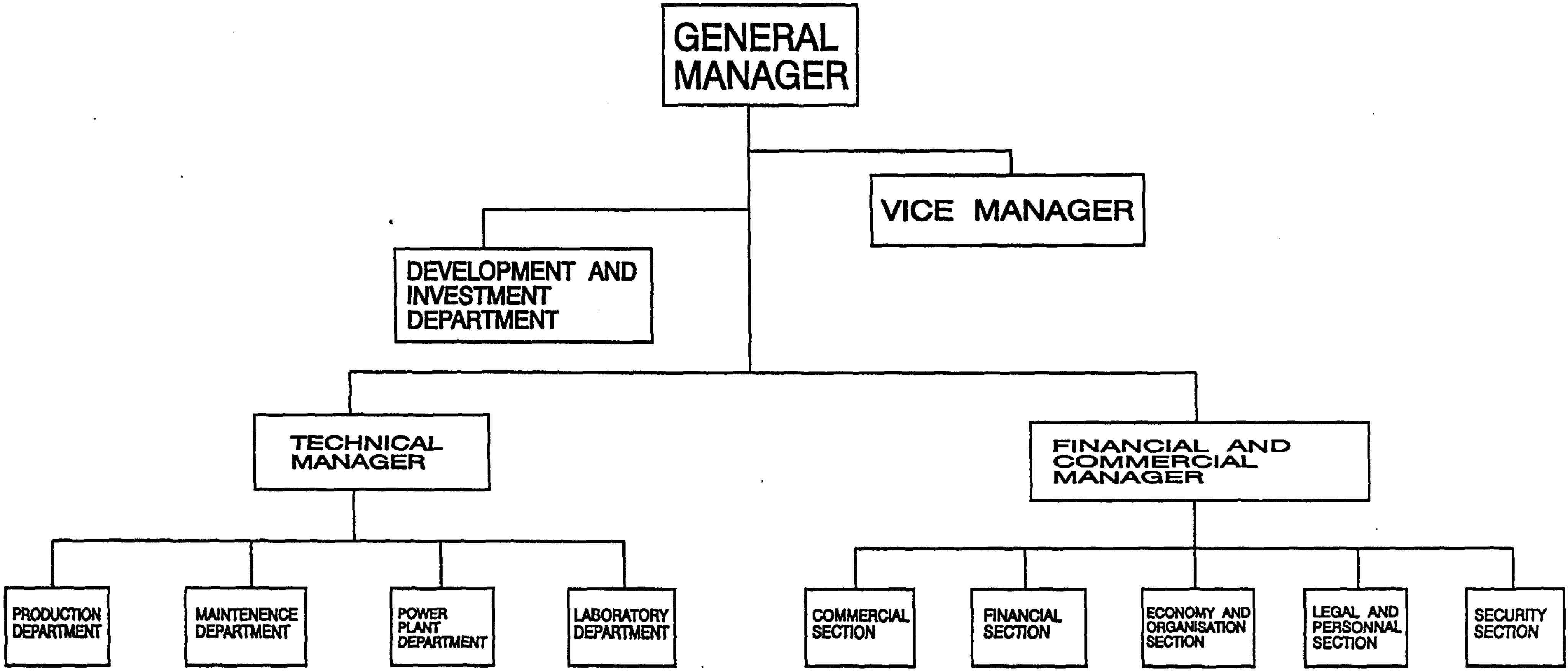
Company:	Refinery, Panchevo
Location:	New Crude Unit, Furnace BA 2101
Date and Time:	October 30, 1996 (13:15 - 14:20)
Fuel:	Fuel Gas & Oil

Measured value		Units	Time						Average value
			Zone I		Zone II		Zone III		
			13:15	13:17	13:52	13:55	14:14	14:20	
Ambient temperature		C	23	23	21	20	23	23	22.17
Flue gas temperature		C	421	421	205	208	187	192	272.33
Flue gas contents	CO_2	%	12.1	12.1	7.8	7.9	4.8	5.0	8.28
	O_2	%	5.1	5.1	10.7	10.6	14.7	14.4	11.27
	CO	ppm	91	90	53	56	33	38	60.17
	NO_x	ppm	221	226	149	152	90	100	156.33
	SO_2	ppm	95	102	39	39	22	33	55.00
C. Efficiency		%	80.7	80.7	86.2	86.1	80.0	80.2	82.32
Excess air		-	1.32	1.32	2.04	2.02	3.37	3.21	2.21

In an earlier study, the furnace efficiencies were found to be between 57% and 85%.

The results show the very poor combustion process in this furnace which results in non-uniform temperatures in the furnace. The excess air in Zones II and III is too high which results in low temperatures of the flue gases. The values of CO_2 and O_2 contents show that the combustion process is without proper control. The measured efficiencies mentioned above prove the fact of the low efficiencies of the furnaces in this refinery.

ORGANIZATION OF REFINERY



Appendix 4.10

Environment affairs, safety work and fair fighting section are in Production Department.
Part of environment affairs are in Development / Investment Department.

FUEL CONSUPTION IN PANČEVO REFINERY AND EMISSIONS OF POLLUTANTS

		Crude Unit I S-100	Crude Unit II S-2100	Vacum Unit S-2200	Visbreaking S-200	Platforming S-300	HDS-I S-400	HDS-II S-2400	FCC S-2300	SUlphur Unit-Claus S-2450	Bitumene S-0250	Power plant
1.	Design capacity of unit (t/d)	4.000	10.600	6.700	3.470	1.050	500	1.400	3.000	56 (sulphur)	200-1.000	3x60 t/h steam (44,6 bar)
2.	Type of fuel	fuel oil/fuel gas	fuel oil/fuel gas	fuel oil	fuel oil/fuel gas	fuel gas	fuel gas	fuel gas	fuel gas	fuel gas	fuel gas	fuel oil
3.	Sulphur content in fuel (%wt)	2/0,9	2/0,9	2	2/0,9	0,9	0,9	0,01	0,01	0,01	0,9	2
4.	Average fuel consuption per unit of charge (kg/t)	11,0/2,25	5,14/5,19	13,1	21,0/0,1	59,5	24,5	9,51	63,5	20,3	16,0	76,8
5.	Average emission of SO_2 (kg/h)	56,7	107,5	96,6	77,5	43,5	5,4	0,03	116,6	49,6	5,7	416,0
6.	Average emission of NO_x (kg/h)	9,5	16,4	14,6	11,8	6,7	0,8	0,5	37,5	-	-	69,0
7.	Average emission of solid particles (kg/h)	-	-	-	-	-	-	-	20,8	-	-	-
8.	Height of heater stack (m)	40	45	150	50	40	30	30	150	150	30	36,5
9.	Diameter of heater stack (m)	1,6	2,25	2,4	2,4	1,8	1,8	1,8	2,4	2,4	1,8	1,8
10	Volume of heater combustion chamber (m^3)	300	1.360	1.600	490	(457+32+81)	2x32	50+44	434	-	-	3x180

Heating value - net of fuel oil: 9.400 - 10.000 Kcal/kg
Heating value - net of fuel gas: 11.200 - 16.000 Kcal/kg

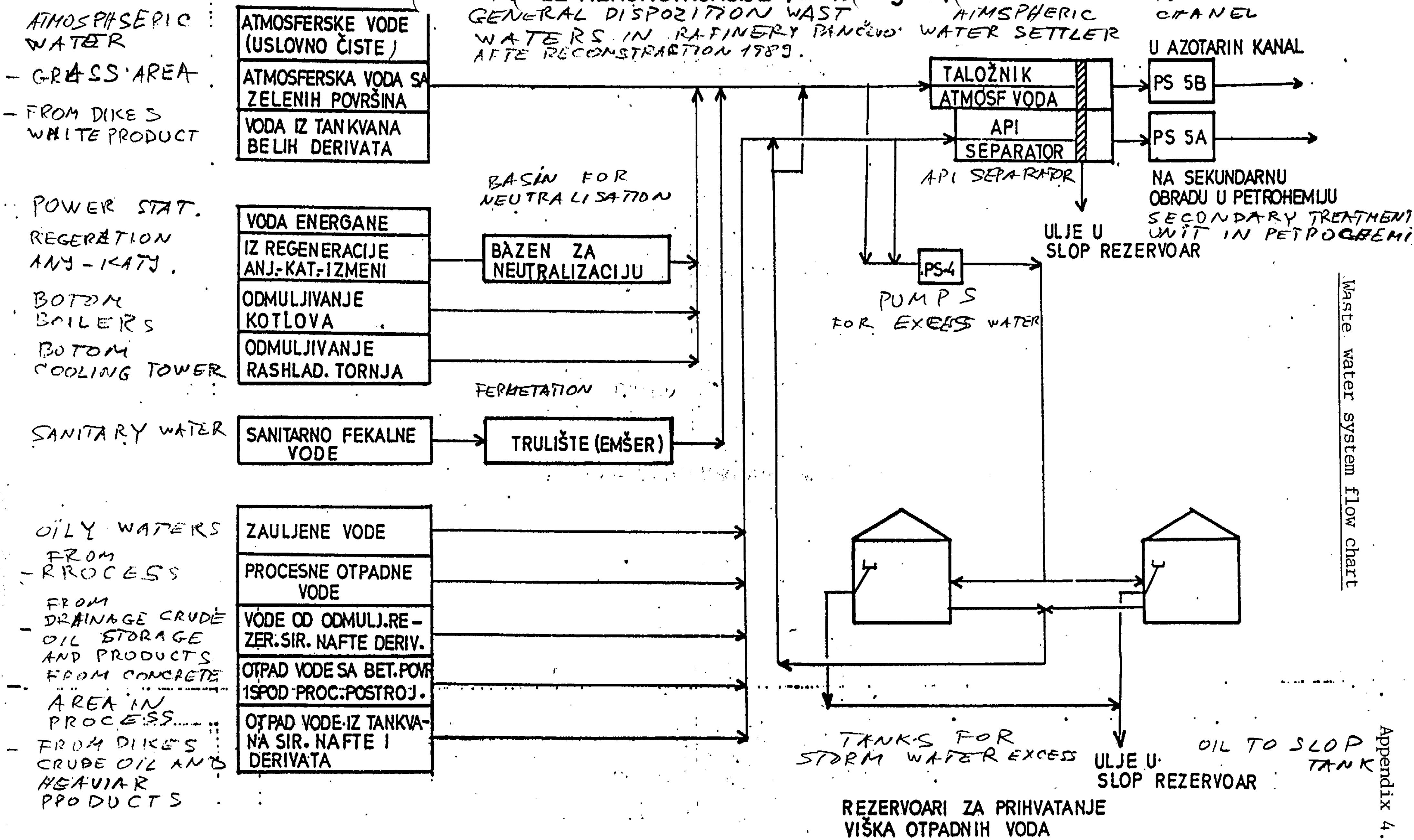
Appendix 4.11

Appendix 4.12

AVERAGE CONCENTRATION OF POLLUTANTS IN FLUE GASES

	SO_2 mg/Nm^3	NO_x mg/Nm^3	Solid particles mg/Nm^3
Crude Unit I	2650	440	
Crude Unit II	1900	300	
Vacum Unit	3000	450	
Visbreaking	3000	460	
Platforming	1500	240	
HDS I	2200	340	
HDS II	25	370	
FCC	1000	320	180
Bitumene	1120	170	
Power Plant	2700	440	

ŠEMA DISPOZICIJE OTPADNIH VODA U RNP PANČEVO
POSLE REKONSTRUKCIJE (iz 198[illegible] god)



PS-4 - PUMPNA STANICA ZA VIŠAK OTPADNIH VODA
PS-5A - PUMPNA STANICA ZA OTPREMU ZAULJENIH VODA
PS-5B - PUMPNA STANICA ZA OTPREMU ATMOSFERSKIH VODA

Sl. 1

Waste water system flow chart

Appendix 4.14

HIP
PETROHEMIJA

Vaš znak:
Naš znak:
Datum:

OSNOVNI PROIZVODI / BASIC PRODUCTS

OSNOVNI PROIZVODI	Projektovani kapacitet t/g Designed capacity t/y	BASIC PRODUCTS
Etilen	200.000	Ethylene
Propilen	85.000	Propylene
C4-frakcija (do 60% butadiena)	45.000	C4-fraction (up to 60% of Butadiene)
Pirolitičko ulje	38.000	Pyrolysis Oil
Pirolitički benzin	138.000	Pyrolysis Gasoline
Hlor	88.800	Chlorine
Natrijum hidroksid (100%)	100.000	Sodium Hydroxide (100 %)
Natrijum hipohlorit	8.000	Sodium Hypochlorite
Vinilhlorid monomer	100.000	Vynil Chloride Monomer
Etilen dihlorid	15.000	Ethylene Dichloride
Hlorovodonična kiselina (min. 28%)	9.600	Hydrochlorid Acid (min. 28%)
Metil tercijarni butil etar - MTBE	35.000	Methyl Tertiary Butyl Ether-MTBE
1,3 butadien	45.000	1.3 Butadiene
Rafinat II	22.000	Raffinate II

POLIMERI / POLYMERS

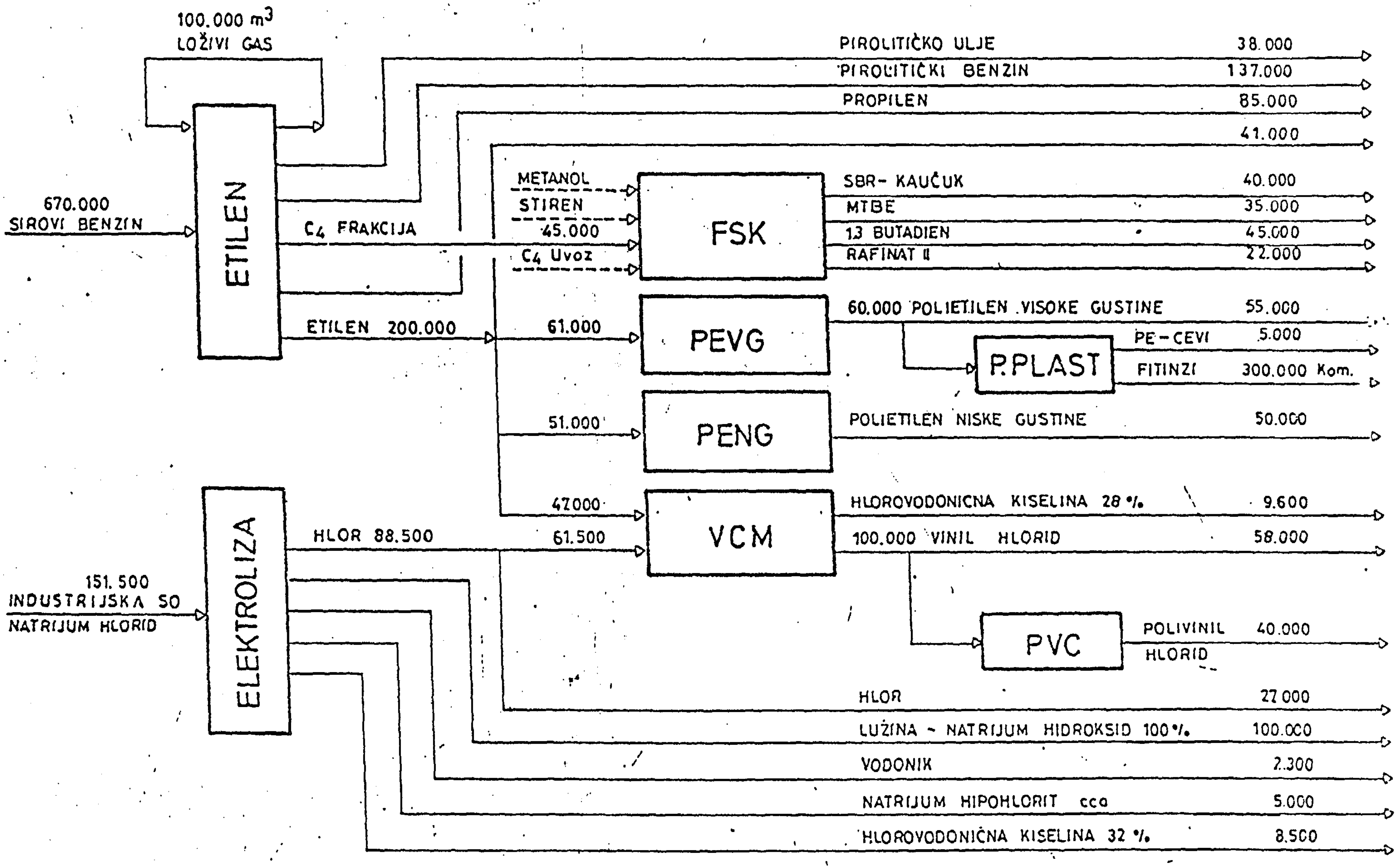
POLIMERI		POLYMERS
HIPLEX -polietilen visoke gustine (PEVG)	50.000	-HIPLEX High Density Polyethylene (HDPE)
HIPTEN -polietilen niske gustine (PENG)	45.000	HIPTEN -Low Density Polyethylene (LDPE)
HIPNIL -polivinilhlorid (PVC)	34.000	HIPNIL -Polyvinyl Chloride (PVC)
HIPREN -stiren butadien kaučuk (SBR)	40.000	HIPREN -Styrene Butadiene Rubber (SBR)

GOTOVI PROIZVODI / FINAL PRODUCTS

GOTOVI PROIZVODI		FINAL PRODUCTS
POLIETILENSKE CEVI		POLYETHYLENE PIPES
-prečnika	20-250 mm	-Diameter
-kapacitet	cca 5.000 t/g (t/y)	-Capacity
-cevi za gas, pritiska	do 4 bara (up to 4 bar)	-Gas Pipes
-cevi za vodovod, pritiska	do 10 bara (up to 10 bar)	-Water Pipes
-cevi za PTT vodove		-PTT Pipes
-cevi za industriju i rudarstvo		-Industry And Mining
ELEKTROFUZIONI FITINZI (spojnice i reducir spojnice, T-komdi, završne kape, kolena, sedla i sedla sa ograrkom)		ELECTROFUSION FITTINGS (couplers, reducers, tees, end caps, elbows, tapping tees, branch saddles)
-prečnika	20-315 mm	-Diameter
-kapacitet	300.000 kom/g (y)	-Capacity
ELEKTROIZOLACIONE REBRASTE CEVI (PVC, PP, PE)		CORRUGATED ELECTRO-INSULATING PIPES (PVC, PP, PE)
-prečnika	16-63 mm	-Diameter
-kapacitet	250 t/g (t/y)	-Capacity

PETROHEMIJA
DRUŠTVENO PREDUZEĆE
SPOLJNOSTARČEVAČKA 82, 26000 PANČEVO, JUGOSLAVIJA, TEL: 013/ 41-665, 510-200, TELEX: 13-181 YU HIP PA, FAX: 013/ 44-187

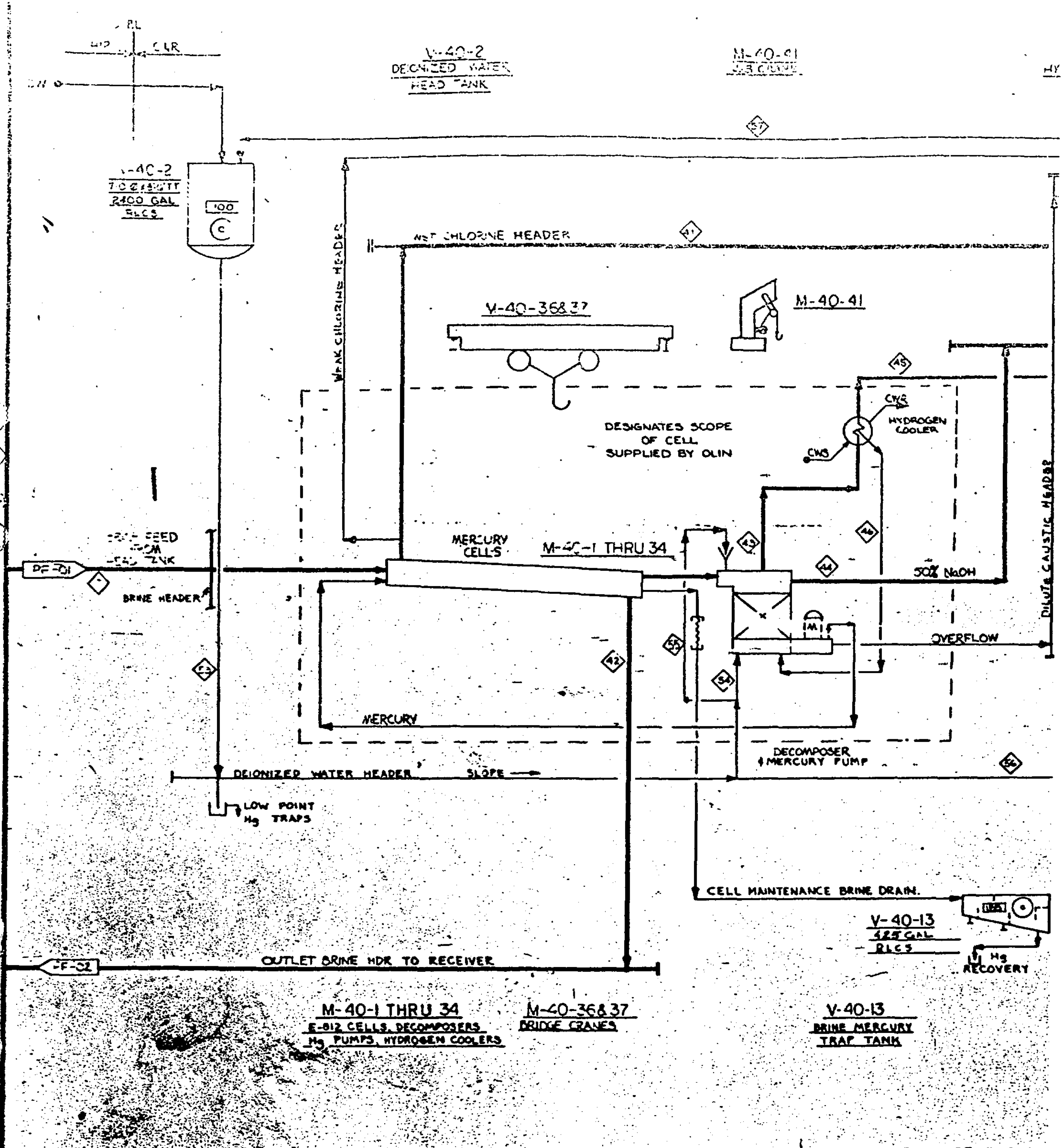
BLOK ŠEMA „PETROHEMIJE"
(u t/g.)



Appendix 4.15

A

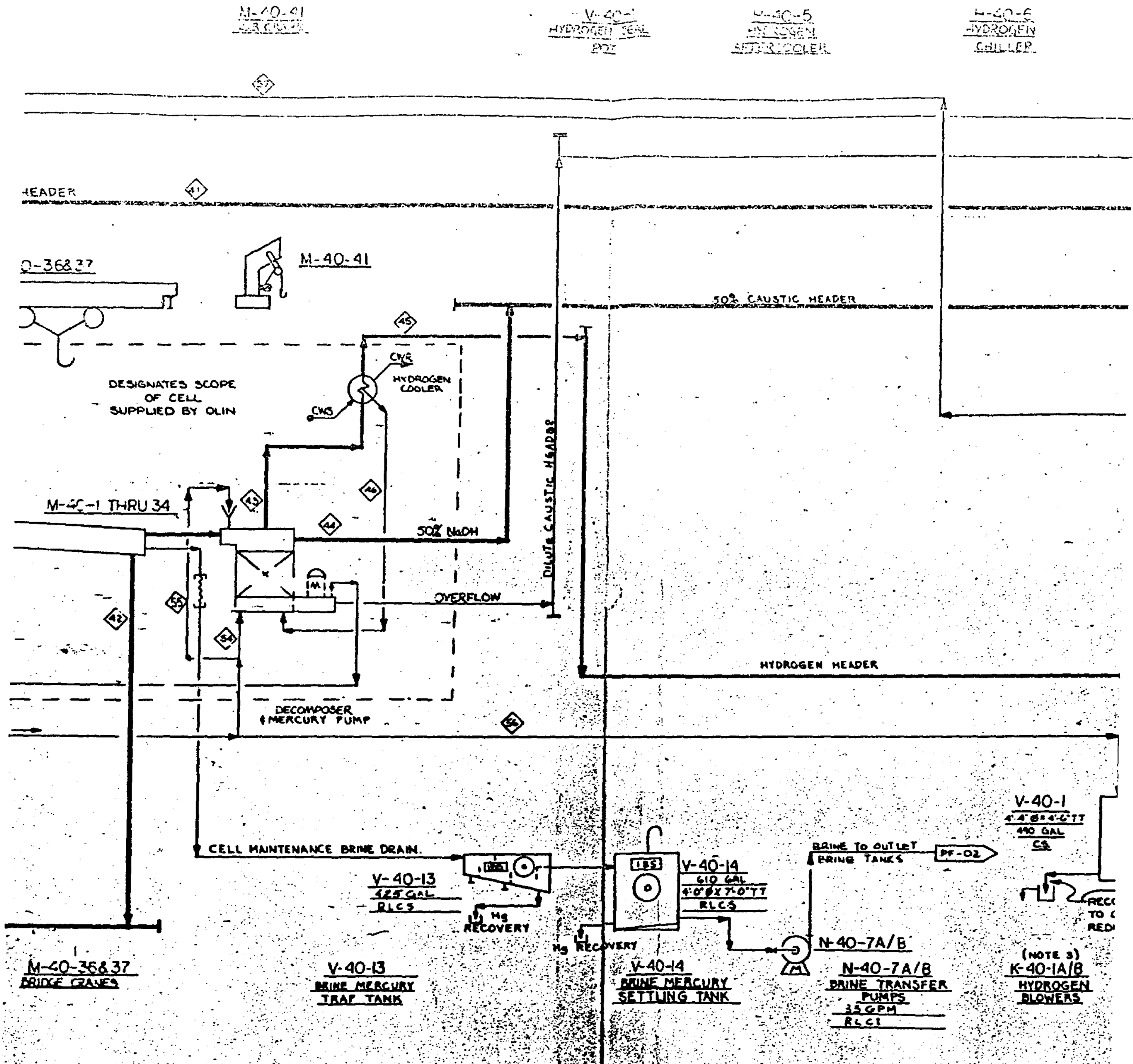
App. 4.16



√ MATERIAL BALANCE BASED

STREAM NO. / COMPONENTS	MW	1		41	42	43	44	45	46	47	(NOTE 1) 48	49	(NOTE 2) 50	51		53	54	55	5
Cl_2	70.914			11,076	139.2														
H_2	2.016			0.8		318		318		373.4	373.4		373.4						
O_2	32.00			15.1															
N_2	28.016			11.0															
NaCl	58.454	43,292.1			124,002.6														
Na_2SO_4	142.06	4,650.8			4650.8														
$CaCl_2$	110.996	772.0			772.0														
NaOH	40.008						12,617.1												
HCl	36.465	28.1			28.1														
Hg	200.61					33.4		0.36	33.05	0.4	0.19	0.21	0.036	0.134					
H_2O	18.016	406,907.1		1,486.4	400,420.7	1,127.7	12,617.1	266	861.7	299.0	150.6	148.4	51.6	99.		21,082.5	18,618.3	171.3	2,29
TOTAL		550480.1		12,589.3	530,013.4	1,479.1	25,234.2	584.36	894.75	672.8	524.19	148.61	425.036	99.134		21,082.5	18,618.3	171.3	2.29
TEMPERATURE °C		60		75	85	115	115	43.3	43.3	60	35	36	10	10		25	26	25	25
PRESSURE, mmHg				762		776		770		1277	1272		1267						
PRESSURE, Kg/cm²G										0.703	0.696		0.689						
DENSITY, Kg/m³		1183		1.826	1157		1460	0.132		0.206	0.182	994	0.163	999.7		996.8	996.8	996.8	99
FLOW m³/HR		465.5		7,894	458.8		17.28	4427		3282	2867	0.15	2600	0.1		21.15	18.68	0.17	2.

B App. 4.16



(NOTE 1) (NOTE 2) ✓ MATERIAL BALANCE BASED ON KG/HR

	46	47	48	49	50	51		53	54	55	56	57	58	59	60	61	62		64	65
18		373.4	373.4		373.4														56.4	316
													34.7							
0.38	33.05	0.4	0.19	0.21	0.086	0.134											.0041		0.05	60 ppb wt
44	841.7	299.0	150.6	148.4	51.6	44		21,082.3	18,618.3	171.3	2,292.7	2,540.1	208						33.0	18.3
54.38	874.75	672.8	524.19	148.61	425.086	44.134		21,082.3	18,618.3	171.3	2,292.7	2540.1	244.7				.0041		88.45	334.3
43.3	43.3	60	35	36	10	10		25	25	25	25	25	60.3						43.3	37.8
170		1277	1272		1267														762	1174
		0.703	0.696		0.689															0.565
132		0.206	0.182	994	0.163	999.7		996.8	996.8	996.8	996.8	996.8	1140						.116	0.128
127		2882	2867	0.18	2600	0.1		21.15	18.68	0.17	2.3	2.35	0.22						763	2627

✓

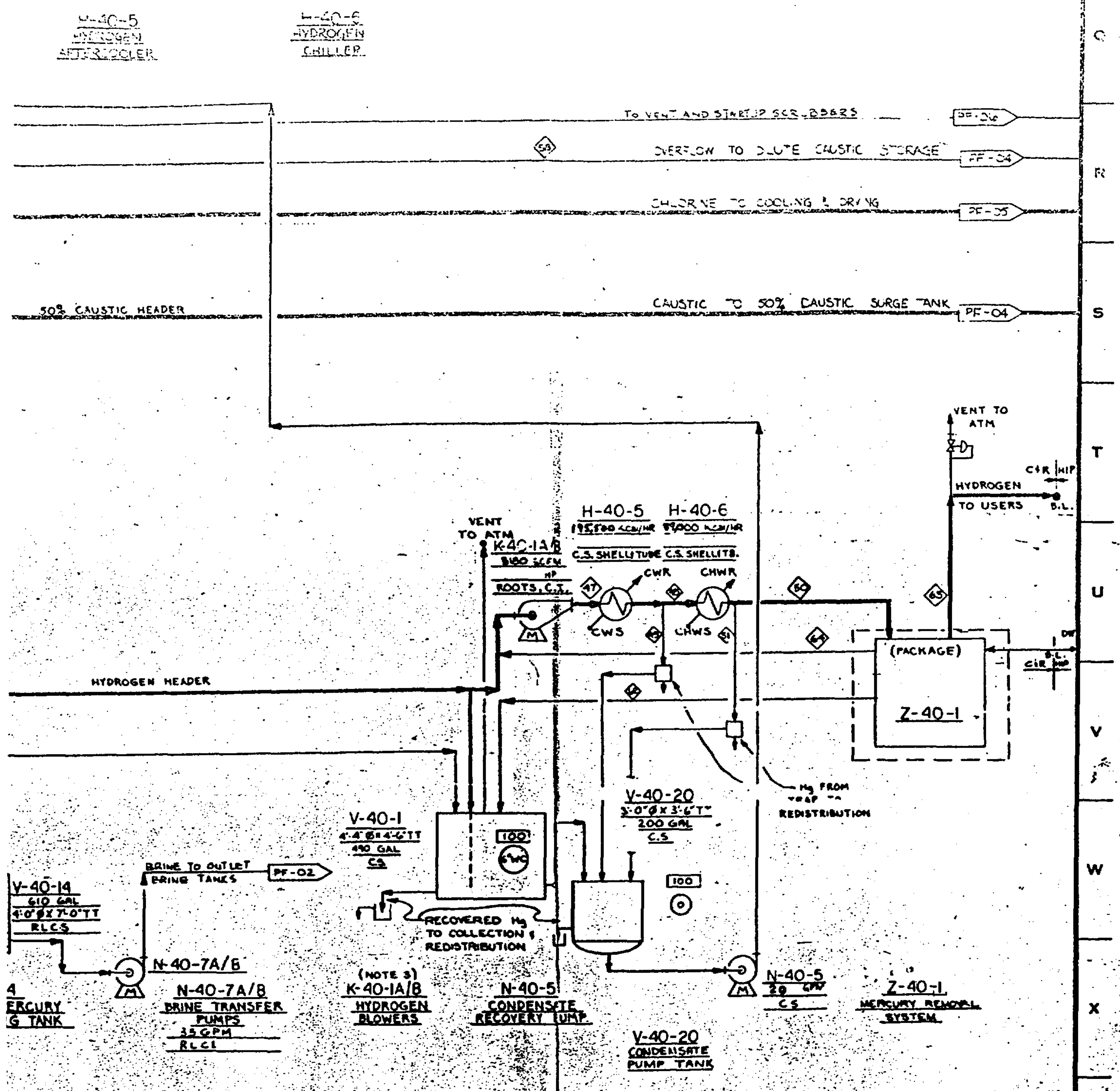
NOTE 1 - T

NOTE 2 - T

NOTE 3 - H

C

Appendix 4.16



59	60	61	62		64	65
					56.4	318
			.0041		0.05	60 ppb vol
					33.0	18.3
			.0041		66.45	336.3
					43.3	378
					762	1174
					[illegible]	0.563
					.116	0.128
					763	2627

NOTE 1 - THIS STREAM CONTAINS ENTRAINED LIQUID
H_2O: 36.2 Kg/HR
HG: 0.066 Kg/HR

NOTE 2 - THIS STREAM CONTAINS ENTRAINED LIQUID
H_2O: 27.2 Kg/HR
HG: 0.042 Kg/HR

NOTE 3 - HYDROGEN BLOWER PACKAGE UNIT CONTAINING BLOWERS K-40-1A/B, SNUBBERS V-40-21A/B AND INDIVIDUAL LUBRICATION SYSTEM FOR EACH BLOWER.

NO.	DESCRIPTION	DATE	APPD. BY	MADE BY
4	ISSUED FOR CONSTRUCTION	10-26-76		
3	GENERAL UPDATE TO INCLUDE Hg	6-?-76		
2	MAT'L BAL CONVERSION (1) METRIC SYSTEM	6-18		
1	ISSUED FOR	(4-?)		
0	ISSUED FOR REVIEW AND COMMENTS			

REVISIONS

	BY	DATE
DRAWN	F. AMBONI	10-21-74
CHKD.	T.M.	2-12-75
APPR. C.R.	J.R.	2-13-75
APPR. HIP		

SCALE: C/H

Crawford & Russell
INCORPORATED
CHEMICAL & PROCESS PLANTS STAMFORD, CONN.

PROCESS FLOW DIAGRAM
267 METRIC TONS Cl_2/DAY
CHLORINE PLANT
CELL AREA & HYDROGEN

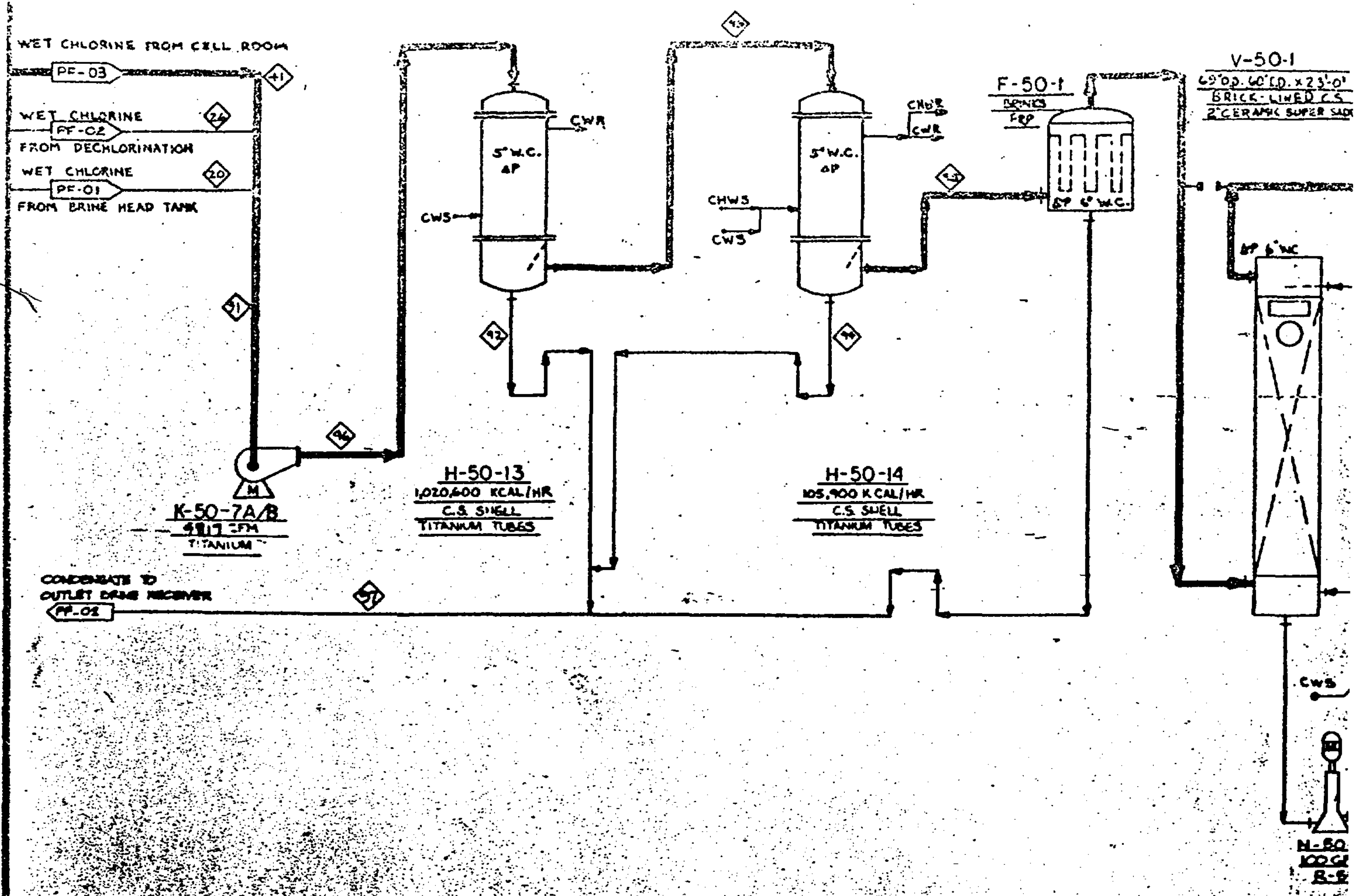
FOR: HIP-YUGOSLAVIA

CONTRACT NO.	DRAWING NO.	REV.
7456	PF-03	4

A

App 4.17

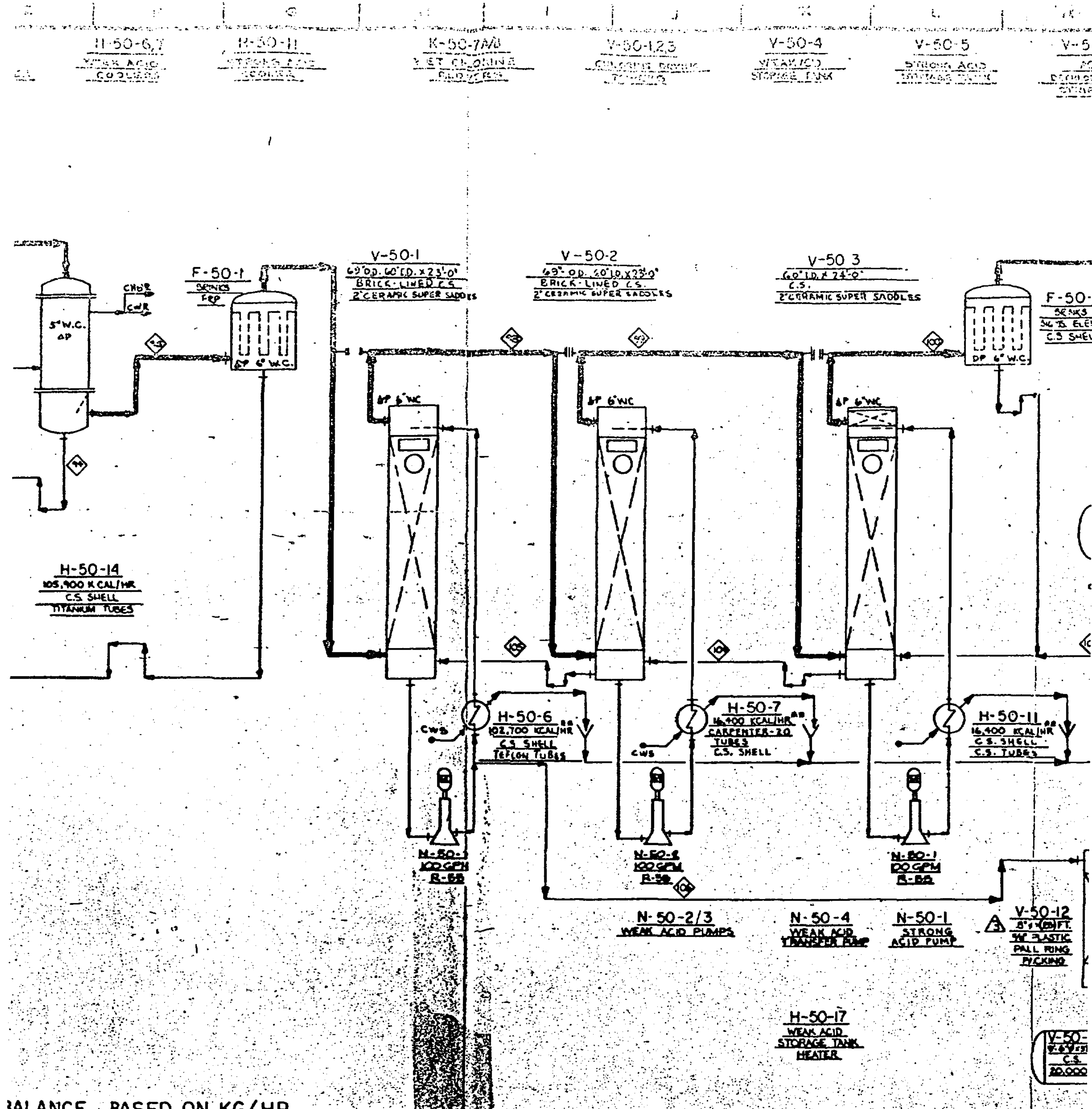
A	B	C	D	E	F	G	H
F-50-1 WET CHLORINE MIST ELIMINATOR	F-50-2 DRY CHLORINE MIST ELIMINATOR	H-50-13 PRIMARY CHLORINE COOLER	H-50-14 SECONDARY CHLORINE COOLER	H-50-6,7 WEAK ACID COOLERS	H-50-11 STRONG ACID COOLER	K-50 WET C



MATERIAL BALANCE BASED ON KG/HR

COMPONENTS / STREAM No.	MW	91	92	93	94	95	96	97	98	99	100	101	102	103
Cl_2	70.9[illegible]	11,108.6	8.1	11,100.5	1.8	11,0[illegible].1	11,108.6	9.5	11,099.3	11,099.3	11,088.9	11,088.9		[illegible]
H_2	2.016	0.8		0.8		0.8	0.8		0.8	0.8	0.8	0.8		[illegible]
O_2	32.000	15.1		15.1		15.1	15.1		15.1	15.1	15.1	15.1		[illegible]
N_2	28.016	11.0		11.0		11.0	11.0		11.0	11.0	11.0	11.0		[illegible]
AIR	28.96[illegible]												110.7	[illegible]
H_2SO_4	98.082													186.4
H_2O	18.016	1,725.9	[illegible]	170.9	1216.1	[illegible]	1725.9	[illegible]	2.7	0.1	10 ppm Vol.	10 ppm Vol.	0.7	77.8
TOTAL		12,861.4	1563.1	11,298.3	1227.[illegible]	11,170.8	12,861.4	1890.6	11,128.9	11,125.3	11,125.8	11,125.8	111.4	194.
TEMPERATURE °C		73	37.8	37.8	15.6	15.6	99	[illegible]	33.3	35.6	36.7	36.7	37.8	37.8 M
PRESSURE mmHG		748.8		[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	782	780	[illegible]
PRESSURE KG/CM² G				0.158		0.127	0.157		0.035	0.026	0.053	0.035	0.027	[illegible]
DENSITY KG/M³		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FLOW M³/HR		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

B App. 4.17



BALANCE BASED ON KG/HR

6	97	98	99	100	101	102	103	104	105	106	107	108*	109
8.6	9.5	11,099.3	11,099.3	11,098.9	11,098.9			0.4	0.4	0.2	0.2	2 ppm Wt.	
0.8		0.8	0.8	0.8	0.8								
15.1		15.1	15.1	15.1	15.1								
11.0		11.0	11.0	11.0	11.0								
						110.7					110.7		
							186.4	186.4	186.4	186.4	200 ppm Wt.	186.4	
5.2	[illegible]	2.7	0.1	10 ppm Vol.	10 ppm Vol.	0.7	7.8	7.9	10.5	52.6	115 ppm VOL.	53.3	
61.4	1880.6	11,128.9	11,126.3	11,125.8	11,125.8	111.4	194.2	194.7	197.3	239.2	110.9	239.2	
[illegible]	236.1	33.3	35.4	36.7	36.7	37.8	37.8 MAX	36.7	36.7	37.8	37.8	41.1	
75.5		[illegible]	[illegible]	[illegible]	782	780					770		
.157		0.035	0.076	0.057	0.035	0.027					0.015		
[illegible]	[illegible]	[illegible]	2.91	2.832	2.91	1.161	[illegible]	[illegible]	[illegible]	[illegible]	1.152	1656	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

* AVERAGE HOURLY RATE
** SIZED FOR ABNORMAL CONDITIONS

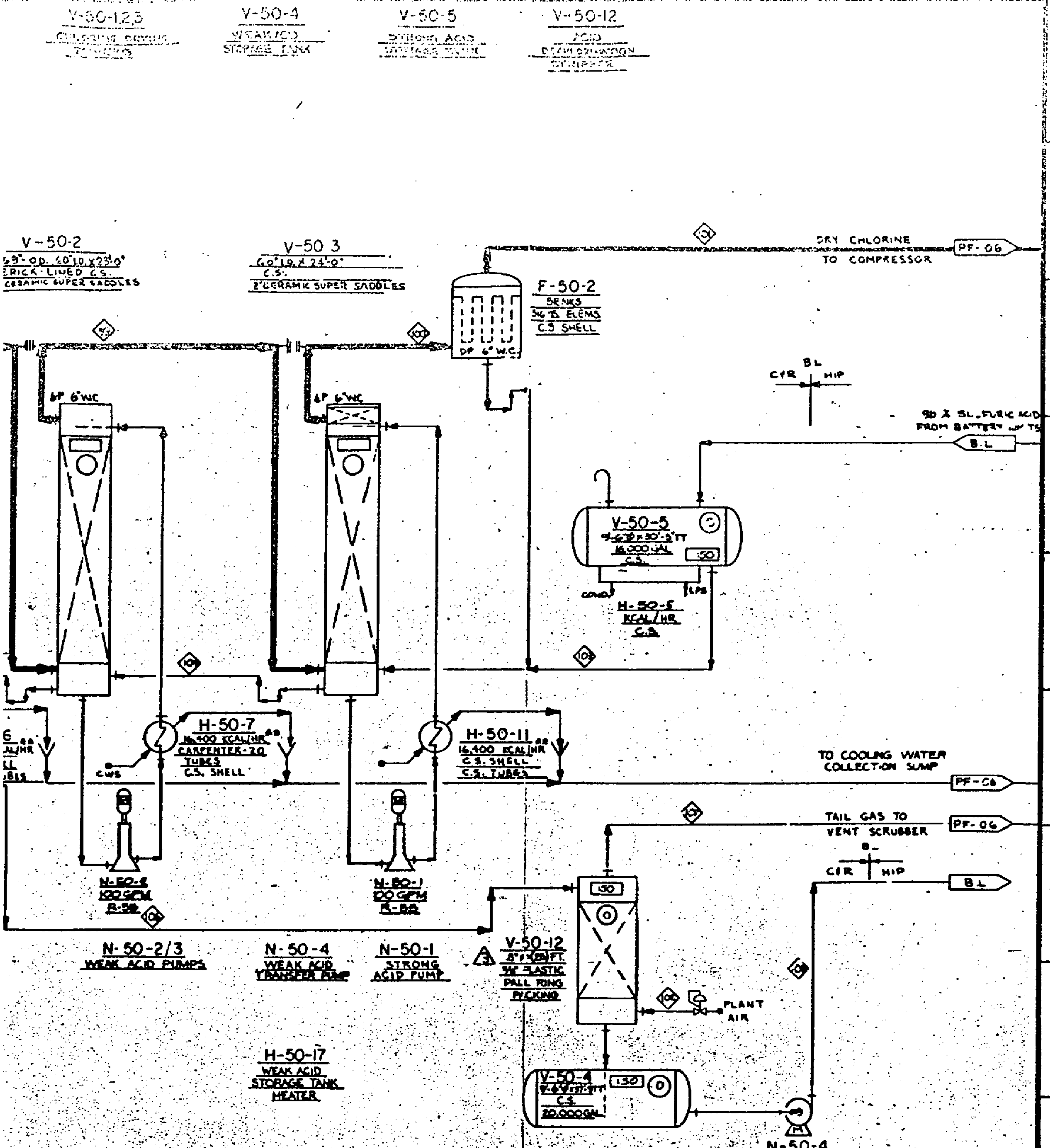
NO.	DESCRIPTION
4	ISSUED FOR CONSTRUCTION
3	GENERAL UPDATE TO INCLUDE DCNS
2	MAT'L BAL. CONVERSION TO METRIC SYSTEM
1	ISSUED FOR PLAN APPROVAL
	ISSUED FOR REVIEW & ID COMMENTS

App. 4.17

C

Appendix 4.17

7



105	106	107	108 *	109
0.4	0.2	0.2	2 ppm Wt.	
		110.7		
186.4	186.4	200 ppm Wt.	186.4	
10.5	52.6	715 ppm VOL.	53.3	
197.3	239.2	110.9	239.2	
36.7	37.8	37.8	41.1	
		770		
		2.015		
[illegible]	[illegible]	1.152	1655	
0.15	0.14	96	0.14	

* AVERAGE HOURLY RATE

** SIZED FOR ABNORMAL CONDITIONS

NO.	DESCRIPTION	DATE	APPR. BY	MADE BY
4	ISSUED FOR CONSTRUCTION	[illegible]		
3	GENERAL UPDATE TO INCLUDE DCNS	[illegible]	[illegible]	
2	MAT'L. BAL. CONVERSION TO METRIC SYSTEM	6-18	[illegible]	JJA
1	ISSUED FOR OLIN APPROVAL		[illegible]	
0	ISSUED FOR REVIEW AND COMMENTS	1/24/75	J.R.	7

REVISIONS

	BY	DATE
DRAWN	A.M	10-22-1974
CHKD.	TM	2-12-75
APPR. C/R	J.R	2-14-75
APPR.		

SCALE:

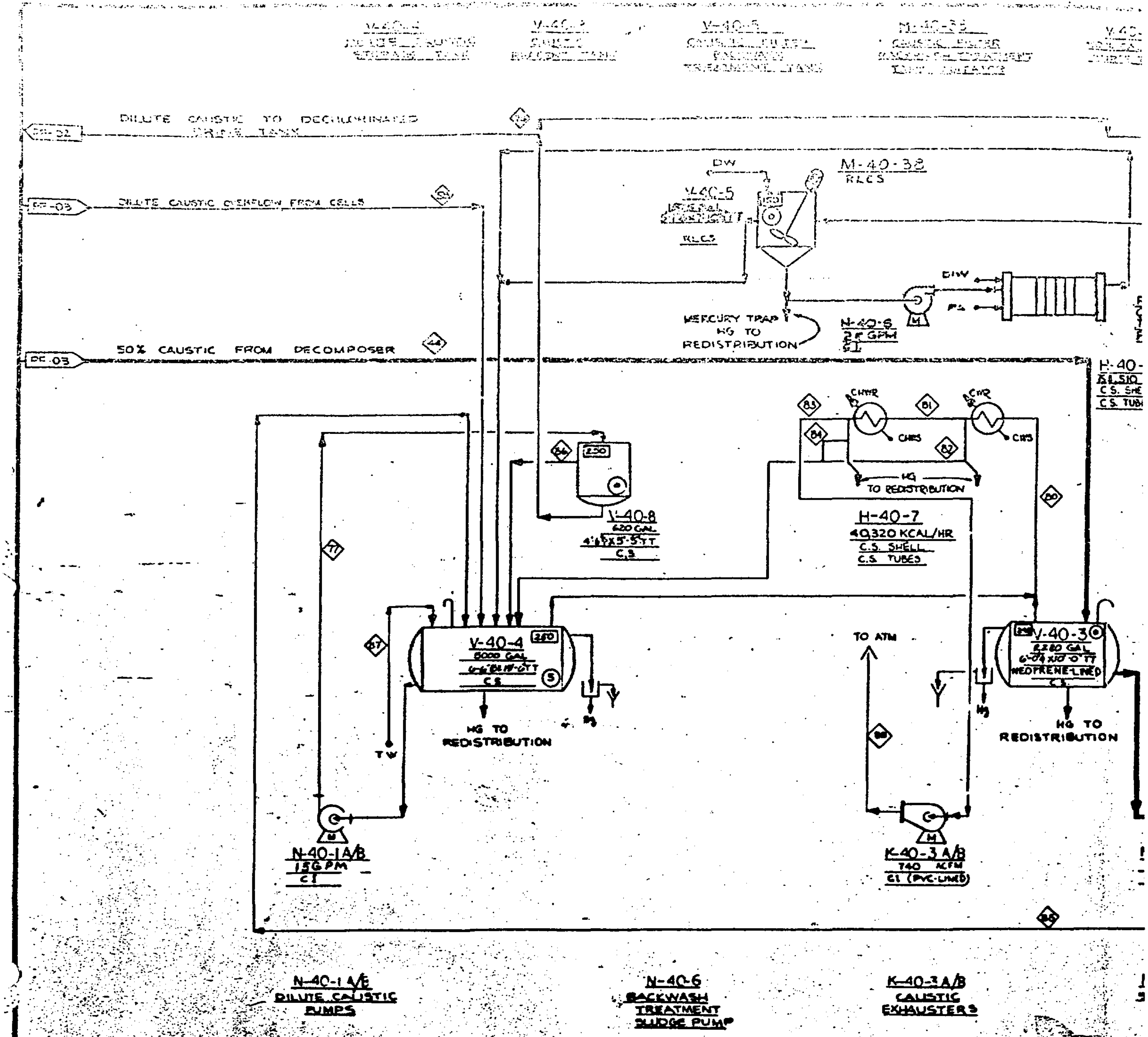
Crawford & Russell
INCORPORATED
CHEMICAL & PROCESS PLANTS
STAMFORD, CONN.

PROCESS FLOW DIAGRAM
267 METRIC TONS Cl_2/DAY
CHLORINE PLANT
CHLORINE DRYING

FOR: HIP-YUGOSLAVIA

CONTRACT NO. 7456
DRAWING NO. PF-05
REV. 4

A App 4.18 App

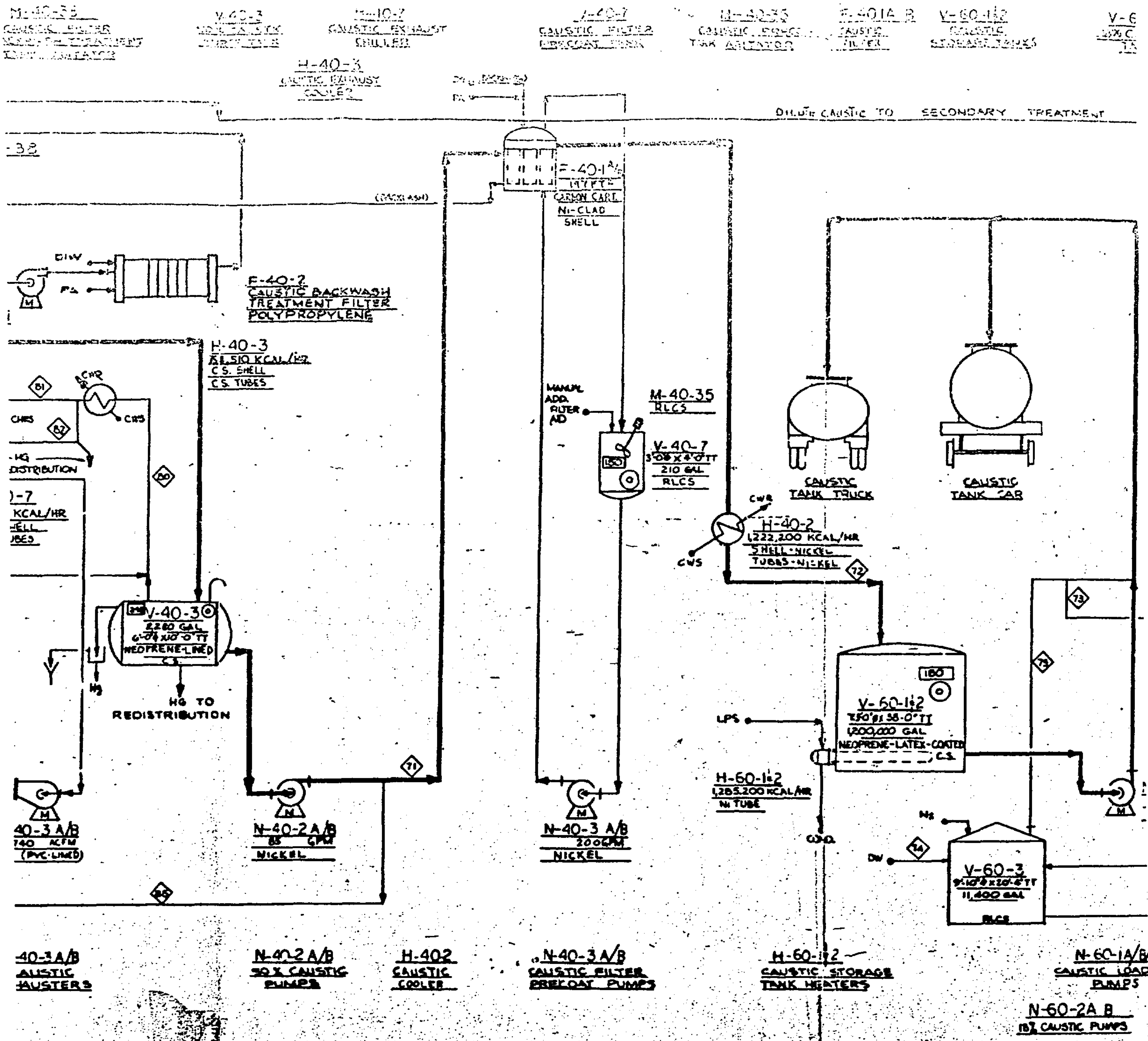


MATERIAL BALANCE BASED ON KG/HR

STREAM NO. / COMPONENTS	MW	◇64	◇86	◇	◇71	◇72	◇73*	◇74 (NOTE 1)	◇75*	◇76 (NOTE 1)	◇77	◇78	◇79 (NOTE 1)	◇80	◇81	◇82
H₂	2.016													4.3	4.3	
AIR	28.966													1474.2	1474.2	
NaOH	40.005	12617.1	36.7	—	12,530.7	12,530.7	94.9		12331.6	1203.6	296.9	86.4	8024			
MERCURY	200.61								100 ppb by wt					2.2	0.1	
H₂O	18.016	12,617.1	208.0		12,530.7	12,530.7	94.9	14.265	12331.6	5483.1	2672.1	777.6	8024	131.5	59.1	72.4
TOTAL		25234.2	244.7	—	25,061.4	25,061.4	189.8	14.265	24,663.2	6686.7	2969.0	864.0	16048	1612.2	1537.7	72.4
TEMPERATURE °C		115	66.5		115	51.7	51.7	25	51.7	66.6	54.4	54.4	51.7	67.8	35	35
PRESSURE, mmHg														760	754.6	
DENSITY KG/M³		1460	1140		1460	1500	1500	996.8	1500	1160	1090	1090	1610	0.905	1.073	994
FLOW, M³/HR		17.28	0.22		17.16	16.7	0.13	4.28	16.44	5.67	2.72	0.79	10.628	128	1433	0.07

App. 4.18 B

Appe



BASED ON KG/HR

79 (NOTE 1)	80	81	82	83	84	85	86	87
	4.3	4.3		4.3				
	1474.2	1474.2		1474.2				
8014						49.7	210.5	
	2.2	0.1		See ppb by vol				
8014	137.5	99.1	72.4	9.9	49.2	49.7	1894.5	398.3
16046	1612.2	1537.7	72.4	1488.4	49.2	99.4	2105.0	398.3
51.7	87.8	35	35	90	72	115	54.4	25
	760	754.6		769.8				
1610	0.905	1.073	998	1.220	1000	1460	1090	936.8
10.668	128	1433	0.07	1220	0.05	0.07	1.95	0.4

& AVERAGE HOURLY RATE

NOTES
(1) BASED ON 2 HR. WATER CHARGE.
(2) BASED ON 1 HR CAUSTIC CHARGE
(3) BASED ON . 6½ HR. PUMPOUT

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	4	3	2	1	0	NO
	ISSUED FOR CONSTRUCTION	GENERAL UPDATE TO INCLUDE DCN'S	MAT'L BAL CONVERSION TO METRIC SYSTEM	ISSUED FOR OLIN APPROVAL	ALT'D COMMENTS	DESCRIPTION
						MADE BY
				J.A.	J.R.	APPR. BY
	76		C-12			DATE

REVISIONS

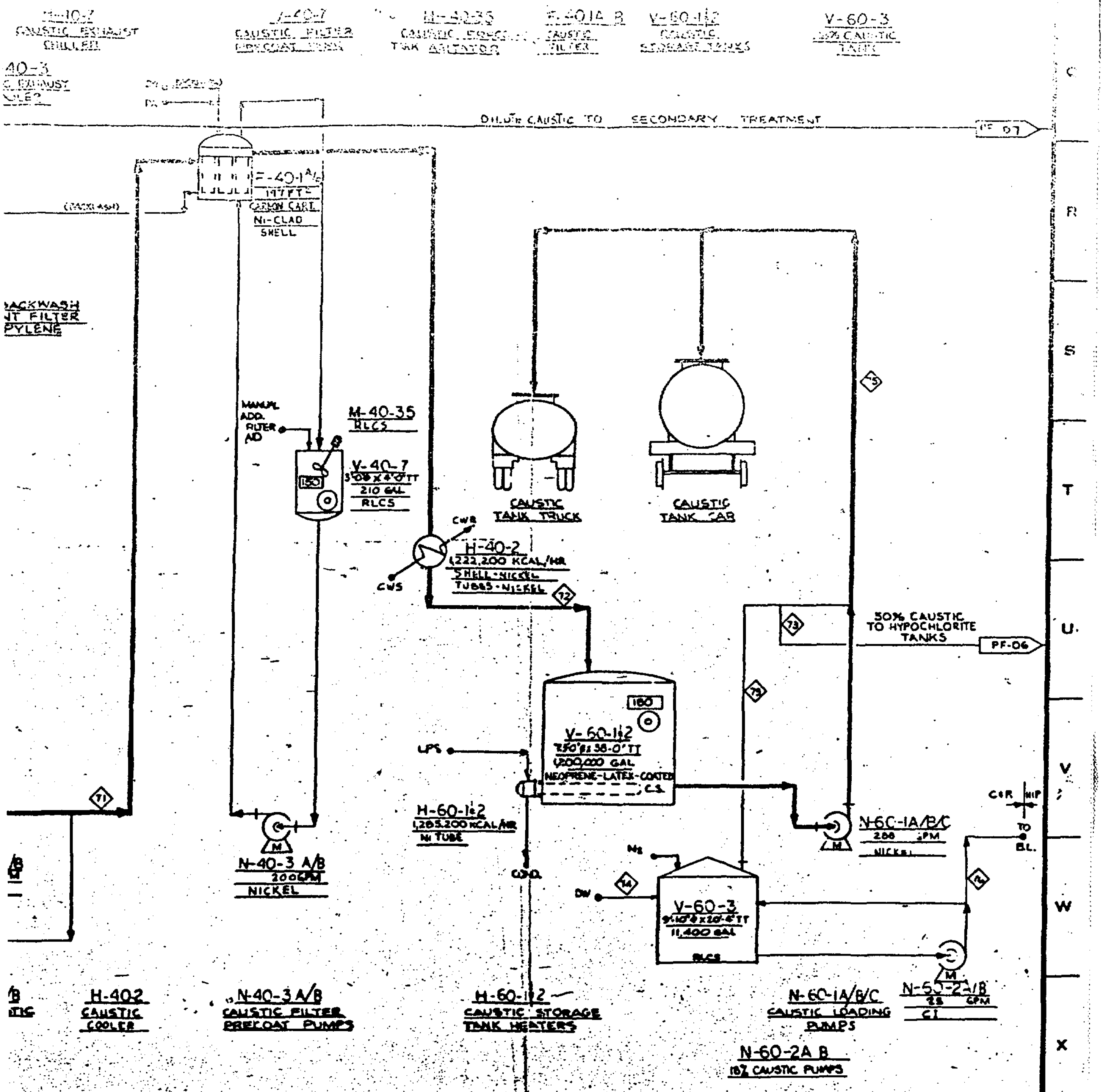
	BY	DATE
DRAWN	CST	10/18/74
CHKD.		2-12-75
APPR. C&R	J.R.	2-12-75
APPR.		

SCALE: ~

Crawford
CHEMICAL & PROCESS
PROCESS F
267 METRIC
CHLORINE
CAUSTIC HA
FOR: HIP-
CONTRACT NO.
7456

B

Appendix 4.18 C



	[illegible]	85	[illegible]	87
	—	49.7	210.5	—
	49.2	49.7	1894.5	398.3
	49.2	99.4	2105.0	398.3
	7.2	115	54.4	2.5
	1000	1460	1090	996.8
	0.05	0.07	1.95	0.4

⊕ AVERAGE HOURLY RATE

NOTES

(1) BASED ON 2 HR. WATER CHARGE.
(2) BASED ON 1 HR CAUSTIC CHARGE
(3) BASED ON 6⅔ HR. PUMPOUT

THIS DRAWING AND THE INFORMATION IT CONTAINS ARE THE PROPERTY OF CRAWFORD & RUSSELL INCORPORATED

NO	DESCRIPTION	DATE	BY	CHKD BY
4	ISSUED FOR CONSTRUCTION	[illegible] 76	[illegible]	[illegible]
3	GENERAL UPDATE TO INCLUDE DCN'S	[illegible]	[illegible]	[illegible]
2	MAT'L BAL CONVERSION TO METRIC SYSTEM	6-12	[illegible]	R.J.
1	ISSUED FOR OLIN APPROVAL	[illegible]	[illegible]	
0	[illegible] AND COMMENTS	[illegible]	[illegible]	[illegible]

REVISIONS

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	BY	DATE
DRAWN	CST	10/8/74
CHKD.	[illegible]	2-12-75
APPR'D	J.R.	2-11-75
APPR'D		

SCALE:

Crawford & Russell
INCORPORATED
CHEMICAL & PROCESS PLANTS STAMFORD, CONN

PROCESS FLOW DIAGRAM
267 METRIC TONS Cl_2/DAY
CHLORINE PLANT
CAUSTIC HANDLING

FOR: HIP-YUGOSLAVIA

CONTRACT NO. 7456
DRAWING NO. PF-04
REV. 4

NAPOMENA:

1. SVI PROTOCI DATI SU U t/h.
2. PODACI SE ODNOSE NA NORMALAN RAD SVIH POGONA.
3. NA MESTIMA GDE POSTOJE RAZLIKE U LETNJEM I ZIMSKOM REŽIMU RADA, PRVI BROJ OZNAČAVA PROTOK U LETNJEM A DRUGI U ZIMSKOM REŽIMU.

NOTE:

1. ALL FLOW RATES ARE STATED IN t/h
2. ALL THE DATA REFER TO THE NORMAL OPERATION OF ALL PLANTS.
3. AT POINT WHERE THERE ARE DIFFERENCE IN SUMMER AND WINTER OPERATIONS, THE FIRST NUMBER REFERS TO THE SUMMER FLOW AND THE SECOND ONE TO THE WINTER FLOW.

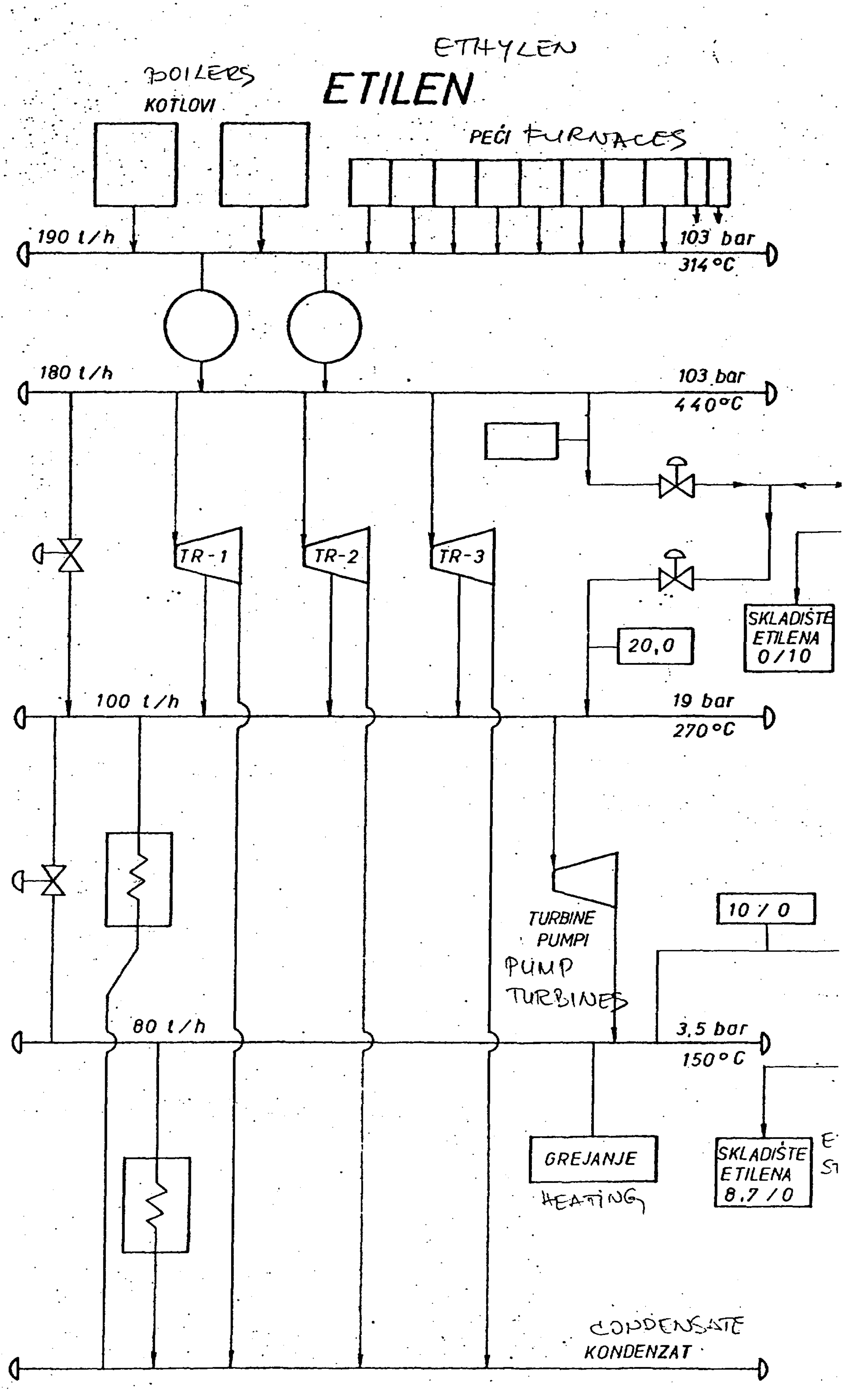
1st APRIL - 1st OCTOBER = SUMMER

1st -OCTOBER - 31st MARCH = WINTER

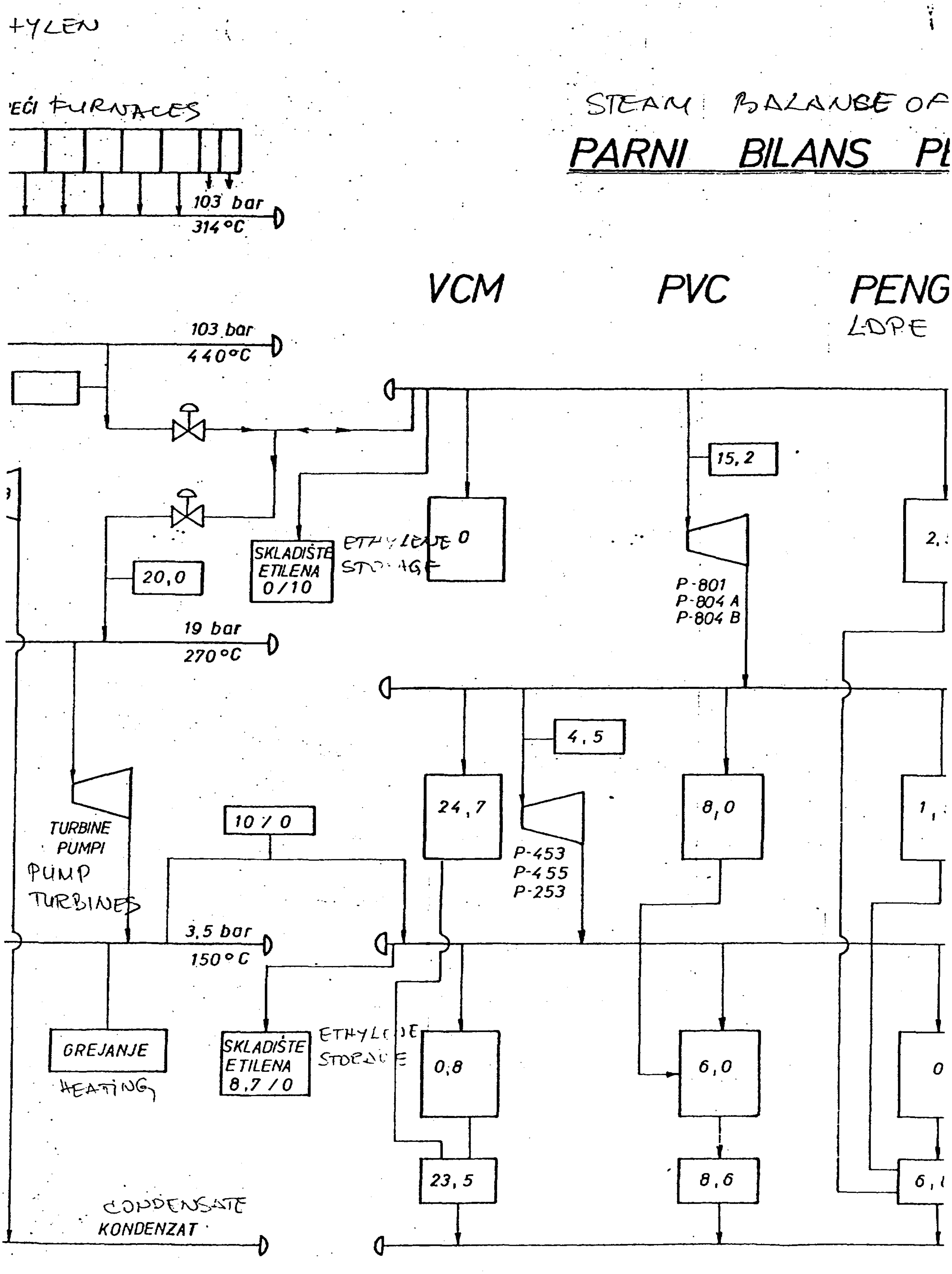
HIP - PETROHEMIJA
OOUR ENERGETIKA
PANČEVO 25.02. 1983.

Sec 1

App. 4.19


ETHYLEN
ETILEN
BOILERS
KOTLOVI
PEĆI FURNACES
190 t/h
103 bar
314 °C
180 t/h
103 bar
440 °C
TR-1
TR-2
TR-3
20,0
SKLADIŠTE ETILENA 0/10
100 t/h
19 bar
270 °C
TURBINE PUMPI
PUMP TURBINES
10/0
80 t/h
3,5 bar
150 °C
GREJANJE
HEATING
SKLADIŠTE ETILENA 8,7/0
CONDENSATE
KONDENZAT

SEC 2


+YLEN
ĆI FURNACES
103 bar
314 °C
STEAM BALANCE OF
PARNI BILANS PL
VCM
PVC
PENG
LDPE
103 bar
440 °C
20,0
SKLADIŠTE ETILENA 0/10
ETHYLENE STORAGE
0
15,2
P-801
P-804 A
P-804 B
2,
19 bar
270 °C
4,5
24,7
8,0
1,
P-453
P-455
P-253
TURBINE PUMPI
PUMP TURBINES
10/0
3,5 bar
150 °C
GREJANJE
HEATING
SKLADIŠTE ETILENA 8,7/0
ETHYLENE STORAGE
0,8
6,0
0
23,5
8,6
6,
CONDENSATE
KONDENZAT

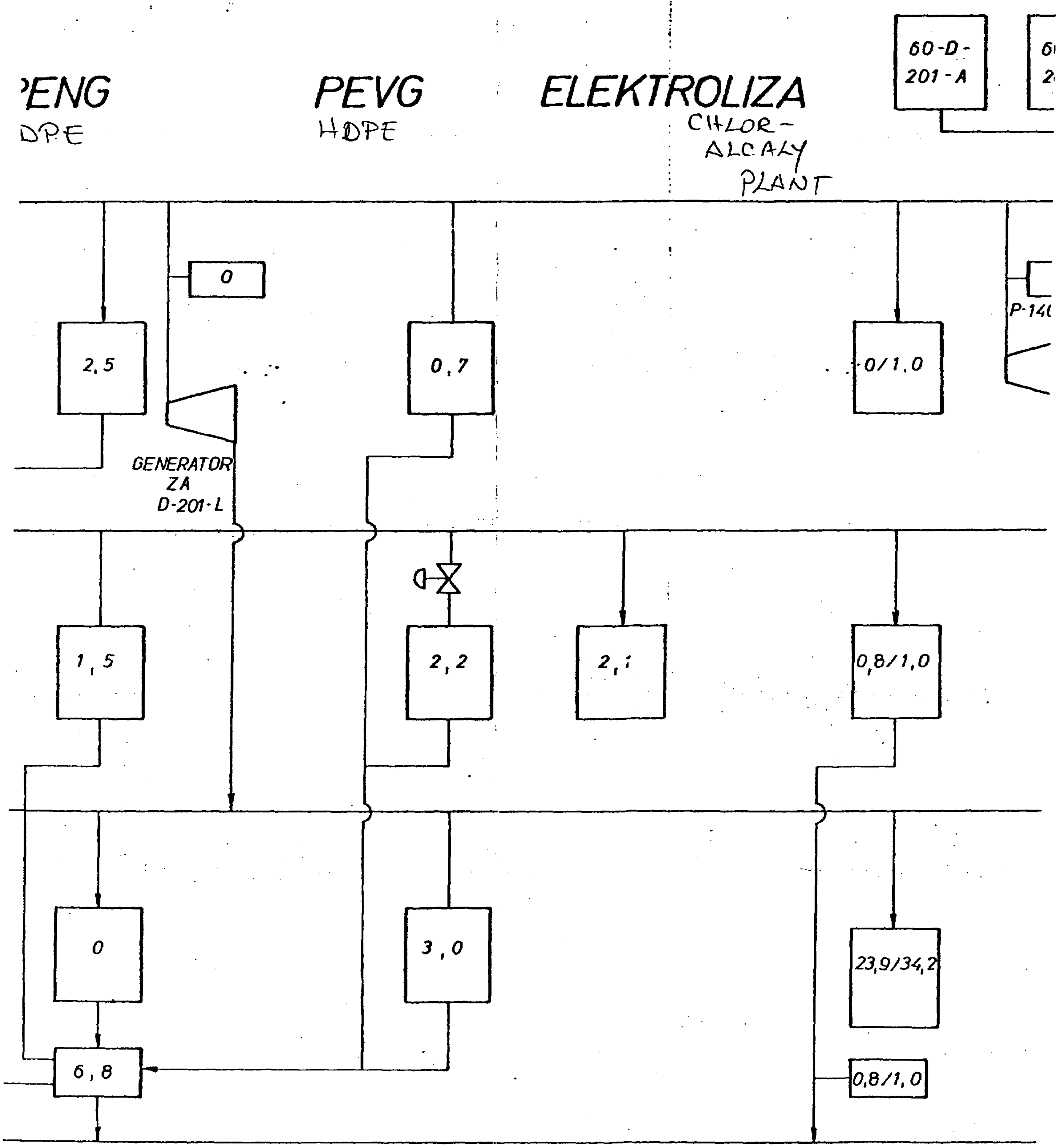
Sec. 3

E OF PETROCHEMICAL COMPLEX

PETROHEMIJE

UTILITY

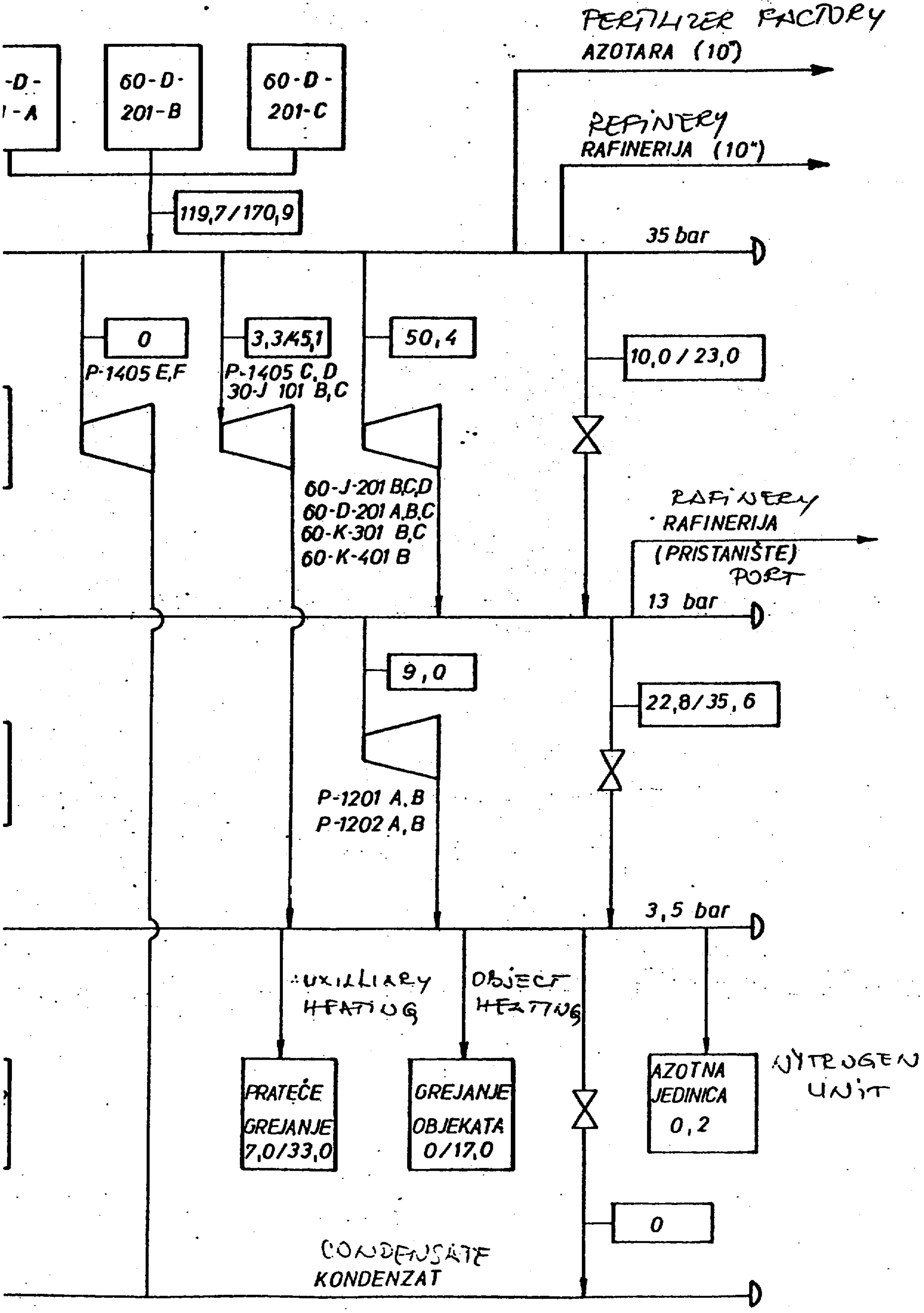
ENER



SEC 4

UTILITY PLANT

ENERGETIKA



FERTILIZER - BOILER HOUSE

1. Design Data and Present Case

1.1 Boiler House

Schematic description of boiler house is shown in Figure 1. Three boilers are installed in the boiler house. The boilers use natural gas.

The contents of fired natural gas and its net calorific value was at November 14, 1996 as:

CH_4	92.14
C_2H_4	2.35
C_3H_8	0.37
iC_4H_{10}	0.04
nC_4H_{10}	0.05
iC_5H_{12}	0.02
nC_5H_{12}	-
C_6H_{14}	-
N_2	1.66
CO_2	3.36
Net Calorific Value	35,068 kJ/nm^3

These are typical content of natural gas which has been in this plant for a long time.

Each boiler is equipped with gas burner made by BABCOCK & WILCOX and the maximum capacity of burner is 4,140 nm^3/h. In boilers No.2 and No.3 an additional heavy fuel oil burner maximum capacity of 3,910 kg/h is installed. Heavy fuel oil is used rarely.

Boiler design data of all three boilers are as follows:

Type:	Integral Water Tube Boiler
Manufacturer:	Babcock & Wilcox
Installed:	1969
Steam Pressure:	33 barg
Steam Temperature:	313 °C
Feed Water Temperature:	108 °C
Capacity:	40 t/h
Design flue gas temperature:	180 °C

During the audit an efficient tests of all boilers were made. The results are presented in Table 1.

The surface temperatures of boilers were: Boiler No.1 → 75 °C, No.2 → 109 °C, and No.3 → 72 °C.

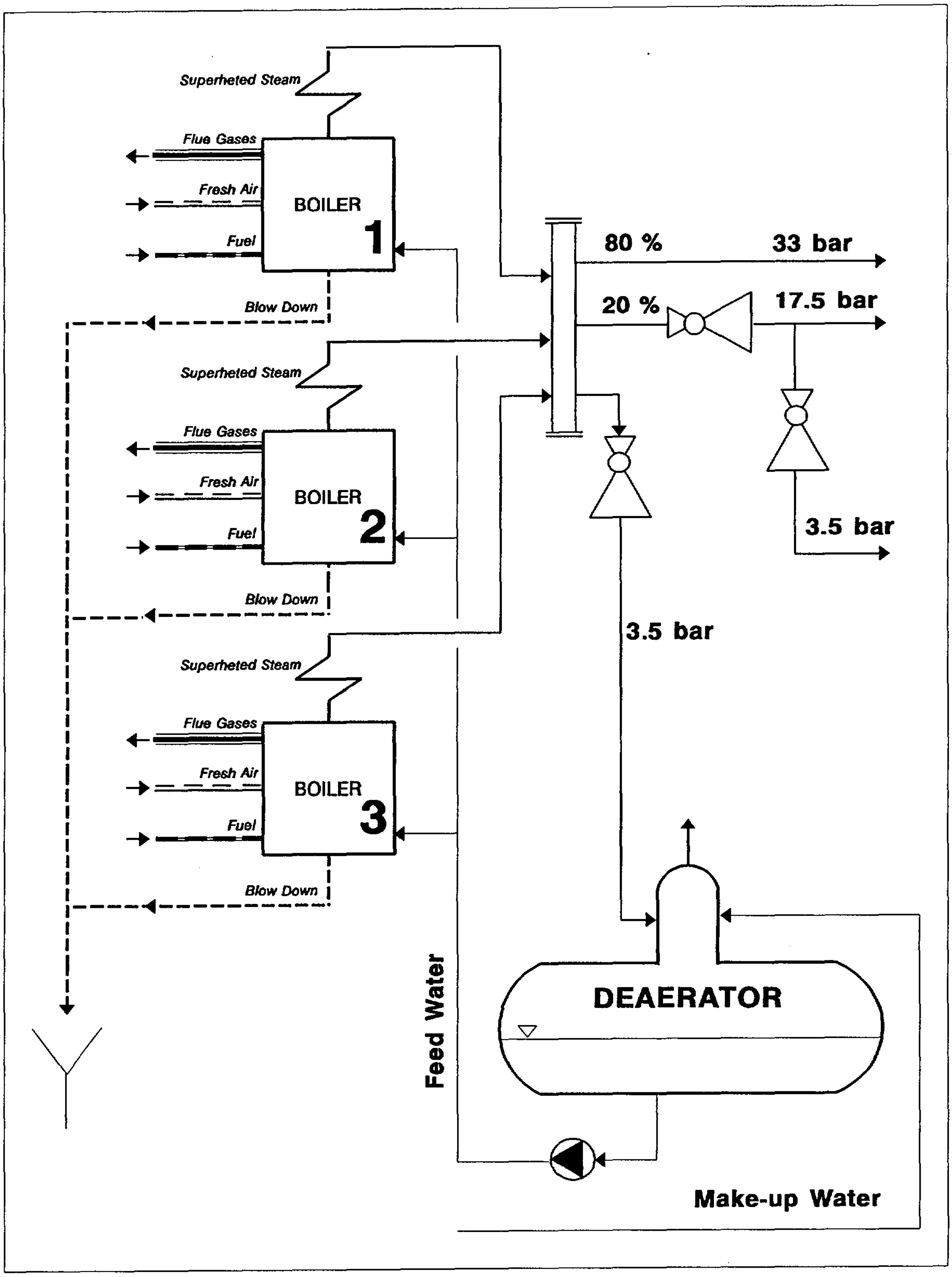


Figure 1: Schematic description of the boiler house

Table 1: Flue gas analysis for boilers No.1, No.2, and No.3

Company: Fertilizer, Panchevo
Location: Boiler House
Date and Time: November 14, 1996 (09:18 - 10:40)
Fuel: Natural gas
Net Calorific Value: 35,068 kJ/nm^3
Load: Boiler No.1 - 50%
Boiler No.2 - 80%
Boiler No.3 - 70%

Measured value	Units	BOILER					
		No.1		No.2		No.3	
		1	2	1	2	1	2
Ambient temperature	°C	24	25	23	25	25	25
Flue gas temperature	°C	291	291	332	336	319	317
Flue gas contents	CO_2	7.6	9.3	10.0	10.1	8.1	8.0
	O_2	7.6	4.7	3.4	3.2	6.7	6.9
	CO	0	1051	5440	5618	40	45
	NO_x	41	18	82	56	129	130
	SO_2	0	0	0	0	0	0
Combustion Efficiency	%	83.8	86.8	85.7	85.8	83.3	83.2
Excess air	-	1.57	1.29	1.19	1.18	1.47	1.49

The desired measuring points for making the energy balance of the boilers is shown in Figure 2. However, during the audit it was possible to measure only some of them. The results are presented in Table 2 for all three boilers.

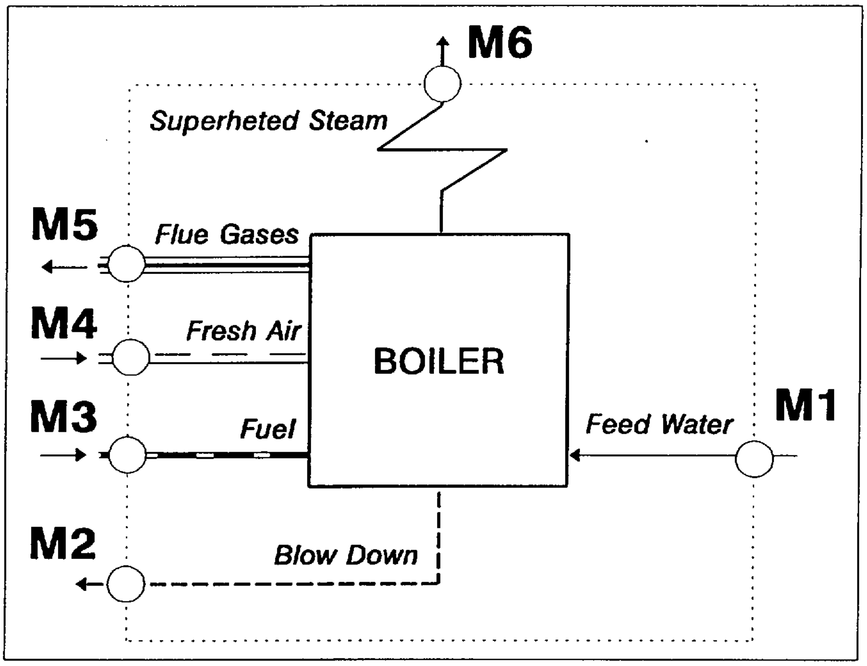


Figure 2: Battery limit of the boiler

Table 2: Measuring data from the existing instrumentations (boiler No.1,2,3)

Measuring point	Measured value	Boiler		
		No.1	No.2	No.3
M1	t_1 [°C]	-	-	-
	p_1 [bar]	40	40	41
M2	m_2 [t/h]	(4-6%)	(4-6%)	(4-6%)
	t_2 [°C]	(180)	(180)	(180)
M3	m_3 [t/h]	-	-	-
	t_3 [°C]	16	16	16
M4	t_4 [°C]	140	140	135
M5	t_5 [°C]	-	-	-
M6	m_6 [t/h]	67	67	64
	t_6 [°C]	360	370	-
	p_6 [bar]	35.4	35.4	35.0

1.2 Feed Water System

The feed water tank is located under the roof and is insulated. There is no return condensate! The feed water which enters the boilers is about 108 °C.

There is a continuous process of desalination in boiler drum which use 4-6% of the total steam production under the pressure of 33 barg. Make-up water is taken from centralized water treatment plant which supplies the whole factory except the Ammonium III plant (they use only decarbonized water from this system).

Blowdown at the boiler is performed once evry 3 days. Blowdown operation is performed manually.

1.3 Steam and Condensate System

The pressures of the distributed steam are as follows: 1) 33 barg, 313 °C to the process; 2) reduced by throttling to 17.5 barg and use in process; and, 3) reduced to 3.5 barg for processes (heating the tanks, premises, etc.). There are some turbines used for running the fans in the boiler house. However, their steam consumption is negligible. Back pressure of these turbines is 3.5 barg. The steam of 3.5 barg is used mostly for heating the tanks, pipelines and premises.

Steam and condensate leakages are huge and the steam traps are in a very poor condition. Some condensate is polluted and it is wasted although that it has a rather high temperature. Because of that there is no returned condensate to the boiler house. That means that a lot of make-up water is used and a lot of energy and chemicals are used for its preparation.

1.4 Daily Production Report of Boiler House

A typical daily production report in boiler house contains only temperatures and pressures in different points of the plant and very restricted number of flows of steam and water and some power values concerning electrical production. That means that there is no possibilities to make reliable energy balance of the plant either in total or in some insulated parts of the plant.

The Figure 3 shows the steam production in boiler house from November 12, 1996 at 6:00 am to November 13, 1996 at 6:00 am. There was a shutdown of all three boilers at 12::00 am because of low pressure of natural gas in national network. This figure is done by using the daily report made manually. In the period of time mentioned, 121,700 nm^3 of natural gas was spent, and 1,268 t of steam for the process was produced. The average production was 58.33 t/h which is 48% of designed capacity.

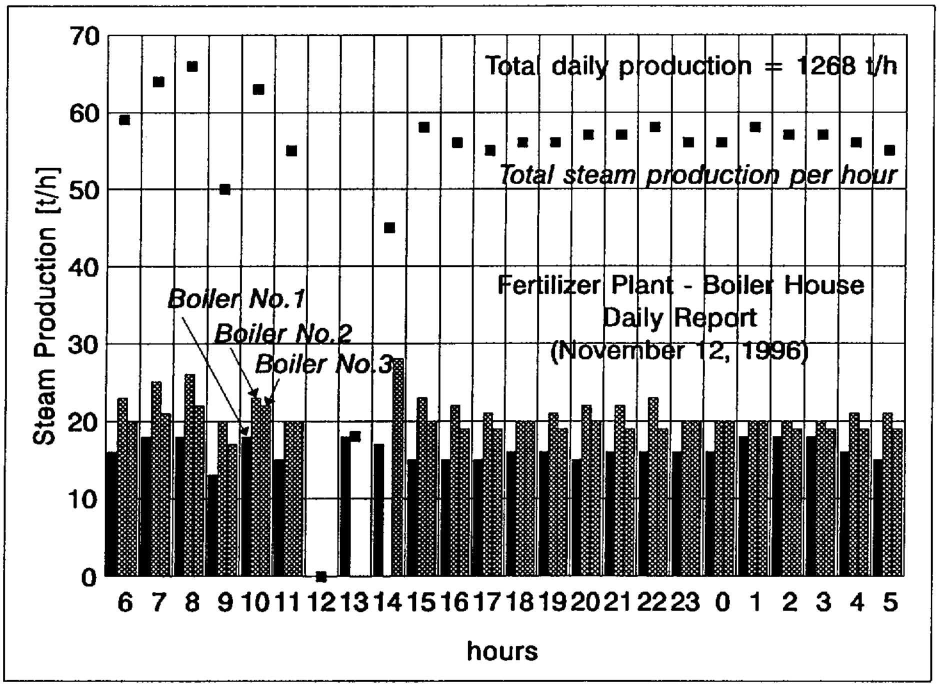


Figure 3: Typical daily steam production

2. Energy Conservation Measures and Discussion of Collected Data

In this Chapter only the following measures will be discussed:

- Housekeeping and Operational Improvements;
- Combustion, Steam and Condensate System Improvements;
- Waste Heat Recovery and Reuse;

Only after analysis and/or implementation of proposed measures prescribed by these three measures, one can have reliable entering data for further consideration of energy efficiency improvements.

Concerning this plant the following n/l cost measures has to be implemented without delay because it can result in 20-25% energy savings. This analyses concerns the boiler house and the steam and condensate systems.

2.1 Housekeeping Procedure

Existing housekeeping procedure is not effective which also means that it is not efficient. A lot of leakages were found in steam and condensate distribution system. There are hundreds of steam traps and only a small number of them operate properly. A flash steam allowed to blow to waste (condensate tanks). There are some points for condensate collection before it is wasted. There are a lot of contaminated condensate which can be recovered by using heat exchangers, but now it is wasted. However, even the clean condensate use for heating the tanks and premises is not returned.

For example, if the mentioned daily production is analyzed, one can calculate that 5.2 MW is lost with waste condensate. For that day (November 12, 1996) the steam production was 1,268 t or an average of 52.8 t/h. If the waste condensate is at temperature of 100 °C and make-up water of temperature of 15 °C, it means that:

$$\frac{52833}{3600} \cdot 4.186 \cdot (100 - 15) = 5222 \text{ kW} \simeq 5.2 \text{ MW}$$

or, using the efficiency of boiler of 0.8, which means that for heating the necessary make-up water has to be spent:

$$\frac{5222 \cdot 3600}{35086 \cdot 0.8} = 670 \text{ nm}^3\text{/h}$$

or, 16,080 nm^3/day. As the daily natural gas consumption was 121,700 nm^3/day, it is possible to save:

$$\frac{16080}{121700} \cdot 100 \% = 13.2 \%$$

of natural gas. If the heat exchangers are used because of polluted condensate, the possible savings will be lower but still sensible and acceptable.

About 5-10% of all steam and condensate pipelines are not insulated. Some pipes are damaged by corrosion and produce other leakages. There are a lot non insulated valves and flanges. Many important steam leaks are hidden such as: a) leaking or stuck traps or by-pass valves discharging to sewer or condensate system; b) leaking valves leading to idle equipment; and c) leaks in heater or other equipment connected to the steam system. It is estimated by some experts in the factory, that there is about 10 km of pipelines with diameter over 50 mm.

Housekeeping includes measures to reduce energy use that can readily be taken by plant engineer or plant operator at little or no cost and in a short time. Examples of simple housekeeping are shutting of standby furnaces, inspecting combustion equipment, adjusting burners, and inspecting and repairing steam traps - preferably on a routine basis. At a slightly more advanced level, the operation of process equipment can be rescheduled to avoid frequent startups and shutdowns - generally, continuous operation is more energy efficient than intermittent operation - or equipment can be adjusted to operate at the lowest economical temperature. Improvement of insulation becomes part of housekeeping if materials costs are low and the payback period is shorter than a year. For example, if the surface temperature of currently insulated steam lines or liquid piping exceeds 40 °C, the insulation should be upgraded. Damaged insulation can result in much heat loss, so regular inspection of distribution lines is desirable. Combustion efficiency is major area of potential operational savings, as 1 - 5% of fuel used can be saved by regular tune-up of the air-to-fuel ratio. Modern technology enables fuel-to-air ratios to be maintained at recommended levels at all times, insuring consistent combustion efficiency. Microprocessor controlled servo motors fitted to fuel valves and air dampers replace the traditional methods of control, providing a programmable system which will automatically select and maintain the fuel-to-air ratio specific to a particular fuel.

The flue gas temperatures of the boilers were in range from 291 to 336 °C. This temperature is higher then the designed one (180 °C). This shows that it is possible that boiler tubes become fouled by soot and deposits and the amount of heat transferred from the hot flue gases to the water is reduced. There is a rule which says that an increase of around 20 °C above that temperature for a clean boiler, means that the tubes must be cleaned. A rise of 17 °C causes a decrease in efficiency of 1 %.

Any discussion on energy conservation in this Fertilizer has to start with housekeeping procedures.

2.2 Monitoring

Monitoring will not of itself lead to energy savings unless the data is analyzed and put in context within the company or establishment.

Monitoring system in this fertilizer is not reliable and complete and it is not used for energy analysis. It is used only for running the process. Instrumentation used is not in such a good condition. For illustration of this statement let us analyze the following example:

The efficiency of boiler house can be calculated using the total steam production (1,268 t/day) and the natural gas consumption (121,700 nm³/day) metered by staff of the factory by using their instrumentation. As the net calorific value is 35,068 kJ/nm³, the boiler house efficiency is:

$$\eta_{BH} = \frac{1268 \cdot 10^3 \, (3048 - 63.5)}{121700 \cdot 35068} = 0.887$$

As there is no returned condensate it is assumed that the make-up water has the temperature 15 °C.

Calculated value is higher that it could be expected. Combustion efficiency (Table 1) measured two days later are lower than this one and, as it is well known, combustion efficiency is only a part of total efficiency of boiler house. Measured mass flow rate of natural gas is used for payment and it is exact. Possibly the mass flow rate of produced steam is not reliable. This metering system must be checked. It is not clear does the internal steam usage is calculated as internal or external one! All this items must be clarified.

Measuring system of steam from boilers has to be re-calibrate or replaced. The natural gas consumption metering system has to be installed for each boiler. The ratio of steam to fuel is the main measure of efficiency of the boiler and it should be measured and maintained at a high level, compatible with good practice.

The measured steam pressures of the superheated steam from each boiler are higher than it is designed (measured: 35.4, 35.4 and 35.0 barg; designed and necessary pressure in process: 33 barg). That is another unnecessary increase of fuel consumption.

Continuously log boiler performance has to be done so that signs of deterioration soon become evident, enabling corrective maintenance to be carried out.

Feed water meter has to be re-calibrated or replaced.

2.3 Air Preheating

For air preheating the heat wheels are used for each boiler. However, there is no explanation why are the flue gas temperatures for each boiler higher than the designed ones. They vary from 291 to 336 °C (Table 1), and design temperature is 180 °C. With the heat wheels these temperatures are lower (without measuring) and the preheat air reaches the temperatures of 140 °C before entering the burners (Table 2).

2.4 Economizer

As it is already mentioned, the heat wheels are installed in this boiler house for pre heat the air. The temperature leaving the heat wheels are still high. As natural gas has minimal sulphur content (see Table 1), it is possible for the flue gas exit temperatures to be below the water dewpoint temperature without causing significant corrosion problems. Energy savings up to 10% are possible by using the recovered heat to pre-heat boiler make-up water. However, the analysis of the possibility to use Condensing Economizer must be followed by the general inspection of the boiler house and the housekeeping measures must be such to fit the real parameters to design ones.

2.5 Condensate Recovery

If the feed water temperature is low, the cause should be discovered. It could be due to:

- a low rate of condensate return;
- the lack of insulation on the condensate return pipes;
- losses from the feed water, either as heat through the walls or as overflow.

As much condensate as it is economically possible should be returned from sources where there is no likelihood of contamination. This will save heat, make-up water and chemicals used in water treatment, as well as reduce blowdown losses. The possible fuel savings resulting from increased condensate return are shown in Figure 3. The make-up water in this case is 15 °C and assumed temperature of returned condensate is 90 °C. The boiler fuel saved is calculated by using the basic consumption when there is no condensate returned.

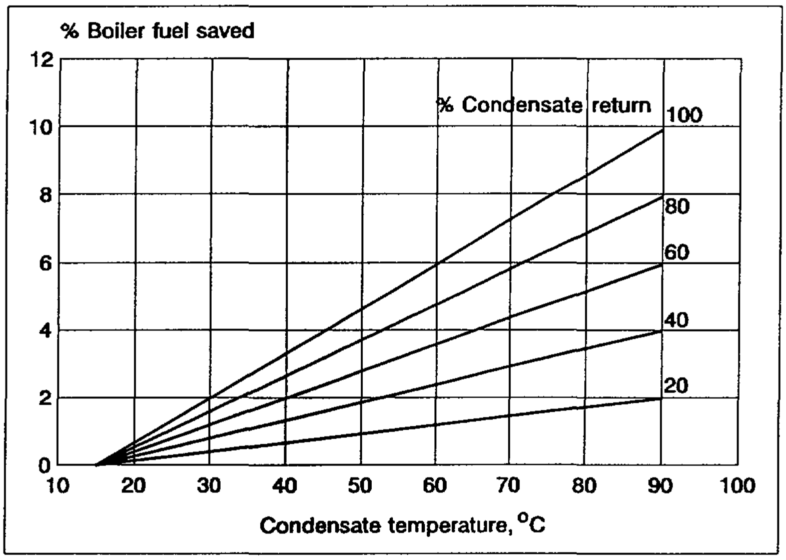


Figure 3: Fuel saved by condensate return

The condensate is wasted. Returning the condensate directly into the boiler or, if it is contaminated, by using the heat exchanger or automatic dumping by measuring the conductivity, it is possible to save fuel from 5% for 50% returned condensate to 9% for 90% returned condensate.

3. Conclusion and Recommendation

This boiler house must be examined throughly and a detailed plan for its retrofitting must be prepared. This action could be expensive and takes a time. Because of that some n/l cost measures have to be done in the meantime.

3.1 Flue gas analysis shows that the tested boilers operate with lower content of carbon dioxide: 7.6 to 9.3 for Boiler No.1,; around 10% for No.2; and around 8% for No.3. Actually, CO_2 for Boiler No.2 could be good. The normal content of carbon dioxide for the natural gas as a fuel is 10 - 9%. Of course, the burner producer must be consulted for proper values. Generally, the performed flue gas analysis shows that boilers do not operate uniformly.

The measured flue gas temperatures are much higher than design one (180 °C), which only shows that the heat transfer surfaces has to be cleaned. This temperature will be even higher if the excess air is reduced to the normal value (for Boiler No.1 and No.3).

Suggestion actions are to:

a) Repair or replace the vital parts of the burners;
b) Improve combustion control by installing the control system for fuel-to-air ratio by measuring CO_2 or O_2.
c) Clean of heat transfer surfaces and control the flue gas temperature history. Any increase of flue gas temperature will be recognised and proper action could be done.

3.2 The following actions can be performed as well:

- Improve and repair the metering system for feed water supplying, steam production and distribution to the main consumers.
- Control of the make up water has to be improved. The quality of make-up water is good (blowdown is performed every three days). However, there is no reason for such a high steam consumption for desalination process (4-6% of total steam production). Metering of waste condensate quality must be checked.

3.3 The temperatures of the boiler surfaces are higher than it is normal. On some spots it was about 120 °C. The insulation of the boiler has to be checked and repair. It could decrease the radiation losses for about 1.0-1.5%.

3.4 A big mass flow rate used for continuous process of desalination could be reuse by installing the heat exchanger for preheating the make-up water. Temperature of this condensate is 180 °C, which means that a huge amount of flash steam is lost. For reuse of flash steam, which is of a very good quality, there is no need even to install heat exchanger.

3.5 The boiler efficiency is (for all boilers) as follows:

Flue gas loses (without wheel heat exchanger)	23 - 26%
Radiation losses	4%
Blowdown loss and desalination	4 - 6%
	Total: 64 - 69%

By performing the suggested actions in items 1-4, there could be an increase in the boiler efficiency for approximately 10%. The pay back period for this is normally less then one year.

3.6 The next step of improving the total efficiency of the boiler house could be analysis of possibility to use flue gases for preheating the make-up by using the condensing economizer. Efficiency improvements of about 5% are common for economizer units installed, often producing pay back period of 1-2 years.

3.7 The steam distribution system is in a very poor condition. It means that a detailed reparation of the system must be done. All steam traps and valves have to be checked, repaired or replaced. Insulation must be checked as well and put on the uninsulated pipelines, valves and flanges. Corroded pipelines have to be replaced.

Just to illustrate the effect of a leak consider the following:

- Steam pressure 7 bar
- Hole size 0.8 mm

Produces the loss equivalent to 1,200 nm^3 of natural gas per year.

Or, to illustrate the loss through uninsulated surface and flanges, the following example could be used:

- A 3 m length of exposed 150 mm diameter piping carrying steam at a pressure of 7 bar can waste 2,400 nm^3 of natural gas per year.
- If there were five uninsulated flanges on the same 150 mm diameter pipe, heat losses would equate to another 2,400 nm^3 of natural gas being wasted in a year.

During the audit it was very difficult to count the number of leaks and uninsulated places. However, there is no doubt that a great energy saving potential is in improving the steam distribution system. The common pay back period for this typical housekeeping procedure is less than one year. Expected effect of efficiency improvement of steam mains in this fertilizer could be up to 10%.

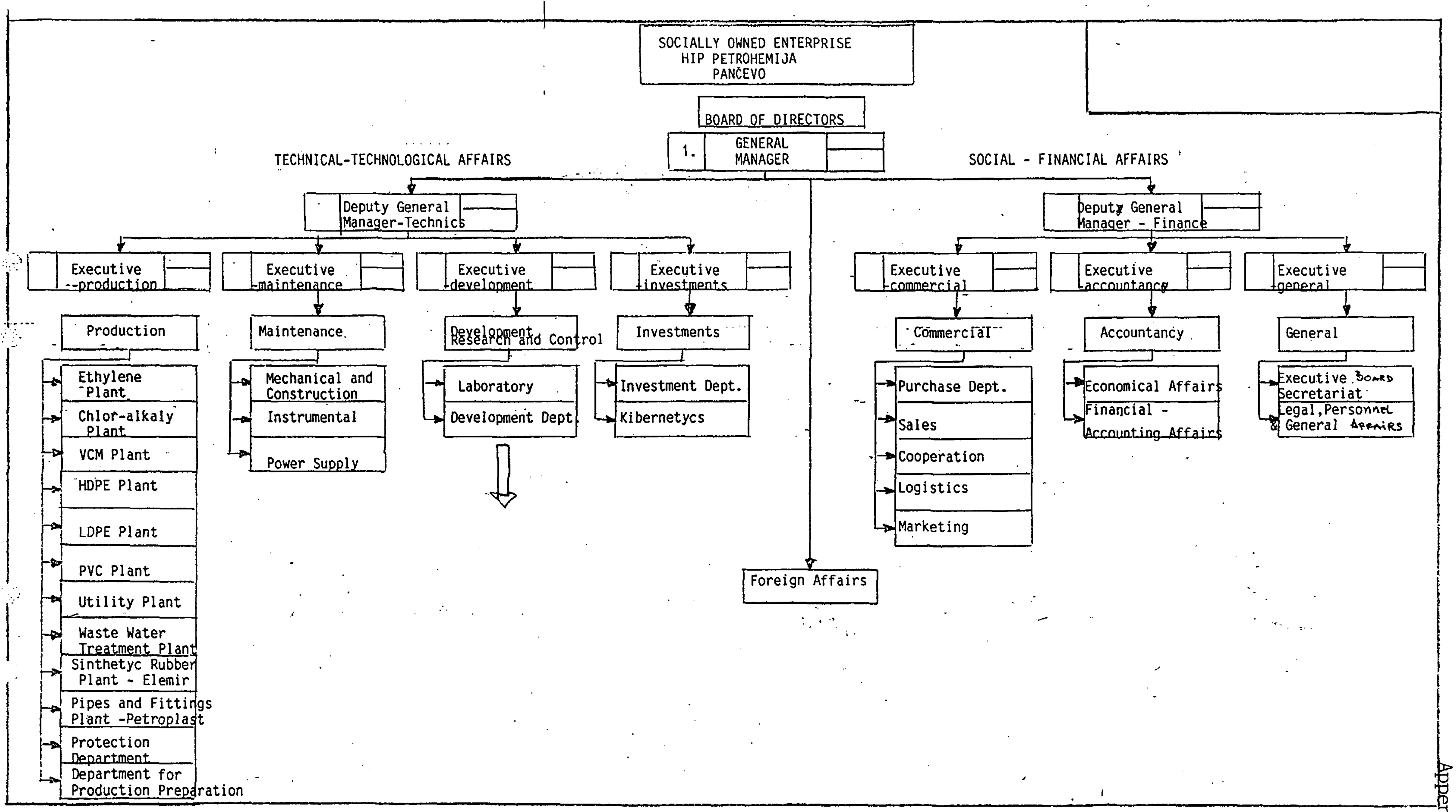
3.8 As it has been mentioned, the condensate from the processes is wasted. There is no good excuse for this. The problem of pollution of the condensate could be overcome by heat exchanger or by measuring the concentration of pollutant in the condensate and automatic relief condensate if it happens that the concentration is too high.

Possible practical boiler fuel saving by returning the condensate in this plant is up to 10%.

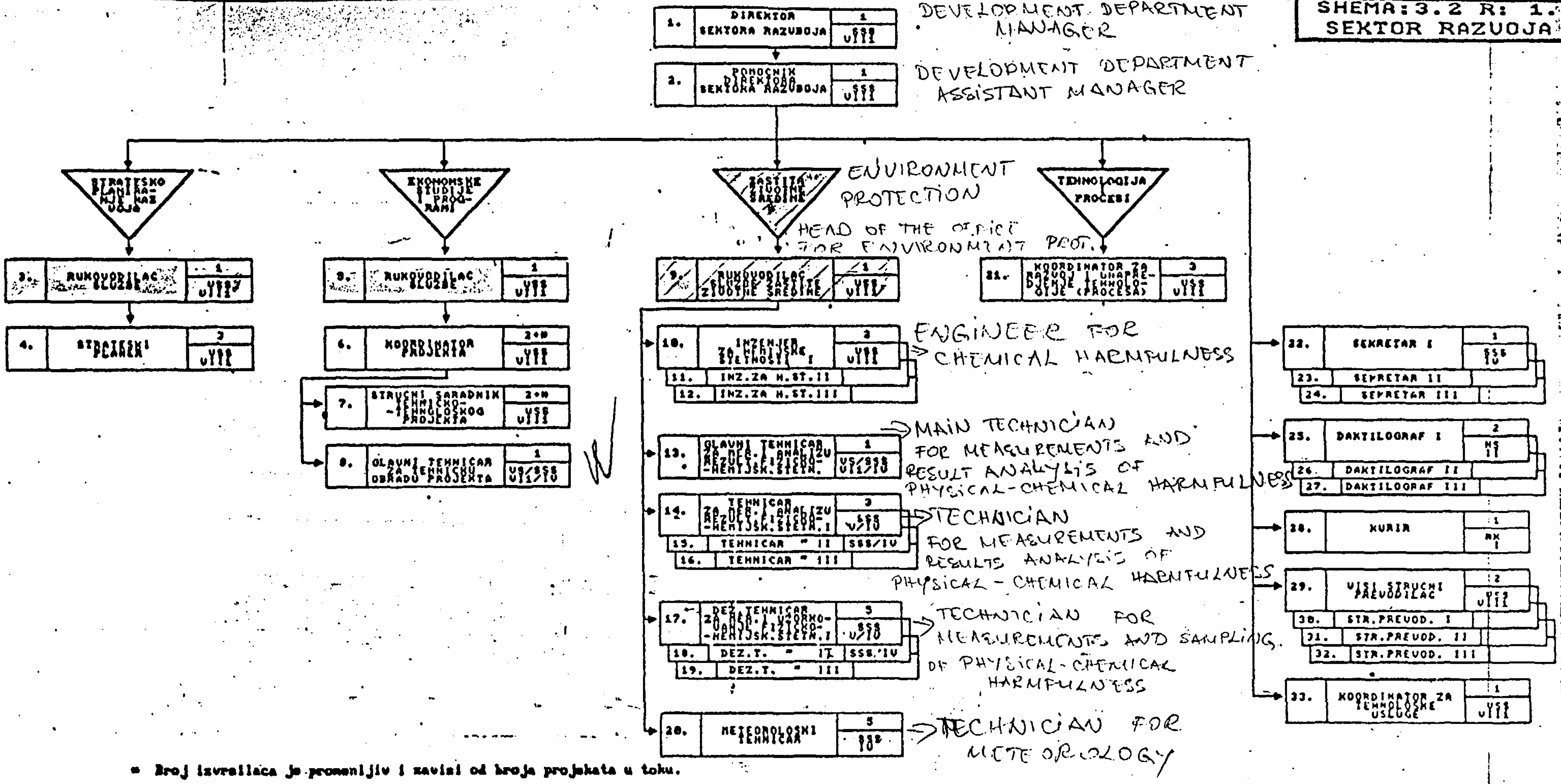
3.9 Total expected energy savings in boiler house and steam and condensate system could be estimated in the range of 20-25% with pay back period around 2 years.

28.10.96 GENERAL QUESTIONNAIRE

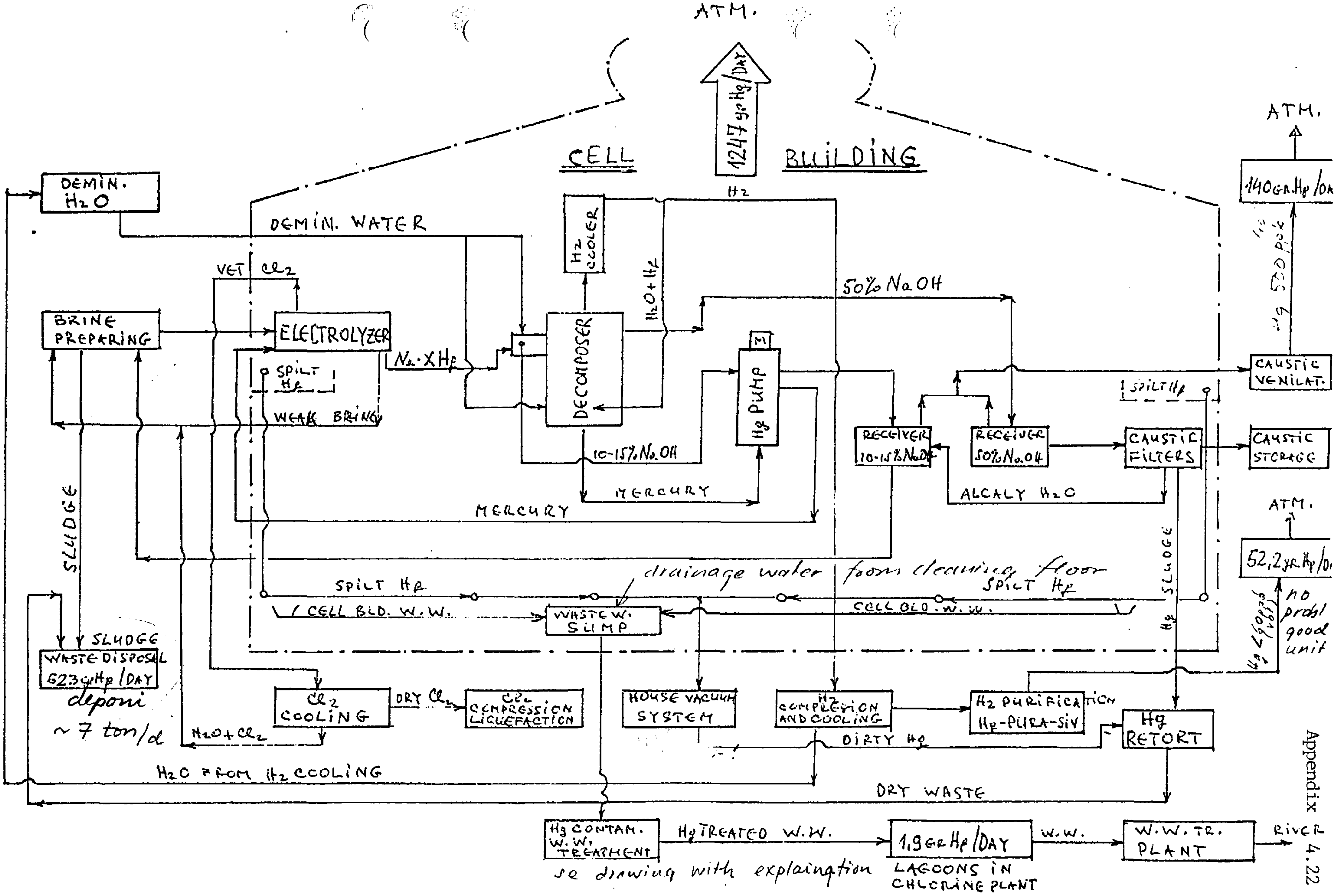
P: 1.3 - 1.3.2



SHEMA: 3.2 R: 1.1
SEKTOR RAZVOJA



* Broj izvrsilaca je promenljiv i zavisi od broja projekata u toku.



Appendix 4.22

„OLIN" E-812 CELLS
DESIG 267 t Cl_2/DAY

DESIGN MERCURY WAYS
AND DAYLY LOSSES

02/PV/X-96

Appendix 4.23

RESULTS OF CHEMICAL
POLLUTANTS MEASUREMENTS
IN CHLOR ALKALI PLANT

REZULTATI MERENJA HEMIJSKIH STETNOSTI
U RADNOJ SREDINI: ZIVA (Instrument MV
FABRIKA "ELEKTROUZA" Sep-96

	POGON UKUPNO TOTAL IN THE PLANT	HALA CEL. I CELL ROOM	HALA CEL. P CELL ROOM	KOMAN SOBA CONTROL ROOM	PROST ZA CEL AREA FOR CELLS	SMENO VODJA SHIFT SUPERVISOR	IZVO-DJACI OUTSIDE ENGAGED PERSONNEL	KOMPR SOR. S COMPRESSOR STATION	RUK. KOMPR COMPRESSOR OPERATOR	UTOVR HLORA CHLORINE LOADING	ZIVINA RETOR MERCURY RETORT	SEKCIJ HIPO HYPO SECTION	BRAVA RAD. FITTERS WORK-SHOP	ELEKT ICARI ELECTRICIANS	INSTRU MENT. INSTRUMENTATION	PLASTI-CARI PLASTICS	MANIP. HEMIK. CHEMICALS HANDLING	PRIP. ELEKT ELECTROLITE PREPARATION	TRPEZ-RIJA DINING-ROOM	GARD ROBA WARDROBE	PERIO-NICA WASH-ROOM	TEHN. ODRZ. MAINTENANCE TECHNICIAN	GL.TEH PROIZV MAIN PRODUCTION TECHNICIAN
1) Ukupan broj analiza TOTAL NO. OF ANALYSIS	1384	89	88	90	90	87	5	90	90	27	90	88	90	66	55	22	41	89	31	87	17	33	19
2) Br. mer. kad nije reg. toksik [illegible] NO TOXICITY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3) Broj merenja > MDK (mg/m3) NO. OF MEASUREMENTS WITH > MAC	188	67	48	25	34	3	0	0	0	0	0	0	1	0	0	8	0	0	0	0	1	1	0
4) Max koncentracija (mg/m3) MAX. CONCENTRATION	0.201	0.175	0.097	0.117	0.135	0.066	0.022	0.014	0.035	0.018	0.024	0.020	0.055	0.040	0.034	0.201	0.048	0.040	0.021	0.040	0.059	0.120	0.040
5) Prosecna vrednost (mg/m3) AVERAGE	0.025	0.066	0.051	0.040	0.046	0.024	0.010	0.007	0.014	0.011	0.013	0.009	0.020	0.013	0.011	0.042	0.012	0.014	0.008	0.023	0.032	0.015	0.014
6) MDK (mg/m3) MAC	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
7) 2 : 1 (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8) 3 : 1 (%)	13.6	75.3	54.5	27.8	37.8	3.4	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	36.4	0.0	0.0	0.0	0.0	5.9	3.0	0.0
9) Aritmet. sredina (mg/m3) ARITHMETICAL AVERAGE	0.025	0.068	0.052	0.042	0.047	0.025	0.014	0.007	0.014	0.011	0.013	0.009	0.021	0.013	0.011	0.051	0.013	0.014	0.009	0.024	0.035	0.019	0.017
10) Stand. devijacija STANDARD DEVIATION	0.022	0.029	0.020	0.019	0.019	0.011	0.007	0.002	0.004	0.004	0.004	0.003	0.007	0.006	0.005	0.038	0.008	0.006	0.005	0.006	0.012	0.019	0.008
11) Varijanea VARIANCE	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000

*

ANALYSIS OF MEASUREMENTS IN THE WORKING ENVIRONMENT

ANALIZA MERENJA U RADNOJ SREDINI

1990. Godina

22 measuring points

min. 1/d

Fabrika "Elektroliza"

Jan Febr . . .

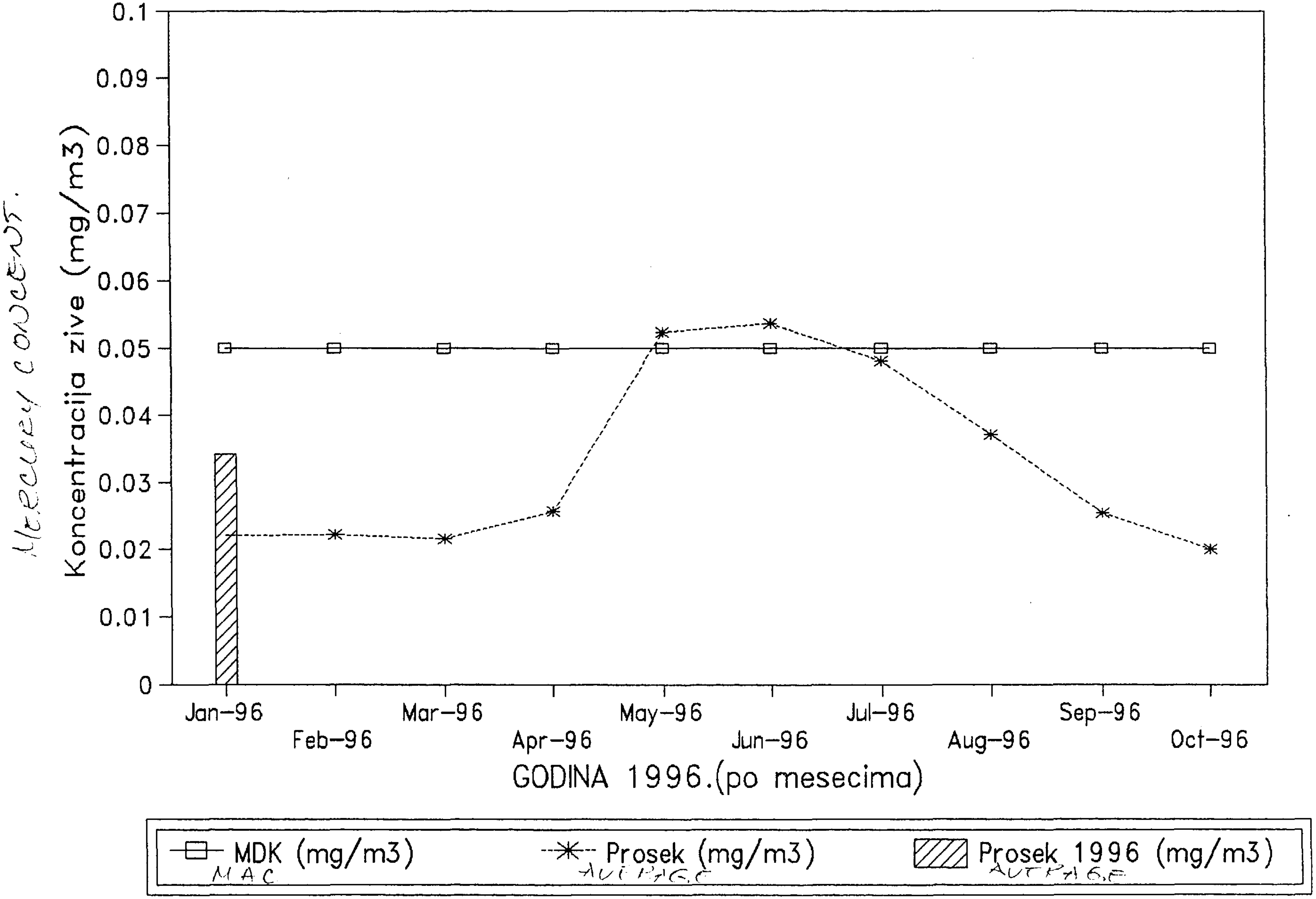
sep.

R.B.	POLUTANT KOJI SE MERI Ziva (Hg)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1	Ukupan broj analiza	646	538	652	628	658	593	644	661	530	665	630	655
2	Br. analiza kad nije reg. toksik	387	299	351	370	345	346	299	364	232	319	303	328
3	Br. analiza kad su vrednosti > MDK	39	68	56	49	47	64	52	71	62	11	26	26
4	Maksimalna koncentracija	0.7	0.8	0.4	0.5	0.5	0.7	0.3	0.6	1	0.25	0.3	0.4
5	Prosecna vrednost medelvärde	0.018	0.043	0.035	0.031	0.032	0.04	0.034	0.034	0.049	0.02	0.024	0.024
6	M D K (mg/m3)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
7	2 : 1 (%)	59.91	55.58	53.83	58.92	52.43	58.35	46.43	55.07	43.77	47.97	48.10	50.08
8	3 : 1 (%)	6.04	12.64	8.59	7.80	7.14	10.79	8.07	10.74	11.70	1.65	4.13	3.97

Appendix 4.24

MERCURY CONCENT. MEASUREMENTS
IN THE WORKING ENVIRONMENT
(CHLOR. ALKALY PLANT)

REZULTATI MERENJA KONCENTRACIJE ZIVE
U RADNOJ SREDINI: FABRIKA "ELEKTROLIZA"



Appendix 4.25

AMMONIA

NATURAL GAS COMPOSITION

Values from 28 October 1996, typical for the month.

CH4	93.1 %	
C2	1.4 %	
C3	0.3 %	
C3+	0.1 %	
N2	1.7 %	
CO2	3.4 %	
H2S	2 ppm	
Heating value	34800	kJ/Nm3

PRODUCTION AND CONSUMPTION

	Jan-March	Jan-June	
	Budget		
Production tonnes	66520	129000	
Production, t/day average	731	709	692
Gas consumption, Nm3/tonne	1356	1358	
	1300		
Gas heating value, kJ/Nm3	34600	34600	
	33338		
Spec. energy consumption, GJ/t	46.9	46.9	
	43.3		
(Spec. energy consumption, MWh_{th}/t	13.0	13.0	
	12.0)		
Time efficiency %	97	92	
Electricity, kWh/t	167	166	170
NaOH (45%), kg/t	3.0	2.6	3.2
HNO3 (100%) kg/t	2.0	1.8	2.4
K2CO3, kg/t	0.14	0.26	
	0.70		

APPENDIX 4.27

SAVINGS IN AMMONIA PLANT.

Assumptions:

Heating value of natural gas: 33 333 kJ/Nm3 = 0,33 GJ/Nm3
Energy consumption 1350 Nm3/tonne = 45 GJ/tonne
Gas price: 0.48 din/Nm3 = 1.44 din/GJ
Energy cost: 64.8 din/tonne NH3
Ammonia price: 954 din/tonne NH3
Production: 233 000 tonnes pro year
750 tonne per day (310 day pro year)
Total ammonia value 222.3 Mdin pro year
Total energy cost: 15.1Mdin/year

Nitric acid price 431 din/tonne
Sulphuric acid price
Hydrochloric acid

1) New catalyst and internals in synthesis reactor:
Ammonia production: 1000 tonnes pro day = 310 000 tonnes pro year
Energy consumption: 40 GJ/tonne NH3
Energy cost: 57.6 din/tonne NH3
Total energy cost: 17.9 Mdin pro year
Ammonia value: 295.7 Mdin pro year
Net profit: 70.6 Mdin pro year

2) Replacing nitric acid for ion exchange regeneration
Nitric acid consumption 550 tonnes pro year
Cost for nitric acid 240 000 din pro year
Equivalent amount sulphuric acid 428 tonnes pro year
Cost for sulphuric acid:

3) Purge gas wash
Purge gas flow 5000 Nm3/h
Ammonia content 3,5 %
Ammonia amount 132 kg/h = 3.2 tonnes pro day
988 tonnes pro year
Ammonia value 943 000 din pro year

NITRIC ACID

PRODUCTION AND CONSUMPTION

For the first quarter 1996 the following operation figures were given:

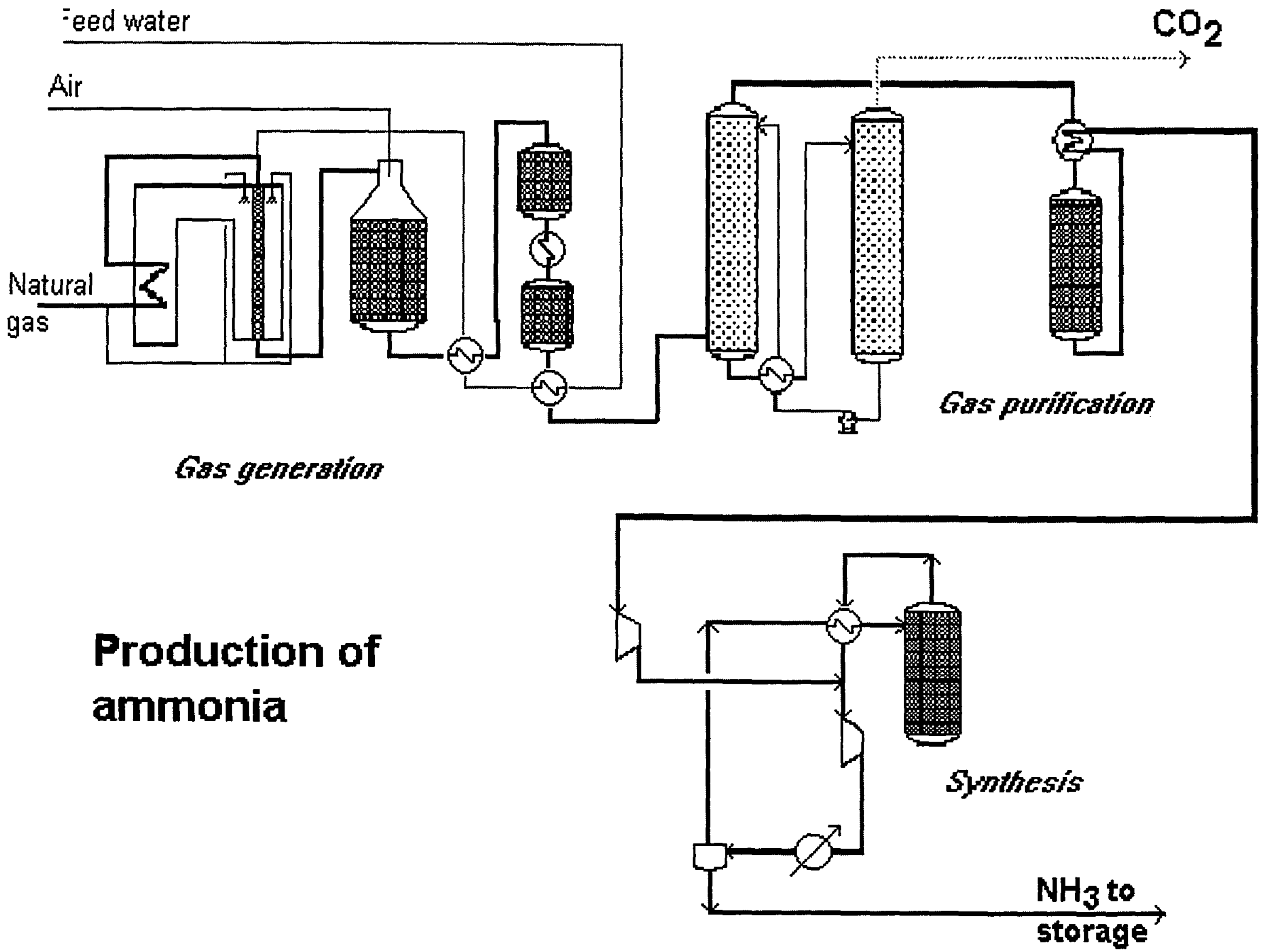
	HNO3 I		HNO3 II	
P	Actual	Budget	Actual	Budget
Productions:				
HNO3, tonnes	38 665	33 000	25 600	35 000
HNO3, tonnes per day	425	362	281	385
Steam, t/h	17,7	16,8		
Steam, t/t HNO3	1,00	1,11		
Consumptions per tonne HNO3:				
NH3, tonnes	0,319	0,307	0,312	0,307
Gas, Nm3			15	26
Electricity, kWh/t	387	338	3	3

CALCULATIONS

Assumptions:

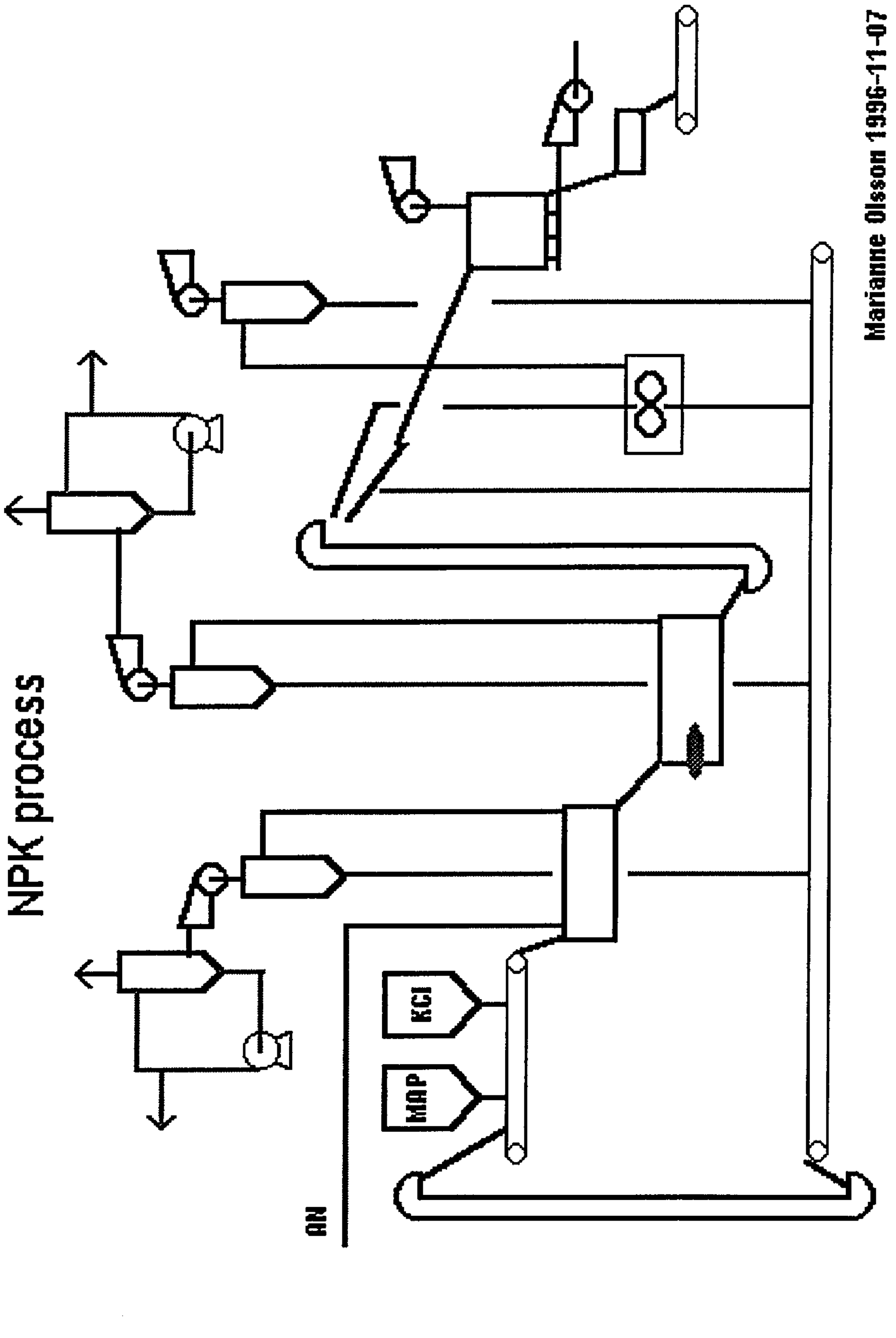
Value of nitric acid	431 din pro tonne
Ammonia consumption	0.307 tonnes pro tonne
Ammonia cost	954 din pro tonne NH3
	293 din pro tonne HNO3
Platinum consumption	0,24 g/tonne HNO3
Platinum cost	109 din/g
	26 din pro tonne HNO3
Contribution I for nitric acid	100 din/tonne
Tail gas flow	3570 Nm3 per tonne HNO3
NOx content	1500 ppm
	5.355 Nm3 per tonne HNO3
	11 kg NO2 per tonne HNO3
Nitric acid production	270 000 tonnes pro year
NOx content after catalytic reduction	150 ppm
NH3 for NOx reduction	0.01 tonne NH3 per tonne HNO3
	2.6 Mdin pro year
Natural gas for tail gas heating	15 Nm3 per tonne HNO3
Natural gas price	0,71 din/Nm3
Natural gas cost	2.9 Mdin pro year

Production of ammonia



HYDRO KEMI/Marianne Olsson 1995-10-24

NPK process



Marianne Olsson 1996-11-07

PETROCHEMICAL PLANT - BOILER HOUSE

1. Design Data and Present Case

1.1 Boiler House

Schematic description of boiler house is shown in Figure 1. Three boilers are installed in the boiler house. The boilers are fired with natural gas.

The contents of fired natural gas and its net calorific value was measured in Fertilizer Plant at November 14, 1996 as:

CH_4	92.14
C_2H_4	2.35
C_3H_8	0.37
iC_4H_{10}	0.04
nC_4H_{10}	0.05
iC_5H_{12}	0.02
nC_5H_{12}	-
C_6H_{14}	-
N_2	1.66
CO_2	3.36
Net Calorific Value	35,068 kJ/nm^3

There are typical contents of natural gas which has been used in all plants in Panchevo for a long time.

Each boiler is equipped with two combined gas and oil burners made by PEABODY, UK. The maximum capacity of the burner is 3,140 nm^3/h (for natural gas) or 5,510 kg/h (for heavy fuel oil). For about 92% of total working hours of boilers per year is used natural gas and for only 8% heavy fuel oil.

Boiler design data of all three boilers are as follows:

Type:	Integral Water Tube Boiler
Manufacturer:	Standard Kessel, Germany
Installed:	1976
Steam Pressure:	38 barg
Steam Temperature:	350 °C
Feed Water Temperature:	130 °C
Capacity:	80 t/h
Design flue gas temperature:	180 °C

During the audit an boiler efficiency tests were made. Boiler No.3 was under reparation in that time and only the boilers No.1 & 2 were the subject of this audit. The results are presented in Tables 1 and 2. The measuring results performed by using the existing instrumentations are presented in Tables 3 and 4, for boiler No.1 and No.2, respectively. The corresponding measuring points are shown in Figure 2.

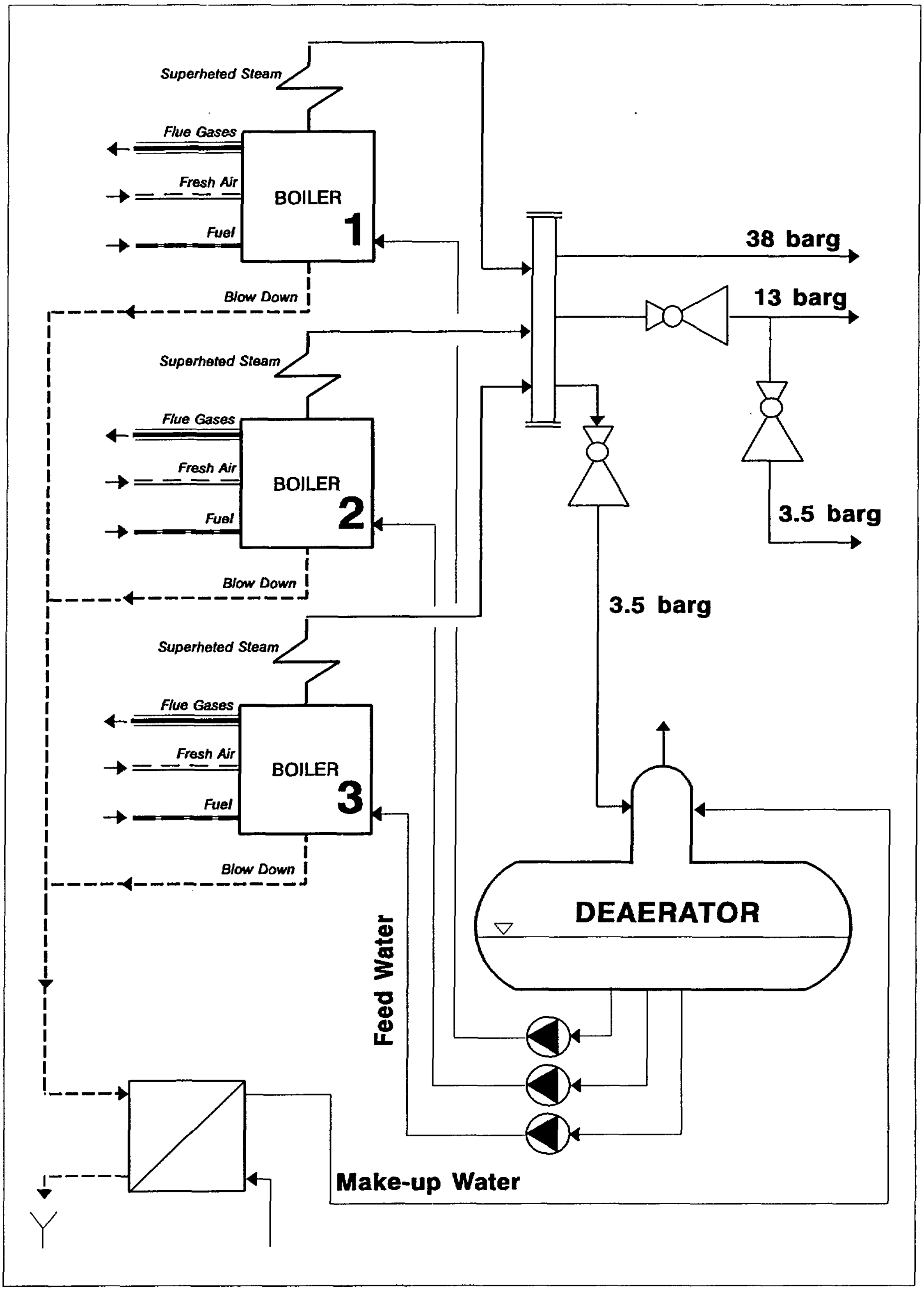


Figure 1: Schematic description of the boiler house

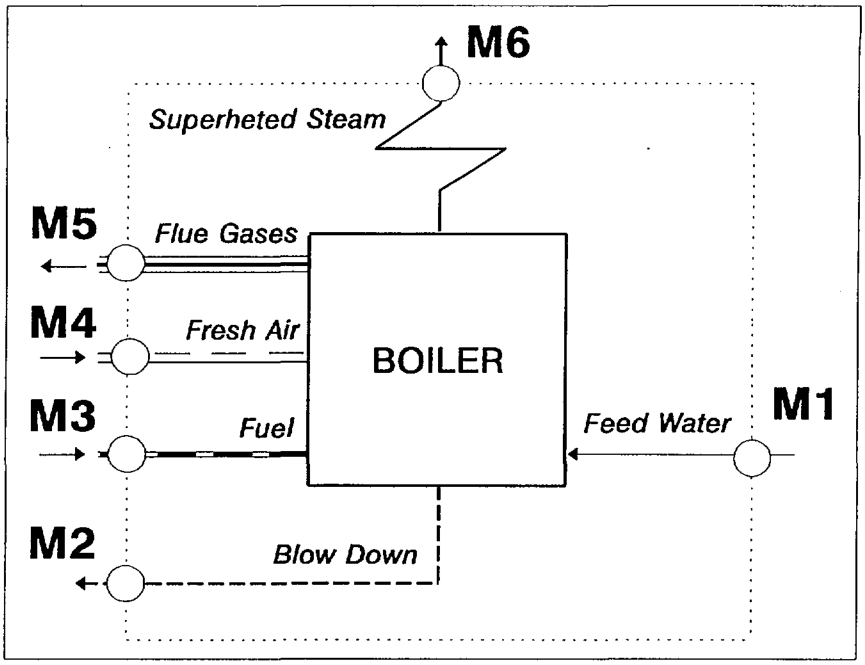


Figure 2: Battery limit of the boiler

Table 1: Flue gas analysis for boiler No.1

Company:	Petrochemical Plant, Panchevo
Location:	Boiler House, BOILER No. 1
Date and Time:	October 31, 1996 (9:40 - 12:35)
Fuel:	Natural Gas

Measured value		Units	Time				Average value
			9:45	10:00	10:15	10:30	
Ambient temperature		°C	16	16	17	17	16.50
Flue gas temperature		°C	159	204	197	200	190.00
Flue gas contents	CO_2	%	9.5	8.8	8.9	9.2	9.10
	O_2	%	1.2	2.7	2.5	1.7	2.03
	CO	ppm	97	1	0	0	24.50
	NO_x	ppm	75	83	85	86	82.25
	SO_2	ppm	0	0	0	0	0.00
C. Efficiency		%	94.2	91.8	92.2	92.4	92.65
Excess air		-	1.06	1.14	1.13	1.08	1.10

Table 2: Flue gas analysis for boiler No.2

Company:	Petrochemical Plant, Panchevo
Location:	Boiler House, BOILER No. 2
Date and Time:	October 31, 1996 (9:40 - 12:35)
Fuel:	Natural Gas

Measured value		Units	Time				Average value
			10:45	11:14	11:21	11:36	
Ambient temperature		°C	18	23	24	24	22.25
Flue gas temperature		°C	200	146	143	134	155.75
Flue gas contents	CO_2	%	9.2	8.0	8.7	8.6	8.63
	O_2	%	1.8	4.3	2.8	3.0	2.98
	CO	ppm	0	77	12	1057	286.50
	NO_x	ppm	84	97	102	97	95.00
	SO_2	ppm	0	0	0	0	0.00
C. Efficiency		%	92.4	94.1	94.8	95.1	94.10
Excess air		-	1.09	1.25	1.15	1.16	1.16

Table 3: Measuring data from the existing instrumentations (boiler No.1)

Measuring point	Measured value	Time						Average value
		9:40	10:20	11:30	11:55	12:25	12:35	
M1	m_1 [t/h]	52	95	60	80	70	72	71.50
	t_1 [°C]	124	124	122	123	123	124	123.33
	p_1 [bar]	61	61	61	57	57	57	59.00
M2	m_2 [m^3/h]							
	t_2 [°C]							
M3	m_3 [nm^3/h]	9600	8610	8400	9600	8400	9600	9,035.00
	t_3 [°C]	16	16	16	16	16	16	16.00
M4	t_4 [°C]							
M5	t_5 [°C]	168	220	187	198	192	192	192.83
	O_2 [%]	1.4	1.4	0.2	0.8	0.6	0.6	0.83
M6	m_6 [t/h]	58	110	100	95	85	85	88.83
	t_6 [°C]	354	364	350	350	350	350	353.00
	p_6 [bar]	38	20	29	35	36	35	32.17

Table 4: Measuring data from the existing instrumentations (boiler No.2)

Measuring point	Measured value	Time					Average value
		9:50	11:25	11:55	12:15	12:35	
M1	m_1 [t/h]	60	30	35	45	35	34.20
	t_1 [°C]	124	122	123	123	124	123.20
	p_1 [bar]	61	59	57	57	58	58.40
M2	m_2 [m^3/h]						
	t_2 [°C]						
M3	m_3 [nm^3/h]	9600	8400	9600	8400	9600	9,120.00
	t_3 [°C]	16	16	16	17	17	16.40
M4	t_4 [°C]						
M5	t_5 [°C]	165	145	145	145	145	149.00
	O_2 [%]	0.4					0.40
M6	m_6 [t/h]	65	30	35	42	50	44.40
	t_6 [°C]	355	350	340	340	342	345.40
	p_6 [bar]	38	29	34	36	35	34.40

1.2 Feed Water System

All condensate from processes in the Petrochemical is wasted! The feed water which goes into the boilers is 130 °C. Demineralized water is preheated in economizer up to 80 °C, and after that in heat exchanger up to 130 °C. This heat exchanger uses the steam.

There is a continuous process of desalination in the boiler drum which uses 3-4% of the total steam production.

The blowdown at the boiler is performed three times per day. The blowdown operation is performed manually.

1.3 Steam and Condensate System

The pressures of the distributed steam are as follows: 1) 38 barg, 350 °C to the process; 2) reduced by throttling to 13 barg and use in process; and, 3) reduced to 3.5 barg for processes (heating the tanks, premises, etc.). From total steam mass flow rate about 40% is spent in boiler house for running the turbines for fans and for preheating the feed water to about 130 °C. The high pressure steam (about 27%), medium pressure steam (about 14%) and low pressure steam (about 19% from total steam production) are sent to the processes.

Steam and condensate leakages are huge and the steam traps are in a very poor condition. Some condensate is polluted and it is wasted although it has a rather high temperature. Because of that there is no returned condensate to the boiler house. That means that a lot of make-up water is used and a lot of energy and chemicals are used for its preparation.

1.4 Daily Production Report of Boiler House

A typical daily production report in boiler house contains temperatures and pressures in different points of the plant and some number of flows of steam and water and some power values concerning electrical production. It can be say that standard type of measurements are done every day and are the contents of the daily report. The part of this measurements are reported in the Tables 3 and 4 for boilers No.1 and No.2. However, in 9:40 for boiler No.1 it was measured that the mass flow rate of feed water was 52 t/h and at the same time the mass flow rate of the steam was 60 t/h. That means that there is a difference of about 13%. Such a difference is possible in transient period of boiler run, but the same differences appear continuously. This difference couldn't be a result of desalination process.

During the audit at 10:15 the accidental shutdown happened at boiler No.2. It produced a decrease of steam pressure on the outlet of boiler No.1 and increase the steam mass flow rate up to 110 t/h (Table 3). This mass flow rate is much higher than the nominal steam production is (80 t/h). Possibly the metering system was out of range. However, that means that there are not any possibilities to make reliable energy balance of the plant either in total or in some insulated parts of the plant.

If the efficiency of boiler No.1 is calculated (using data from Table 3 at 9:40) the following result is obtained:

$$\eta = \frac{58 \cdot 10^3 (3089 - 4.187 \cdot 80)}{9600 \cdot 35068} = 0.47$$

This value is to low, but it confirms the statement about the unreliable instrumentations.

2. Energy Conservation Measures and Discussion of Collected Data

In this Chapter only the following measures will be discussed:

- Housekeeping and Operational Improvements;
- Combustion, Steam and Condensate System Improvements;
- Waste Heat Recovery and Reuse;

Only after analysis and/or implementation of proposed measures prescribed by these three measures, one can have reliable entering data for further consideration of energy efficiency improvements.

Concerning this plant the following n/l cost measures has to be implemented without delay because it can result in 15-20% energy savings. This analyses concerns the boiler house and the steam and condensate systems.

2.1 Housekeeping Procedure

Existing housekeeping procedure is not effective which also means that it is not efficient. A lot of leakages were found in steam and condensate distribution system. There are hundreds of steam traps and only a small number of them operate properly. A flash steam allowed to blow to waste (condensate tanks). There are some points for condensate collection before it is wasted. There are a lot of contaminated condensate which can be recovered by using heat exchangers, but it is wasted now. However, even the clean condensate used for heating the tanks and premises is not returned.

Some analysis performed by authorized personnel in boiler house have shown that the mass flow rate of lost condensate could be about 70 m^3/h. The price of waste condensate is estimated on the level of 3 DEM/m^3, which means that the hourly lost is 210 DEM/h. Calculation of this lost per year (8,000 working hours) it results in 1,680,000 DEM. The mentioned analysis shows the environmental effects as well, and the pay back period was estimated to about 3 years.

About 5-10% of all steam and condensate pipelines are not insulated. Some pipes are damaged by corrosion and produce other leakages. There are a lot non insulated valves and flanges. Many important steam leaks are hidden such as: a) leaking or stuck traps or by-pass valves discharging to sewer or condensate system; b) leaking valves leading to idle equipment; and c) leaks in heater or other equipment connected to the steam system.

Housekeeping includes measures to reduce energy use that can readily be taken by plant engineer or plant operator at little or no cost and in a short time. Examples of simple housekeeping are inspecting combustion equipment, adjusting burners, and inspecting and repairing steam traps - preferably on a routine basis. At a slightly more advanced level, the operation of process equipment can be rescheduled to avoid frequent startups and shutdowns - generally, continuous operation is more energy efficient than intermittent operation - or equipment can be adjusted to operate at the lowest economical temperature. Improvement of insulation becomes part of housekeeping if materials costs are low and the payback period is shorter than a year. For example, if the surface temperature of currently insulated steam lines or liquid piping exceeds 40 °C, the insulation should be upgraded. Damaged insulation can result in much heat loss, so regular inspection of distribution lines is desirable. Combustion efficiency is major area of potential operational savings, as 1 - 5% of fuel used can be saved by regular tune-up of the air-to-fuel ratio. Modern technology enables fuel-to-air ratios to be maintained at recommended levels at all times, insuring consistent combustion efficiency. Microprocessor controlled servo motors fitted to fuel valves and air dampers replace the traditional methods of control, providing a programmable system which will automatically select and maintain the fuel-to-air ratio specific to a particular fuel.

The flue gas temperatures of the boilers were in range from 165 to 210 °C. This temperature is in a range of the designed one (180 °C). However, it has to be controlled on a regularly basis because of the rule which says that an increase of around 20 °C above that temperature for a clean boiler, means that the tubes must be cleaned. A rise of 17 °C causes a decrease in efficiency of 1 %.

Any discussion on energy conservation in Petrochemical has to start with housekeeping procedures.

2.2 Monitoring

Monitoring will not of itself lead to energy savings unless the data is analyzed and put in context within the company or establishment.

Monitoring system in this factory is not reliable and complete and it is not used for energy analysis. It is used only for running the process. Instrumentation used is not in such a good condition. For illustration of this statement the boiler efficiency calculation in Chapter 1.4 can be used.

Measuring systems of steam, feed water and fuel for each boilers have to be re-calibrate or replaced. The ratio of steam to fuel is the main measure of efficiency of the boiler and it should be measured and maintained at a high level, compatible with good practice.

Continuously log boiler performance has to be done so that signs of deterioration soon become evident, enabling corrective maintenance to be carried out.

It is highly recommended to improve monitoring system and to use these data for running the boiler house in optimal way. The next step is to introduce automatic boiler control system. Inadequate or incorrect application of boiler control can easily add 15% to fuel consumption compared with a well-controlled system. In particular, control of multiple boilers is generally poorly understood, as a consequence of which many existing systems are misconfigured and some cases uncontrollable. The main aim of a boiler control should be to reduce avoidable wastage to a minimum whilst providing the necessary output as required.

2.3 Air Preheater and Economizer

There is no air preheater in this boiler house, but there is an economizer for preheating the make up water up to 80 °C, because, as it was mentioned, there is no returned condensate. Each boiler is supplied with such economizer.

The boilers use the natural gas as a fuel which contains minimal sulphur and it is possible for the flue gas exit temperatures to be below the water dew point temperature without causing significant corrosion problems. Considerable improvements in efficiency can be obtained if the water vapour in the flue gas is condensed by further cooling. The maximum increase in energy obtained is approximately equal to the difference between Gross Calorific Value and Net one. However, again it has to be stressed that the real potential of energy saving from waste flue gases can be determined after performing all prescribed housekeeping measures. Only after attaining the maximal energy efficiencies of all consumers within the factory, realizing the efficient distribution steam system and effective returning the condensate in the boiler house, and maximal energy efficiency of boilers, one can estimate and realize real potential of waste energy usage.

2.4 Condensate Recovery

If the feed water temperature is low, the cause should be discovered. It could be due to:

- a low rate of condensate return;
- the lack of insulation on the condensate return pipes;
- losses from the feed water, either as heat through the walls or as overflow.

As much condensate as it is economically possible should be returned from sources where there is no likelihood of contamination. This will save heat, make-up water and chemicals used in water treatment, as well as reduce blowdown losses. The possible fuel savings resulting from increased condensate return are shown in Figure 3. The make-up water in this case is 15 °C and assumed temperature of returned condensate is 90 °C. The boiler fuel saved is calculated by using the basic consumption when there is no condensate returned.

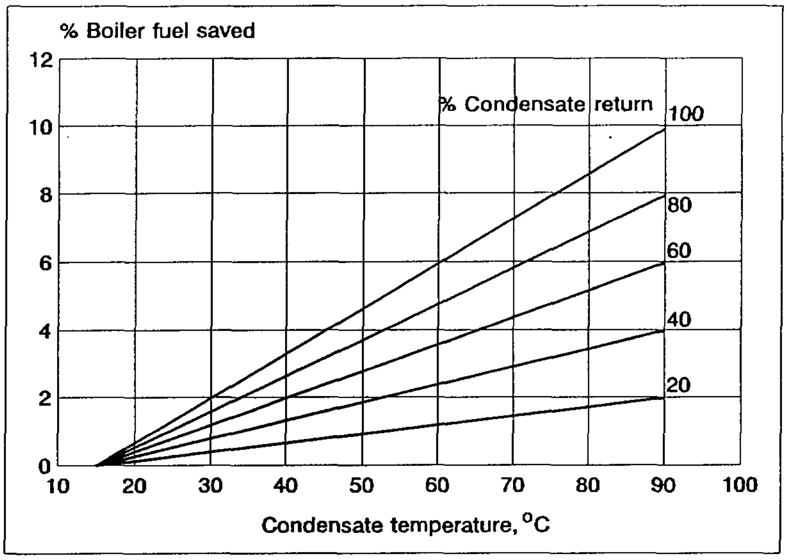


Figure 3: Fuel saved by condensate return

The condensate is wasted. Returning the condensate directly into the boiler or, if it is contaminated, by using the heat exchanger or automatic dumping by measuring the conductivity, it is possible to save fuel from 5% for 50% returned condensate to 9% for 90% returned condensate.

3. Conclusion and Recommendation

This boiler house must be examined thoroughly and a detailed plan for its retrofitting must be prepared. This action could be expensive and takes time. Because of that some n/l cost measures have to be done in the meantime.

3.1 The measuring of the content of combustion products are not significantly different from the expected values, which shows that the process is well conducted. Unfortunately, the process conducted manually, and it is understandable that the higher efficiency can be expected once the automatic combustion process control is installed. The factory experts created some suggestions concerning automatic control of the boiler house. This study proposed control system worth 1,000,000 US$.

Suggested actions are to:

a) Repair or replace the vital parts of the burners;

b) Improve combustion control by installing the control system for fuel-to-air ratio by measuring CO_2 or O_2.

c) Clean the heat transfer surfaces and control the flue gas temperature history. Any increase of flue gas temperature will be recognised and proper action could be taken.

3.2 The metering system for feed water supplying, steam production and distribution to the main consumers has to be repaired or installed.

3.3 The temperatures of the boiler surfaces are higher than it is normal. At some points it was more than 100 °C. The insulation of the boiler has to be checked and repaired. It could get a decrease in the radiation losses for about 1.0%.

3.4 The boiler efficiencies are (for boilers No.1 and No.2) as follows:

Flue gas loses	17.0 - 19.6%
Radiation losses	3%
Blowdown loss and desalination	4%

Total: 73.4 - 76.0%

By performing the suggested actions in items 3.1-3.3, there could be an increase in the boiler efficiency for approximately 10%. The pay back period for this is normally less then one year.

3.5 The steam distribution system is in a very poor condition. It means that a detailed reparation of the system must be done. All steam traps and valves have to be checked, repaired or replaced. Insulation must be checked as well and put on the uninsulated pipelines, valves and flanges. Corroded pipelines have to be replaced.

Just to illustrate the effect of a leak consider the following:

- Steam pressure 7 bar
- Hole size 0.8 mm

Produces the loss equivalent to 1,200 nm^3 of natural gas per year.

Or, to illustrate the loss through uninsulated surface and flanges, the following example could be used:

- A 3 m length of exposed 150 mm diameter piping carrying steam at a pressure of 7 bar can waste 2,400 nm^3 of natural gas per year.
- If there were five uninsulated flanges on the same 150 mm diameter pipe, heat losses would equate to another 2,400 nm^3 of natural gas being wasted in a year.

During the audit it was very difficult to count the number of leaks and uninsulated places. However, there is no doubt that a great energy saving potential is in improving the steam distribution system. The common pay back period for this typical housekeeping procedure is less than one year. Expected effect of efficiency improvement of steam mains in this petrochemical could be up to 10%.

3.6 As it has been mentioned, the condensate from the processes is wasted. There is no good excuse for this. The problem of pollution of the condensate could be overcome by heat exchanger or by measuring the concentration of pollutant in the condensate and automatic relief condensate if it happens that the concentration is too high.

Possible practical boiler fuel saving by returning the condensate in this plant is up to 10%.

3.7 The next step in improving the total efficiency of the boiler house could be analysis of possibility to use flue gases for preheating the make-up by using the *condensing* economizer. Efficiency improvements of about 5% are common for economizer units installed, often producing pay back period of 1-2 years.

3.8 Total expected energy savings in boiler house and steam and condensate system could be estimated in the range of 15-20% with pay back period about 2 years.

Project UNIDO SI/YUG/89/803

Plant calculation of Steam Turbines, Boilers and Process supply

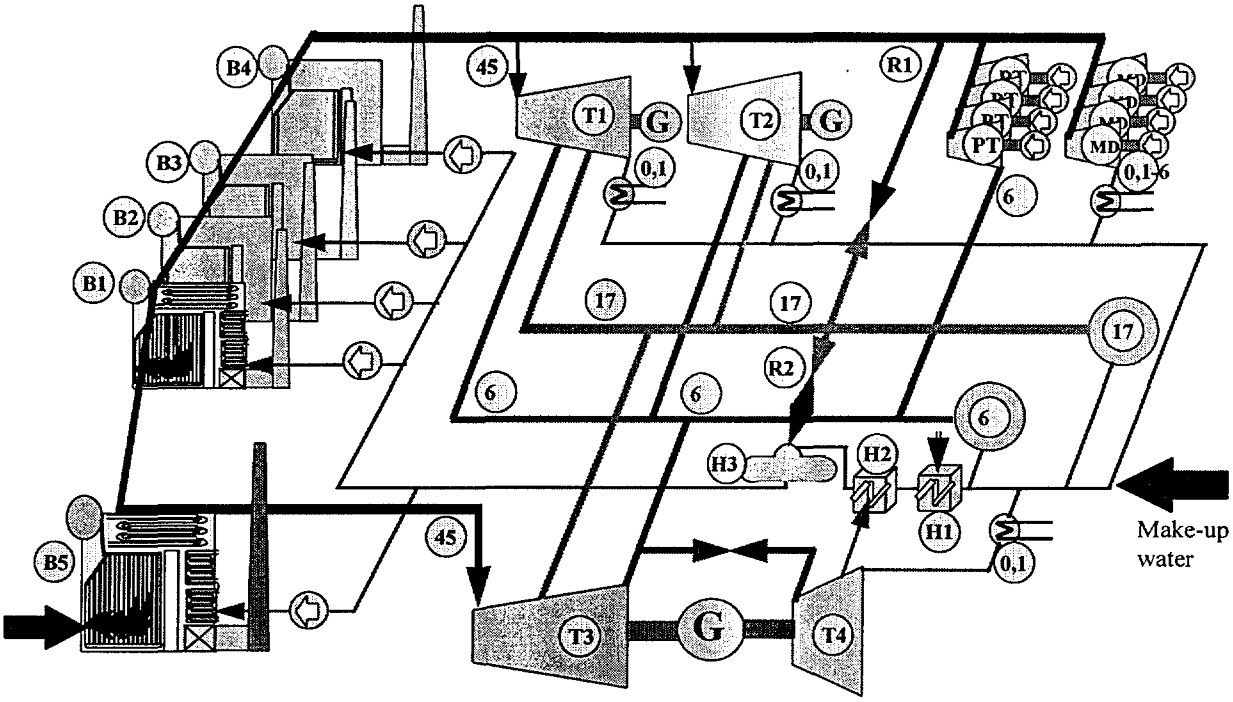


Fig. 1 Sitewide Steam and Power generation, overview showing today's situation and suggested new equipment.

Normal operation today

B1-B3: Boilers in boiler house. Boiler efficiency given to 92 % by client
B4: FCC, CO-boiler. Boiler efficiency 82 %.
B5: New boiler, planned in the future. Boiler efficiency 92 %.
T1-T2: Old turbines, running at partload, oversized backend. Turbine front end efficiency approx. 70-80 % at high loads, backend efficiency low (approx. 30%, due to low load and throttling losses)
T3-T4: New turbines, planned in the future. Design efficiency 85-86%.
R1-R2: Reduction of steam, used for process demands.
H3: Deaerator used for deaeration and feed water heating. Should preferably be combined with heater using waste heat from new crude unit or by recovering process water from other steam consumers. Supplied by steam from pump turbines and 4-6 bar(a) steam header.
H1-H2: Additional heater supplied with heat from different sources:
1/ Process water of high temperature from steam consumers (with 15 bar condensed water we need 21 t/h in order to heat up 200 t/h condensate water from 46 to 60°C).
2/ One additional LP heater supplied with extracted steam of low quality from new turbine. (9.6 t/h steam extracted at 1.1 bar(a) for heating up 200 t/h from 60 to 90°C).
45: Steam header with 45 bar(a) pressure (temperature: 412°C). This header supplies steam to all present turbines within the plant
17: Steam header with 17.2 bar(a) pressure (temperature: 300-320°C). This header supplies steam to industrial processes around the whole plant.
6: Steam header with 4-6.6 bar(a) pressure (temperature: 200-300°C). This header supplies steam to some industrial processes located closely to the mechanical drive turbines in the plant. If these turbines are closed down, a new steam header will be needed for the supply of steam to the 4-6 bar(a) steam consumers.

LEVEL\UNIT	B1	B2	B3	B4	B5	T1	T2	4 * PT	?* MD	T3	T4	R1	R2/ H3
Inlet: 45 bar(a), 412°C,	-45 t/h	-45 t/h	-45 t/h	-65 t/h	N/A	35 t/h	35t/h	47 t/h	45 t/h	N/A	N/A	38 t/h	
17 bar(a)/ 300°C net:					N/A	-29 t/h	-29 t/h	0 t/h		N/A	N/A	-38 t/h	0 t/h
6 bar(a)/ 200°C **net:**					N/A	0 t/h	0 t/h	-47 t/h		N/A	N/A		-0 t/h
0,1 bar(a)/ 45°C	48 t/h	48 t/h	48 t/h	69 t/h	N/A	-6 t/h	-6 t/h		-45 t/h	N/A	N/A		
Power	42464 kW$_{oil}$	42464 kW$_{oil}$	42464 kW$_{oil}$	68361 kW$_{fuel}$	N/A	2500 kW$_{el}$	2500 kW$_{el}$	500 kW$_{mec}$	600 kW$_{mec}$	N/A	N/A		

Table 1. Situation today, with new possibilities indicated

Suggested improvements

LEVEL\UNIT	B1	B2	B3	B4	B5	T1	T2	4* PT	?* MD	T3 + T4		R1	R2/ H3
Inlet: 45 bar(a), 412°C,	-45 t/h	-45 t/h	-45 t/h	-65 t/h	N/A	0 t/h	0 t/h	0 t/h	0 t/h	200 t/h	0 t/h	0 t/h	
17 bar(a)/ 300°C net:					N/A	-0 t/h	-0 t/h	0 t/h	0 t/h	-108 t/h	0 t/h	-0 t/h	0 t/h
6 bar(a)/ 200°C **net:**					N/A	0 t/h	0 t/h	-0 t/h		-40 t/h	52 t/h		-0
0,1 bar(a)/ 45°C	48 t/h	48 t/h	48 t/h	69 t/h	N/A	-0 t/h	-0 t/h		-0 t/h	0 t/h	52 t/h		
Power	42464 kW$_{oil}$	42464 kW$_{oil}$	42464 kW$_{oil}$	62285 kW$_{oil}$	N/A	0 kW$_{el}$	0 kW$_{el}$	0 kW$_{mec}$	0 kW	18000 kW	6000 kW		

Table 2. Situation after energy conservation project

Replace low-efficient equipment

Pump turbines

The feed water pumps is making a pump work that corresponds to approx. 300 kW power. with a pump efficiency of 60%, this means approx. 500 kW power supply. Today we can estimate that 40-50 t/h is used for pump turbine drive. This amount of steam can produce 5-5.6 MW electrical Power in a new Steam Turbine. Net savings approx. **4800 kW** electricity. The calculations are based on an expansion between 45 and 6 bar in the turbine.

Mechanical drive turbines

There are a lot of different mechanical drive turbine equipment at different locations of the plant. Earlier investigations shows that a typical efficiency of this small scale equipment is lower than 20%. If the total steam supply flow for mechanical drive turbines are approx. 45 t/h, we can produce 5.4 MW electrical power with this steam, assuming that we extract the steam at 6 bar pressure level. With electrical motors we will consume approx. 600 kW. Net savings **4800 kW.**

Feed water heating

By recovering a small portion (21 t/h) of the heat from the warm water condensate at 17 bar pressure level (assuming water with 15 bar/197°C), we can heat up feedwater including make up water with 15°C.

In addition to this we can introduce a low pressure feed heater, supplied with steam from a bleed in the new steam turbine. By extracting 9.6 t/h at 1.1 bar(a) pressure, we can heat up the feedwater additionally 30°C.

By adding heaters we will decrease the steam consumption for the feed water from today: 24 t/h at 6 bar level to: 7.1 t/h at 6 bar level with the suggested equipment (heaters and turbine). The savings by producing extra power output will be: **1710 kW**. It would be possible to save more by extracting the steam at 3.8 bar(a) pressure level instead of 6 bar(a) but then we would need additional control valve systems for two-hole-extraction. Final feed water temperature (boiler inlet) level is supposed to be 140°C. Fig. 2 indicates 140°C as final feed water temperature and Fig. 3 indicates performance with 109°C.

Using old turbines as standby equipment

The old turbines are not running under design conditions and are consequently not that effective during normal operation. By using a new turbine well below design conditions and by not using the old turbines under normal operation we can improve the total power output substantially. The total expected output is shown in the table below (Total improvement: 17700 kW)

LEVEL\UNIT	**B1**	**B2**	**B3**	**B4**	**Sum 1996**	**Sum 2000**
Inlet: 45 bar(a), 412°C,	-45 t/h	-45 t/h	-45 t/h	-65 t/h	200 t/h	200 t/h
17 bar(a)/ 300°C **net:**					-96 t/h	-108 t/h
6 bar(a)/ 200°C **net:**					-47 t/h	-40 t/h
0,1 bar(a)/ 45°C	48 t/h	48 t/h	48 t/h	69 t/h	-57 t/h	-52 t/h
Power Today	42464 kW_{oil}	42464 kW_{oil}	42464 kW_{oil}	62285 kW_{oil}	5000 kW	24000 kW- 1300 kW = 22700 kW

Financial analyses

As the suggested savings will require some investments we have to make an financial analyses showing the expected payback time for suggested investments.

Boundary conditions:

- 8000 operational hours/year
- One extra kWh electrical output has a value of 0.015 USD. (International level 0.1 USD/kWh, electrical output)
- Budget Price for equipment includes installation for turbines and heaters.
- Interest rate for capital is not included. (International level 5-10%)
- It is assumed that all turbines for mechanical drive is running on HP steam.
- It is assumed that the four boilers available have a high efficiency, as indicated by employees in the refinery.

Investment	Savings	Value of savings/year	Investment costs	Payback time
5 Pumpmotors and pumps,	4800 kW +	570 kUSD/Y	150 kUSD +	
40 Mechanical drive motors,	4800 kW +	570 kUSD/Y	300 kUSD +	
Heaters,	1700 kW +	200 kUSD/Y	150 kUSD +	
New turbines with generator, auxiliary equipment etc.,	6400 kW	760 kUSD/Y	3800 kUSD +	
New piping for process steam when mechanical drive turbines are removed.			100 kUSD	
Total identified savings/costs	17700 kW	2100 kUSD/Y	4500 kUSD	Approx. 3 years

Table 3. Budget figures for a financial analyses on suggested investments

New boiler ?

From environmental and energy conservation aspects it is not needed with a new boiler. It may however, when considering availability and reliability aspects, become necessary with a new boiler. As we want to build in a high degree of redundancy we recommend to use the same pressures as before (45 bar(a)). By using a low pressure we can also limit the requirements on make up water. The consumption of water is extremely high today.
The most reliable system will consist of a standby boiler, a power production that will meet the necessary power demands and a connection to the national power net as backup in case of a failure in steam supply system or steam turbine(s).

Heat balance plot

When making a Steam Turbine design without compromising on efficiency, we can reach an electrical output of over 24 MW. The results from this heatbalance calculation is shown in a balance on next page. In given performance figures are included a margin for later adaptation to specific requirements on unusual load conditions
In order to make the turbine concept more flexible and less sensitive for changes in operational conditions we recommend to separate HP- and LP part of the turbine, with a possibility to disconnect the LP part in the future (in case of increased process steam demand). We also suggest to build in the possibility to have a two hole extraction to the deaerator and to the process nets.
All process extractions has to be controlled.

Performance for new Steam Turbine

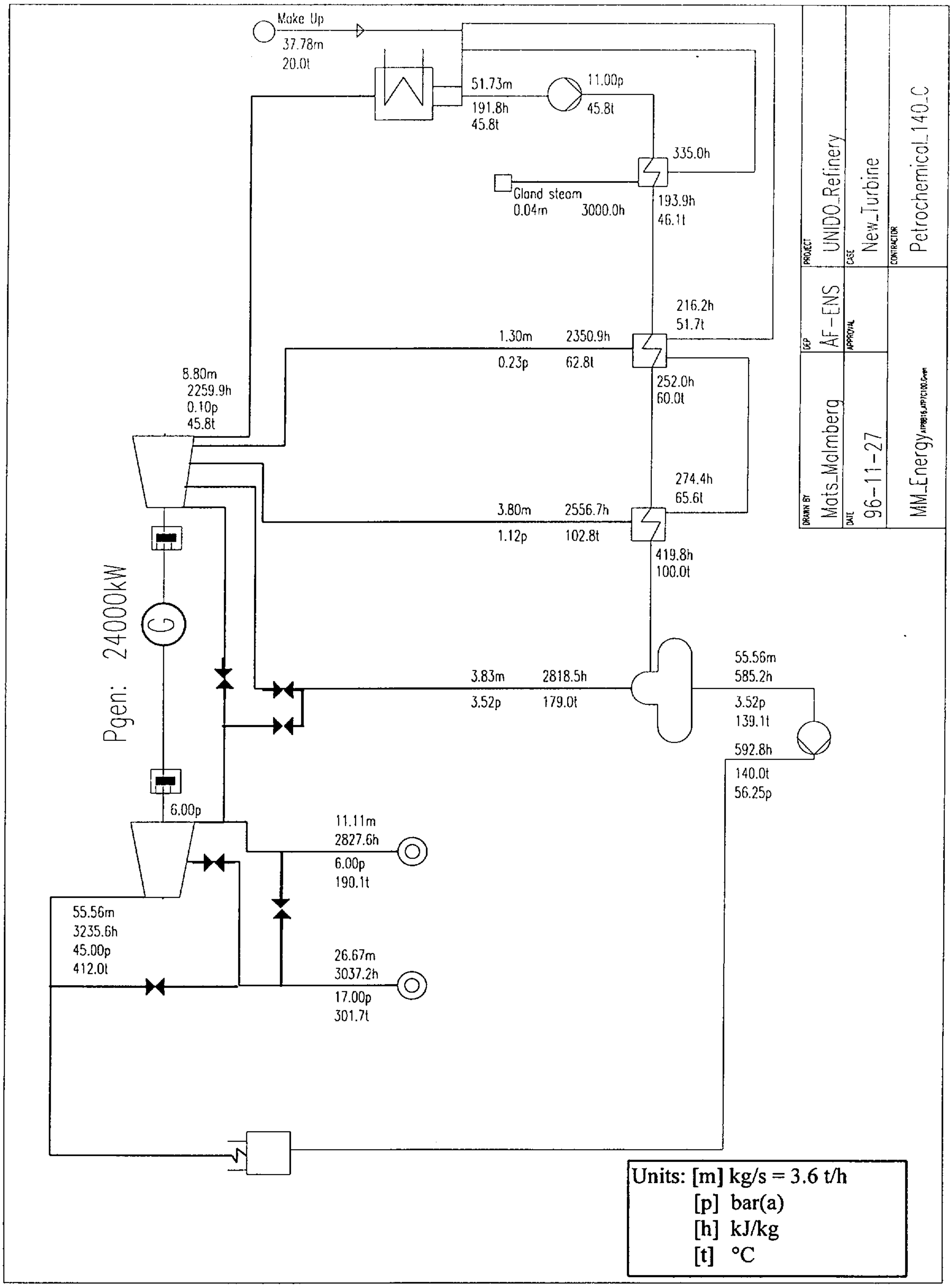


Fig. 3 Heat balance plot for new turbine with 140°C feed water temperature

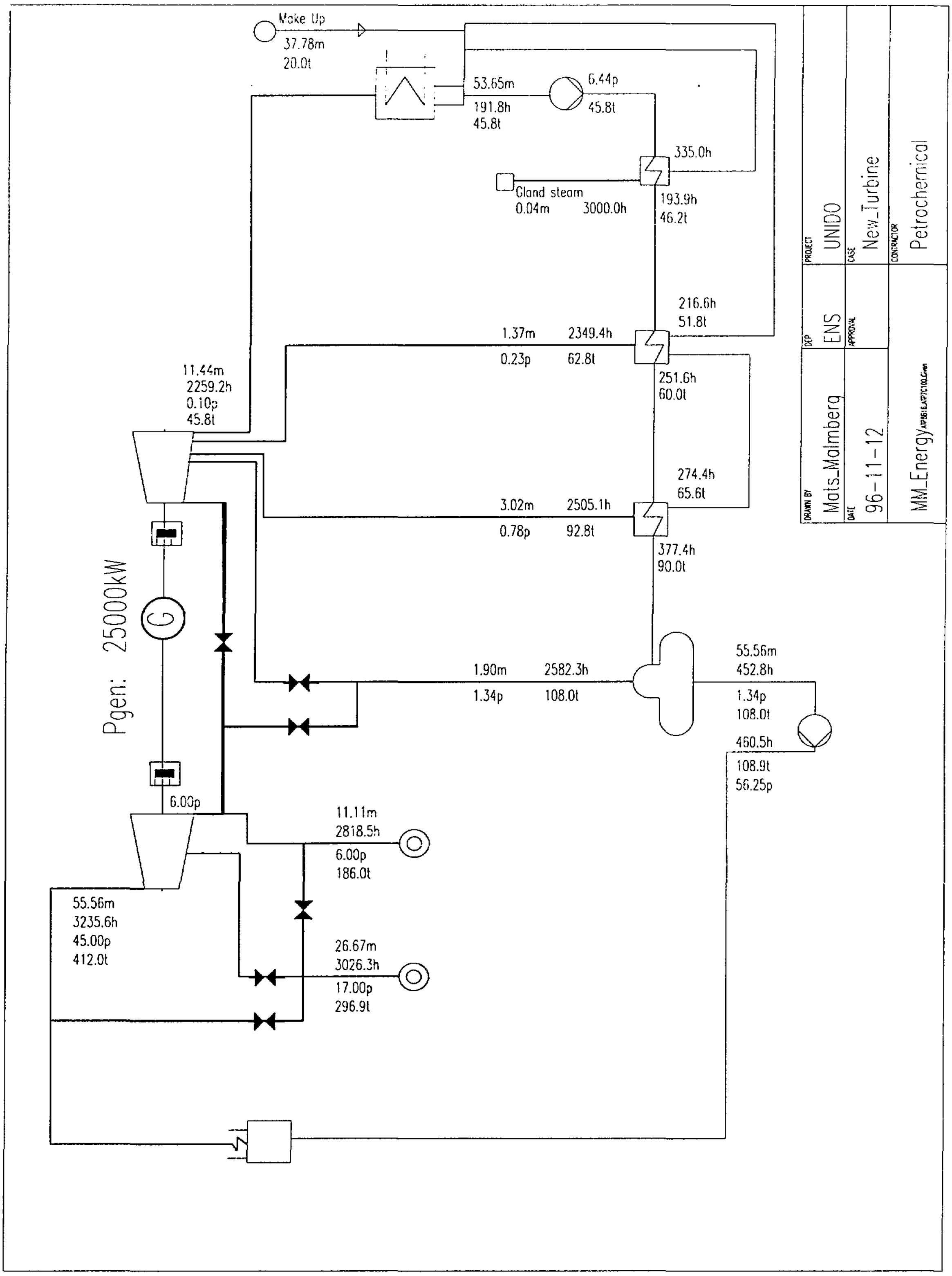
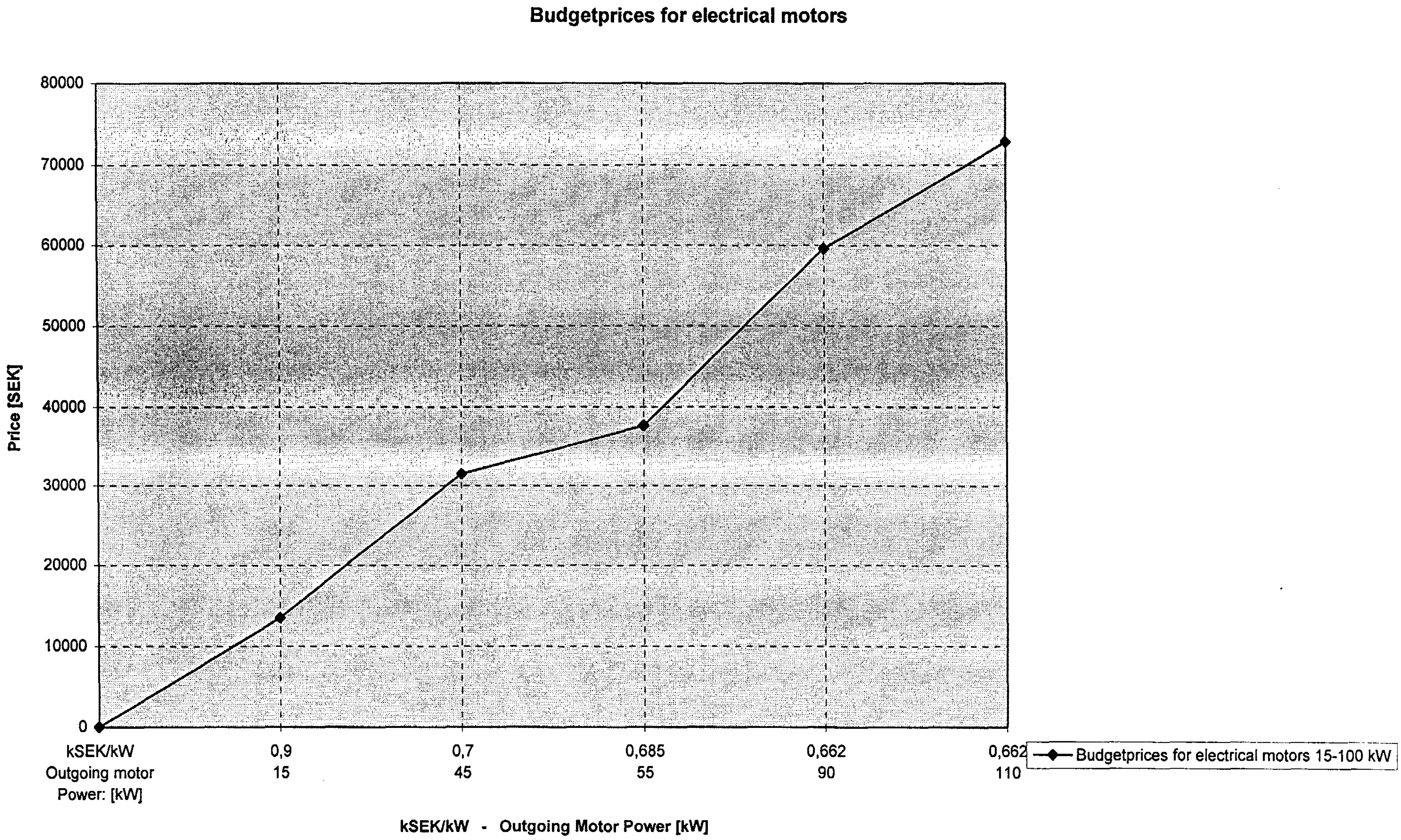


Fig. 3 Heat balance plot for new turbine with 109°C feed water temperature


Budgetprices for electrical motors
80000
70000
60000
50000
40000
30000
20000
10000
0
Price [SEK]
kSEK/kW
Outgoing motor
Power: [kW]
0,9
15
0,7
45
0,685
55
0,662
90
0,662
110
Budgetprices for electrical motors 15-100 kW
kSEK/kW - Outgoing Motor Power [kW]

Topsøe Process for Regeneration of Spent Sulphuric Acid from Alkylation, Organic Syntheses and Coke Chemicals Production

Salient Features

- No scrubbing, wet ESP and drying of the SO_2 gas
- No production of dilute, waste sulphuric acid
- All process steps up to the WSA condenser are dry
- High concentration of SO_3 from incinerator is allowed
- Increased heat recovery and low consumption of support fuel
- High overall recovery of sulphur
- Flexible capacity
- Incomplete combustion of hydrocarbons and ammonia is allowed

Introduction

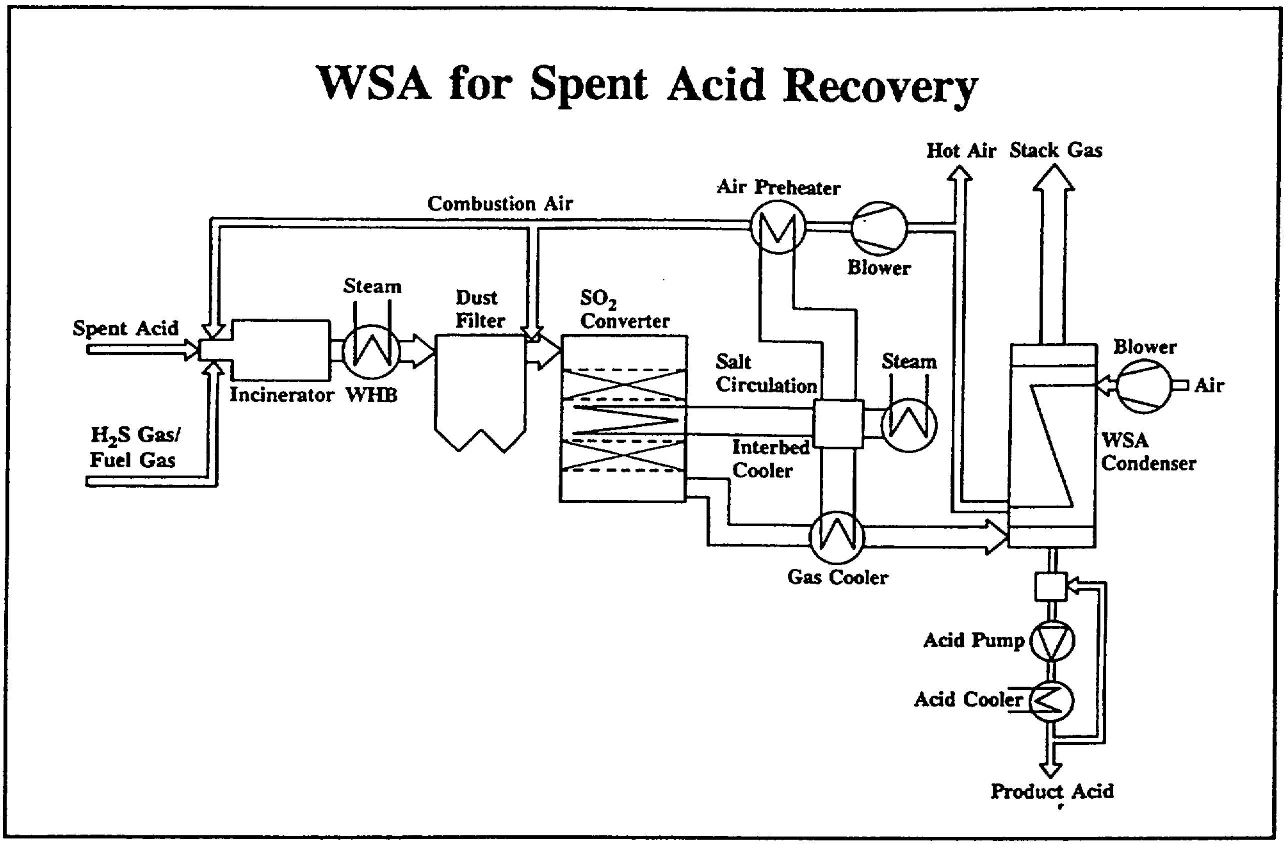
The Topsøe process is suited for regeneration of organic and ammonium-loaded spent sulphuric acid. The spent acid is recovered as concentrated sulphuric acid of commercial quality generally of minimum 98 wt%.

The method is based on the use of the Topsøe WSA (Wet gas Sulphuric Acid) process for production of concentrated sulphuric acid from the off-gas from a furnace in which the spent acid is completely decomposed or gasified into a furnace effluent gas which may have a high SO_3 content and may contain small amounts of hydrocarbons and NH_3. This means that the incineration temperature is not critical and even may be lowered to approx. 850°C.

There is no lower limit to SO_2 concentration, and both H_2S, S or fuel gas or light fuel oil may be used as heat source.

In a conventional process the furnace gas is cooled, washed and dried upstream the acid plant. In order to limit the acid effluent from the scrubber, furnace temperatures of up to 1150°C are required to minimize SO_3 formation.

Further, it is necessary to maintain a SO_2 concentration inlet the acid plant of 7-8% by burning S or H_2S, which necessitates a large compulsory excess production of sulphuric acid.



Process Description

The process lay-out is shown in the above flow diagram using as an example the regeneration of spent sulphuric acid from alkylation.

The acid is decomposed in an incinerator at 800-1000°C with preheated air and support fuel, which may contain H_2S.

If ammonium is present in the spent acid, this will be oxidized into free nitrogen, nitrogen oxides and sulphur oxide. In this case an SCR reactor for catalytic reduction of NO_x may be installed upstream the SO_2 converter. Ammonia is injected to selectively reduce the NO_x into free nitrogen and water.

After the incinerator, the gas is cooled in the waste heat boiler to about 350°C upstream of the dust removal, which may be either a ceramic candle filter or an electrostatic precipitator in which the dust content is reduced to below 5 mg/Nm^3. Before entering the catalytic SO_2 reactor preheated air is mixed with the process gas to achieve the necessary oxygen for the SO_2 oxidation.

The gas then passes through the SO_2 reactor which consists of two adiabatic beds with interbed cooling. The conversion of SO_2 into SO_3 is typically above 99%.

The catalyst acts as a very efficient dust filter catching nearly all remaining dust in the process gas. In order to maximize the operating period between siftings of the first catalyst layer, 20 mm catalyst rings are used as a top layer.

The converted gas is cooled in the hydration cooler whereby SO_3 is hydrated into sulphuric acid vapour.

Finally, the acid is condensed in the proprietary Topsøe WSA condenser/concentrator. The condenser is a falling film condenser with tubes of a special acid and shock resistant glass. The tubes are cooled by ambient air leaving the condenser at approx. 200-220°C.

Part of the air is further preheated to approx. 475°C and used as combustion and process air. The remaining hot air is used to increase the buoyancy of the clean gas which leaves the WSA condenser at approx. 100°C and is sent directly to the stack.

The hot acid leaving the WSA condenser is cooled in a plate cooler before being pumped to a storage tank.

Reactions in the Spent Acid Recovery Plant

Incineration/gasification

$2H_2SO_4\ (liq) = 2H_2O + SO_3 + SO_2$

Combustion

$2\ \text{"HC"} + 5SO_3 \rightarrow 5SO_2 + 2CO_2 + H_2O$
$4\ \text{"HC"} + 5O_2 \rightarrow 4CO_2 + 2H_2O$
$(NH_4)_2\ SO_4 + O_2 \rightarrow N_2 + SO_2 + 4H_2O$

NO_x Reduction

$NO + NH_3 + \frac{1}{4}O_2 = N_2 + 1\frac{1}{2}H_2O$

SO_2 Oxidation

$2SO_2 + O_2 = 2SO_3$

Hydration

$SO_3 + H_2O = H_2SO_4\ (gas)$

Condensation

$H_2SO_4\ (gas) + H_2O\ (gas) \rightarrow H_2SO_4\ (96\text{-}98\ wt\%\ liq)$

Reactions

The reactions take place in the following process steps as mentioned in the process description:

- Gasification and combustion of the acid take place in the incinerator
- SO_2 oxidation takes place in the catalytic SO_2 reactors
- Hydration takes place in the gas cooler
- Condensation takes place in the WSA condenser

In case of incineration of spent acid containing ammonium sulphate, e.g. from production of monomethylmetacrylate (MMA), the ammonium will be combusted as well. Depending on the specific acid and required NO_x level in the stack gas, selective NO_x reduction is introduced. In such cases it may be necessary to remove NO_x by selective catalytic reduction with NH_3 in catalyst bed above the beds with sulphuric acid catalyst.

Performance of Topsøe Spent Alkylation Acid Regeneration Plant

Basis	
Acid feed	
Flow, kg/h	4000
Composition, wt%	
H_2SO_4	92
H_2O	4
Hydrocarbons	4
Support Fuel, Type 1	
Flow, Nm^3/h	46
Composition, vol%	
H_2S	85
H_2O	7
Cl_{-5}	8
Support Fuel, Type 2	
Flow, Nm^3/h	103
Type (LHV = 10223 $kcal/Nm^3$)	Refinery gas
Typical Performance	
H_2SO_4 production, kg/h	3920
Concentration, wt%	98
Steam production, kg/h	3400
Pressure, barg	40
Temperature, °C	252
Sulphur recovery, %	~99.2

Performance of Regeneration Plant

The above figures are for a spent acid regeneration unit of medium size. In this example, two types of support fuel are used, however, pure H_2S gas may also be used.

If an SO_2 recovery exceeding 99% is required, a final scrubber using H_2O_2 or caustics will be installed. This allows for 99.6-99.9% SO_2 recovery. In case of a H_2O_2 scrubber the SO_2 is captured as 50-70% sulphuric acid which may be recycled to the incinerator, thus, there are no liquid effluents.

Application	**Components Removed**
Chemical Plant Off-gases	
From metallurgical roasters	SO_2, SO_3, CO
From Claus plants	H_2S, SO_2, COS
From natural gas cleaning	H_2S, HCN, CS_2, C_xH_y, COS
From gasifiers gas cleaning	H_2S, COS, CHS
From HDS-amine units	H_2S, NH_3
From coke oven gas cleaning	H_2S, HCN, NH_3, CHS
From viscose plants	H_2S, CS_2
Flue Gases	
From industrial steam generators	SO_2, SO_3, C_xH_y, NO_x
From power plants	SO_2, SO_3, C_xH_y, NO_x
From FCC regenerators	SO_2, SO_3, CO, NO_x

Other Applications of the WSA Process

The Topsøe WSA process is applied for producing concentrated sulphuric acid from practically any sulphur-containing off-gas without initial or intermediate drying of the gas. Hydrogen sulphide and other compounds containing sulphur such as COS, CH_3SH and CS_2 are at first oxidized into SO_2. Hereafter SO_2 is further oxidized into SO_3 and subsequently recovered as sulphuric acid in the Topsøe WSA condenser.

A number of applications for the process are shown above. In the process, carbon monoxide, ammonia, cyanides, organic compounds, such as hydrocarbons, which may be present in the gases, are oxidized simultaneously into carbon dioxide, nitrogen and water. In case of high content of nitrogen compounds, catalytic NO_x reduction is introduced (SNOX™ process).

The application of the WSA (and SNOX™) technology for treating chemical plant off-gases and flue gases are described separately.

State of Technology

- Process concept
- Well-proven process steps
- New combination
- Industrial applications

State of Technology

Conventionally, spent acid decomposition has been combined with a dry sulphuric acid plant. This has a number of disadvantages as discussed earlier.

In the Topsøe approach a number of known process steps are combined into a unique plant design. Incineration of acid at 1000°C is proven technology, dedusting at 400°C is known as well, and the Topsøe WSA technology has been proven in a number of industrial plants.

The combination of these process steps has been proven in a plant regenerating spent acid from MMA production. The plant was started up in mid 1993 at Asahi Chemical Industries in Japan. A second plant operating on spent acid from a BTX refinery at Bitmac, U.K. is expected to be started autumn 1995.

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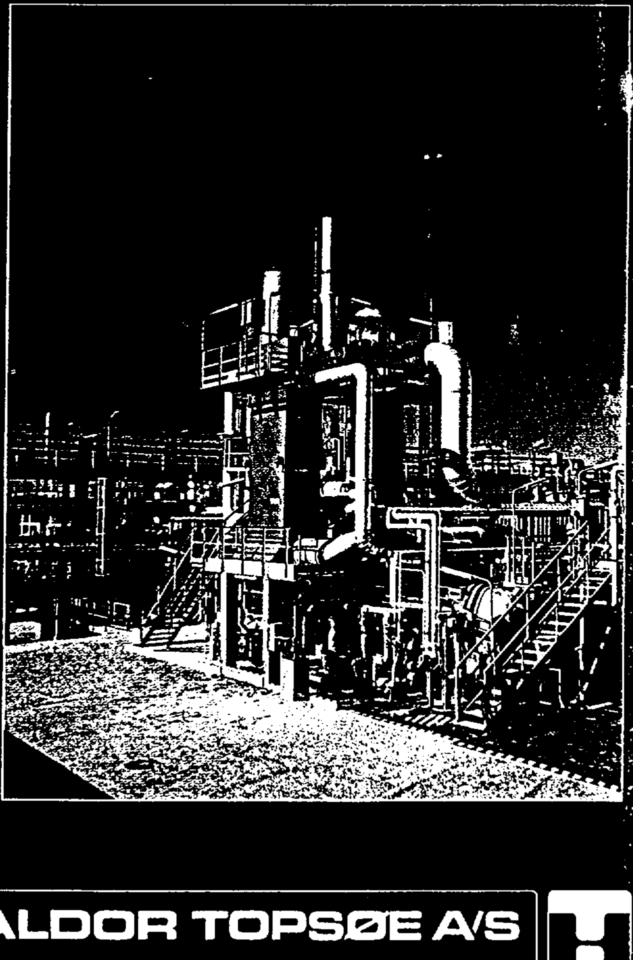
Rev 4/96

WSA

Treatment of Off-gases from Coking Plants, Oil Gasifiers and HDS Units



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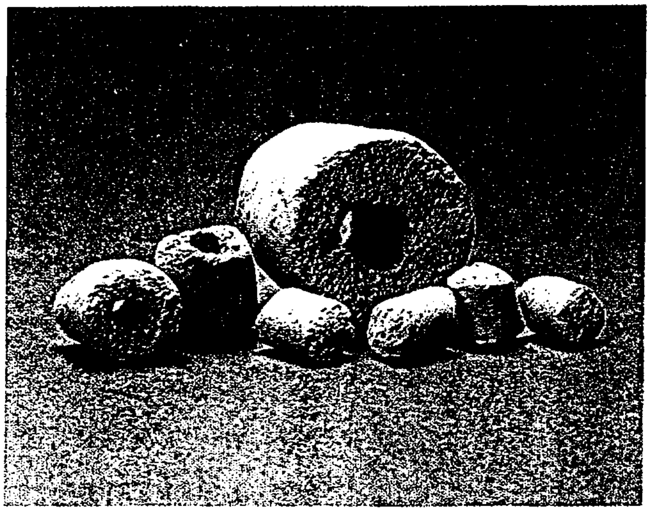
The sulphuric acid is condensed and recovered in the air cooled WSA condenser as concentrated sulphuric acid of high quality.

All process steps evolve heat which is recovered as steam. The converter and the gas cooler are cooled by a circulating heat transfer salt connected to the steam generator. This system having a large heat capacity ensures a high degree of flexibility and turn-down range.

No waste streams are generated by the WSA process.

The majority of construction materials are carbon steel or low-alloy steel.

The Catalyst



The catalyst used in the SO_2 converter belongs to the VK-WSA series, the well-known Topsøe sulphuric acid catalysts. This type of catalyst is installed in more than 200 converters in sulphuric acid plants all over the world. The catalyst is characterized by excellent activity and high mechanical strength.

Sulphuric Acid

The sulphur dioxide is recovered as concentrated sulphuric acid of commercial grade. Representing the largest chemical commodity in the world the acid may be sold both domestically or internationally on a well-established market.

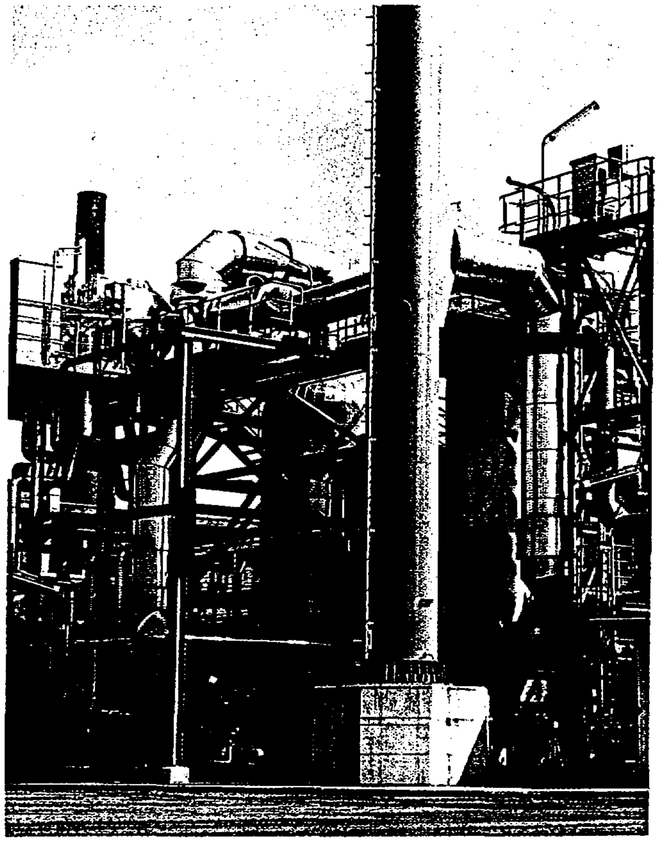
Salient Features

- Recovery of all sulphur compounds as concentrated sulphuric acid.
- No consumption of chemicals or absorbents, no generation of waste products.
- Low cooling water consumption.
- Efficient recovery of heat as MP steam.
- Simple process layout offering low operating and maintenance costs.

References

The Topsøe WSA process is installed in a number of plants throughout the world with capacities ranging from 10,000 to 1,000,000 Nm^3/h process gas and to 350 MTPD sulphuric acid.

The WSA process is applied not only for H_2S / SO_2 gases but also for other gases such as SO_2 from metal sulphide roasting, power plants, H_2S / CS_2 from viscose plants etc., and for spent acid recovery.



Other Topsøe Environmental Technologies

CATOX

Catalytic Combustion of solvents and other combustibles (VOC's) in air and off-gases.

DENOX

Removal of nitrogen oxides from flue gases and other industrial off-gases. Nitrogen oxides are selectively reduced by means of ammonia over Topsøe catalysts.

SNOX™

A process combining the WSA and DENOX processes for the efficient removal of nitrogen and sulphuroxides from industrial and utilities off-gases and flue gases.

SNOX is a registered trade mark of Haldor Topsøe A/S, Denmark.

Operating and maintenance procedures

1. Inspect entire steam system for leaks, defective valves and flanges, corroded piping, buried return lines, leaking pump packing weeping or dripping safety and relief valves, and the condition of insulation.
2. Inspect door gaskets and replace if they do not provide a tight seal.
3. Inspect all boiler insulation, refractory, brickwork, and boiler casings for hot spots and air leaks. Repair and seal as necessary.
4. Check insulation on hot water tanks and supply lines.
5. Clean coils in storage water heaters.
6. Inspect fireside of furnace and tubes for deposits of soot, fly ash, and slag. Inspect fire-side of refractory surface. Remove deposits us necessary.
7. During annual shutdown, inspect boilers for scale deposits accumulation of sediment, or boiler compounds on water-side surfaces. Check rear portion of the boiler (area most susceptible to formation of scale). Remove scale, sediment, sand, or boiler compound residue to improve heat transfer.
8. Check smoke coming out of stack; it should be free of haze. If not, a burner adjustment is probably necessary.
9. Inspect linkages periodically for tightness. Adjust when slippage or jerky movements are observed.
10. Be sure all blower belts are tight to minimize slippage and resulting power waste.
11. Observe burner flame when unit shuts down. If flame does not cut off immediately, it could indicate a faulty solenoid valve. Repair or replace valves as necessary.
12. Check boiler stack temperature and keep log. If it is too high (more than 20 C above designed temperature) clean tubes and adjust fuel burner.
13. Note firing rate when log entries are made. A sharp rise in stack temperature does not necessarily mean poor combustion or fouled water-side or fire-side. During load change, stack temperatures can vary as much as 35 C in 5 minutes.
14. Inspect condensate tank and its vent at least once a month. Some vented steam is normal from condensate "flashing", but a plume of steam may indicate leaking traps with a resulting waste of steam and condensate.
15. Keep daily logs of pressure, temperature, and other data obtained from instrumentation. This is the best available method to determine the need for tube and nozzle cleaning, pressure or linkage adjustments, and related measures. Deviations from normal can be spotted quickly, enabling immediate action to avoid serious trouble.
16. Be sure strainers and filters are kept clean.
17. Check and repair oil leaks at pump glands, valves, or relief valves.
18. Inspect nozzles or cup of oil-fired units regularly. Clean as necessary.
19. Inspect oil heaters to ensure that oil temperatures are as specified, and that heavy oil is heated sufficiently for proper burning with low excess air. To minimize fuel waste, avoid overheating or underheating of fuel. Keep the proper viscosity before the burner.
20. Clean mineral or corrosion build up on gas burner.

21. To minimize purchased energy consumption, load byproduct-fuelled boilers to their capacity before utilizing oil-gas-coal-fuelled boilers.

Minor cost improvements

1. Consider improved water treatment to minimize scale formation. For instance, a mere 1.6 mm of scale can reduce boiler heat transfer by 12%.
2. Analyze and monitor boiler dissolved solids to reduce any excessive blowdown with its resultant waste of treated hot water.
3. Insulate both hot and cold process and heating lines, and all steam pipes, for maximum energy conservation.
4. Consider installing urethane foam or metal-covered, block-type insulation on aboveground fuel oil storage tanks to reduce heat loss and oil heating steam usage.
5. Consider installing a positive closing damper on furnace stacks to reduce air flow through shut-down installations.
6. Replace obsolete packed steam expansion joints with bellows joints to eliminate steam leakage.
7. Remove all obsolete or seldom-used pressure vessels.
8. Investigate the economics of using compressed air instead of steam for fuel atomization or soot blowing.
9. Investigate the economics of replacing leaky, high-maintenance, gate type steam valves with low-maintenance ball valves. Modern ball valve designs are available for up to 40 bar steam duty. (Ball valves are not designed for steam throttling service).
10. Utilize waste oil for boiler fuel.
11. If your plant generates both high and low-pressure steam, investigate use of high-pressure boiler blowdown water for low-pressure boiler feed-water. (Note: Must be handled by water treatment specialist).
12. Return all condensate to boilers. In addition to saving expensive water treatment compounds, considerable savings in fuel oil may be realized.

Major cost improvements

1. Use engine exhaust heat to make steam.
2. Use waste heat from hot flue gases to generate steam for processes, or consider selling excess steam.
3. Use overhead condenser to generate steam from condensates in distillation process.
4. Recover and reuse as much condensate tank flash steam as possible.
5. To reduce feedwater heating costs investigate feasibility of feeding boiler make-up water into steam-turbine condensers.
6. Investigate utilizing waste air compressor aftercooler cooling water 35-46 C as boiler make-up. This saves energy that would be required to heat city water from 13 C to 35 C and reduces waste water discharge to city sewers with a resultant sewer charge reduction. As a rule of thumb, this will result in a 9 litres fuel oil saving per 4500 litres of make-up water.

7. Investigate installing turbulators in the boiler tubes to improve the heat transfer within the boilers, particularly if boiler tubes are 3" or larger.
8. If your stack temperature is over 177 C, consider installing a finned-tube economizer or a regenerative-type air heater. Many packaged process-steam boilers have an optimum efficiency of about 85% at a stack temperature 177 C. In general every 17 C rise reduces efficiency about 1%.
9. Use hot flue gases to preheat combustion air.
10. Use hot flue gases in radiant heater for ovens and dryers.
11. Use hot flue gases to preheat wastes for incinerator boiler.
12. Use hot flue gases to preheat products or material going into ovens and dryers.
13. Install soot blower on all residual-fuelled boilers.
14. Investigate replacing old or worn boiler control equipment with modern controls capable of maintaining low excess air over the burner's firing range.
15. Where economically justified, install automatic viscosity controllers on fuel oil systems both to ensure good atomization and to permit mixing various grades of fuel oils. The most important consideration is to have proper viscosity at the burner type.
16. Consider installing continuous excess carbon dioxide or oxygen analyzer to automatically adjust burner air fuel ratio.
17. Consider installing metering type of combustion control equipment to single-fuel-fired burners. Since this system meters both fuel and air, it can respond quickly and accurately to boiler load changes.
18. Periodically check thermostat setting at oil preheater.