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Delivery order #30
Energy Efficiency in the industry of Ukraine
May 1998

REPORT

ON ENERGY AUDIT

AT CLOSED -TYPE JOINT STOCK COMPANY

UKRTATNAFTA

City of Kremenchug, POLTAVA Region, UKRAINE

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Prepared for United States Agency for Independent Development,
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1 0 EXECUTIVE SUMMARY

1 1 Introduction

This energy audit has been conducted under a program sponsored by the US Agency for International Development This project, referred to as Delivery Order #30, consisted of performing twenty four audits throughout Ukraine The purpose of the project was to develop Ukrainian energy service company (ESCO) capabilities To accomplish this task, ***Burns and Roe Enterprises, Inc*** (the primary contractor) hired Ukrainian engineers These engineers were trained in U S techniques of conducting energy audits and in ESCO concepts The industrial energy audits were conducted to facilitate the ESCO training
The team made up of two representatives of the Burns and Roe Enterprises - energy management experts Mikhail V Tarnovsky and Vladimir V Prokopenko - carried out the energy audit from May 11 to 15, 1998 in accordance with the purposes of the Project and prepared the report

Since these industries are very large, a one week site visit is not sufficient to adequately audit the entire facility Therefore, the work was focused on a single gasoline catalytic reforming production plant

This audit is based on what could be accomplished during the one week allocated While this audit contains numerous recommendations for the plant management, the plant management is encouraged to perform a complete audit of the entire facility Hopefully, the plant management will consider hiring the engineers trained under this project to continue this work, which will result in a complete understanding of energy usage within the plant, as well as a complete listing of all potential energy improvement projects and their turnkey implementation

The current report describes the findings of the energy efficiency audit performed by Burns and Roe at the JSC UKRTATNAFTA The UKRTATNAFTA is the largest oil refinery in Ukraine The gross income in 1997 amounted to US$370,290,000 and the share of exports in the total volume of sales was 4 6% The share of energy in the production cost was 14 7%

The tasks of the energy audit were as follows

- to conduct informal training in energy management practices
- to create an institutional awareness of energy management
- to recommend medium-cost and capital investment actions reflecting large-scale energy conservation opportunities

1 2 Brief survey

The JSC UKRTATNAFTA is a modern dynamically growing enterprise, it is well-known in Europe, the largest of its kind in Ukraine

The enterprise management is interested in energy efficiency improvement that is proven by the establishment of an energy laboratory

Due to the short term of the energy audit by the concurrence with the refinery management the LCh-35/11-600-68 gasoline reforming plant was selected for the study with the purpose of replication on other plants of the refinery

In the total energy costs incurred by the plant seventy five per cent make up fuel and thermal energy Sixty per cent of consumed electric power are used by the drives of pumps, fans and compressors These usages actually determine primary energy saving sources Energy cost constitute 47 2% of production costs

As expected the energy audit team has discovered many attractive opportunities of improving energy efficiency at current energy and fuel prices When the energy costs were 20 to 30 times lower the energy conservation measures were not economically essential Presently the energy efficiency improvement is cost effective though difficult to implement due to high interest rate of the bank credit and general economic difficulties linked to bartering and mutual non-payment

The lack of computerized technical energy submetering does not permit to institute the basis for energy conservation and introduce the full-scale energy management system

A significant energy conservation opportunity is improvement of the use of gas and other fuels by utilization of modern burners and automatic systems of combustion control, enhancement of piping and heat exchanger insulation

Reduction of electric power consumption can be achieved by the improvement of compressed air generation and utilization systems, and by energy efficient lighting

The energy auditors consider the JSC UKRTATNAFTA to be a potentially reliable partner of energy servicing companies

After equipping the energy laboratories with energy audit instrumentation it is advisable to regroup it into an energy management section

The energy auditors see the prospects in continuation of work both at the studied plant and at other production lines and at general energy and auxiliary facilities

The project envisages further implementation of long-term measures by the plants themselves in concert with private Ukrainian energy servicing companies One of the main tasks of ESCO development is the possibility of acquiring long-term (for 2-3 years) financing for implementation of energy conservation measures at the enterprises

The energy audit team saw a realistic opportunity to render considerable assistance in energy use reduction by institution of energy management service and other ECOs at the plant by an individual contract after completion of the USAID project

Introduction of measures proposed in this project will reduce energy consumption and respective costs by 11 2%
If to extend the measures proposed for the LCh35/11-600-68 onto other production lines of the refinery the sum total of energy cost savings can be forecasted within 20-25%

The time limits of the present Project do not permit to monitor the operation of the equipment intended for space heating season

1 3 Recommendations

Recommendations listed below will improve energy efficiency of the plant, reduce the costs and consolidate competitiveness of the enterprise These measures are recommended to be implemented in the shortest terms The refinery management is recommended to consider the issue of implementing other measures as financially possible

To encourage the facility to implement energy efficiency and energy conservation, USAID is contributing energy auditing equipment to the plant This equipment consists of standard energy auditing instrumentation and meters that will enable them to implement an energy saving activity For example, **ECO #1** "Energy management institution" will set up systematic energy conservation activities by establishment of an energy management section responsible for the control and analysis of the energy consumption at the plant and development of recommendations for renovation and improvement of any energy saving systems

Generally the energy management section should consist as a minimum of three persons technical supervisor, electrical and thermal engineers The supervisor should be a part of the plant management and report directly to the plant general manager It is essential as energy consumption and energy costs acquire a special importance and a plant manager should be aware of energy conservation potential

ECO #2 "Automatic energy metering system" It will provide get an objective picture of energy use at the enterprise without manual operations, enhance the grounds for energy conservation and reliability of energy use indicators for internal settlements between production units

ECO #3 "Retrofitting of P-601 hydraulic purification oven with utilization of exhaust gas heat" Utilization of exhaust gas heat, automatic control of fuel-to-air ratio by the exhaust gas analysis and of oven load depending on the temperature of raw materials, installation of ribs in the radiating part of the oven will ensure savings of fuel for the hydraulic purification oven and energy costs

ECO #4 "Improvement of fuel combustion efficiency in P-602 reforming oven" Upgrading of the oven burners and installation of metering and control devices, elimination of air infiltration in the exhaust gas duct, improvement of insulation in the convection part of the oven will lead to 6% savings of fuel

ECO #5 "Retrofitting of heat exchange equipment at the reforming plant and improvement of its operation efficiency " The analysis of the entire set of heat exchangers showed that there is a potential for reduction of residual temperature impact by 50% as a minimum For this purpose it is necessary to install additional high-efficiency heat exchange equipment simultaneously with scheduled replacement of equipment terminating its service life This will increase the temperature of raw materials before the hydraulic purification and reforming ovens by 20-25^{0}C and thus reduce fuel consumption by 20-25%

ECO #6 "Improvement of LCh-35/11-600-68 reforming plant insulation" It is recommended to design and install at the refinery plants easy-to-dismantle insulation permitting multiple use after overhauls By the experts' estimate, insulation of bare surfaces is an attractive and cost-efficient opportunity reducing heat emission into the environment by 90-95%

ECO #7 "Energy efficient lighting" By introducing energy-efficient lighting sources instead of DRL-type lamps at the plant, the lighting system reliability will improve and power use will be reduced

ECO #8 "Monitoring and optimization of electric equipment capacities" Introduction of instrument metering, full use of rated capacities will exclude impractical modes of operation and ensure unreasonable use of power

If implemented the measures proposed by the auditors will ensure an opportunity to reduce energy consumption annually

- electric power by - 33,300,800 kWh (9 1% of 1997 consumption)
- fuel by - 36,039,800 tce (9 8% of 1997 consumption)
- thermal energy by - 64,822 Gcal (9 8% of 1997 consumption)

and will result additionally in reduction of pollutant emissions

1 Solid particles - 146 0 tons/year
2 Sulfur dioxide - 329 7 tons/year
3 Carbon oxide - 83 47 tons/year
4 Nitrogen oxide - 170 95 tons/year

Capital investments of $4,485,050 into the improvement of energy efficiency (ECO#1 through ECO#8) will result in annual savings of $6,079,718 later

Energy conservation opportunities

Table No1

ECO	Description	Electric power, 1,000 kWh	Fuel, tce	Thermal energy, Gcal	Annual savings, $	Project cost, $	Payback, years
1	Institution of energy management	18285	17 680	40 500	2 700 000	1 356 300	0 5
2	Automatic energy use metering system	10972	858 8	24 322	1 627 500	1 400 000	0 9
3	Retrofitting of P-601 hydraulic purification oven with utilization of exhaust gas heat		6 026		548 000	330 000	0 6
4	Improvement of fuel combustion efficiency in P-602 reforming oven		2 040		186 000	142 000	0 8
5	Retrofitting of heat exchange equipment of reforming plant and improvement of its operation efficiency		9 187		846 000	1 150 000	1 4
6	Improvement of LCh-35/11-600-68 reforming plant insulation		248		22 600	14 500	0 64
7	Energy efficient lighting	389 1			14 396	17 250	1 2
8	Monitoring and optimization of electric equipment capacities	3654 7			135 222	75 000	0 6
	TOTAL	***33 300 8***	***36 039 8***	***64 822***	***6 079 718***	***4 485 050***	

Brief survey of the ECOs is given in Section 7 "Energy audit",
full description - in Appendix A of this report

2 0 GENERAL BACKGROUND

Chairman of the board	Vladimir M Matytsin
Director general	
First deputy chairman, technical director	Sergey P Leitar
Deputy chief power manager	Nikolay V Eskov

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3 Svishtovskaya str , Poltava region,
Kremenchug, Ukraine 315309

2 1 Enterprise history

Construction of the plant began in April 1961 July 10, 1966 the first oil was accepted and July 19 first tons of ready products were received

The first-phase facilities commissioned for operation included the following plants

- ELOU-10/6 electric desalination plant
- AVT-A-12/5 plant
- inert gas generation plant
- ethyl mixing plant
- general service facilities

In August 1967 the L-35-11/300 gasoline catalytic reforming plant was commissioned

Simultaneously with the L-35-11/300 the 19/6 oil asphalt plant was commissioned for operation

In May 1969 the gas fractionation plant went into operation At this plant production of liquefied gas and individual hydrocarbons n-butane and isobutane - raw materials for petrochemical industry - was mastered

In December 1969 the atmospheric oil refining plant with the ELOU electric desalination unit was commissioned The catalytic cracking plant went into operation in June 1970

In 1971 the following plants significantly improving oil product quality were commissioned

- L-35-11/600 catalytic reforming plant with the processing capacity of 600,000 tons of raw materials
- LCh-24-7 hydraulic diesel fuel purification plant with the processing capacity of 600,000 tons of raw materials

Further growth of oil refining was achieved by commissioning of the atmospheric oil refining unit within the GK-3/1 combined plant No2

In 1973 - 1976 the unit complex for production of lubricating oils G-37, G-39-40, G-36-37, G-24 In 1975 the process of catalytic reforming was introduced with an extraction facility and new petrochemical products - benzene and toluene were received

Further improvement of oil refining was connected with the start of the second unit of catalytic cracking within the No2 GK-3/1 combined plant in 1976 Thus the catalytic cracking capacities were increased to the design output of 1,480 thousand tons a year

Given the increasing share of high-sulphur content oil processing and taking care of the environment a comprehensive catalytic cracking gas purification program for hydrogen sulphide removal at the dry gas desulphurisation unit and further processing of hydrogen sulphide at the industrial sulphur production plant The industrial sulphur is supplied to chemical works for production of sulphuric acid

In 1978 the LK-6u combined plant for production of several types of fuel and gas In 1980 this plant began production of isopentane fraction

At the end of 1981 the Dneprol ash-free detergent and dispersing additive production plant started operation The additive is used in lubricant production

Further construction of facilities for primary oil refining has been discontinued since commissioning of the LK-6u combined plant

Considering large demand for lubricating oil in Ukraine in 1988 a combined plant for regeneration of used lubricants was commissioned However, poor results of used lubricating oil collection was the reason of actually permanent idling of the plant due to the lack of raw materials Currently the plant is mothballed

The JSC *UKRTATNAFTA* has large primary oil refining capacities and insufficient production lines for deep processing of oil wastes Some of the plants have equipment with service life of over 20 years

The LCh-35/11-600-68 plant belongs to the production facility No2 and consists of the following units

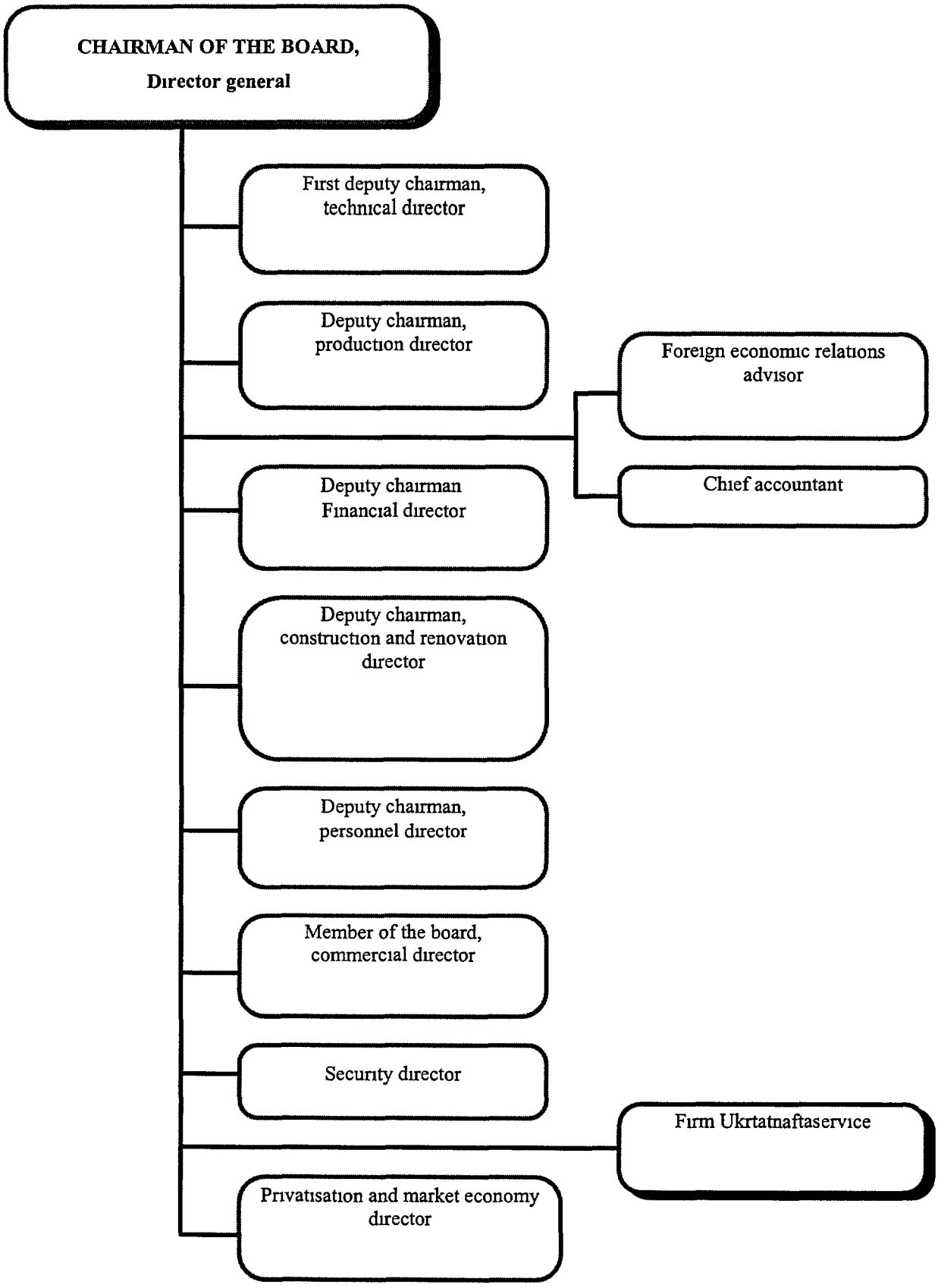
- raw material preliminary hydraulic purification unit with hydrogenation product stripping and hydrogen sulphide stripping hydrocarbon gas monoethanolamine purification subunits
- catalytic reforming unit with hydrogen-containing gas dehumidification subunit
- reformate stabilization unit
- exhaust gas heat utilization subunit (utilization boilers)

For reception and storage of oil and storage and delivery of finished products the refinery has a product and raw material handling facility equipped with storage parks with 10-20-50 thousand cubic meter tanks, draining and filling railroad trestles and oil pumping stations The main handling operations are automated

Average number of the UKRTATNAFTA personnel in 1997 was 4,698

The management structure is given in Fig 2 1

Management structure of joint-stock company
UKRTATNAFTA

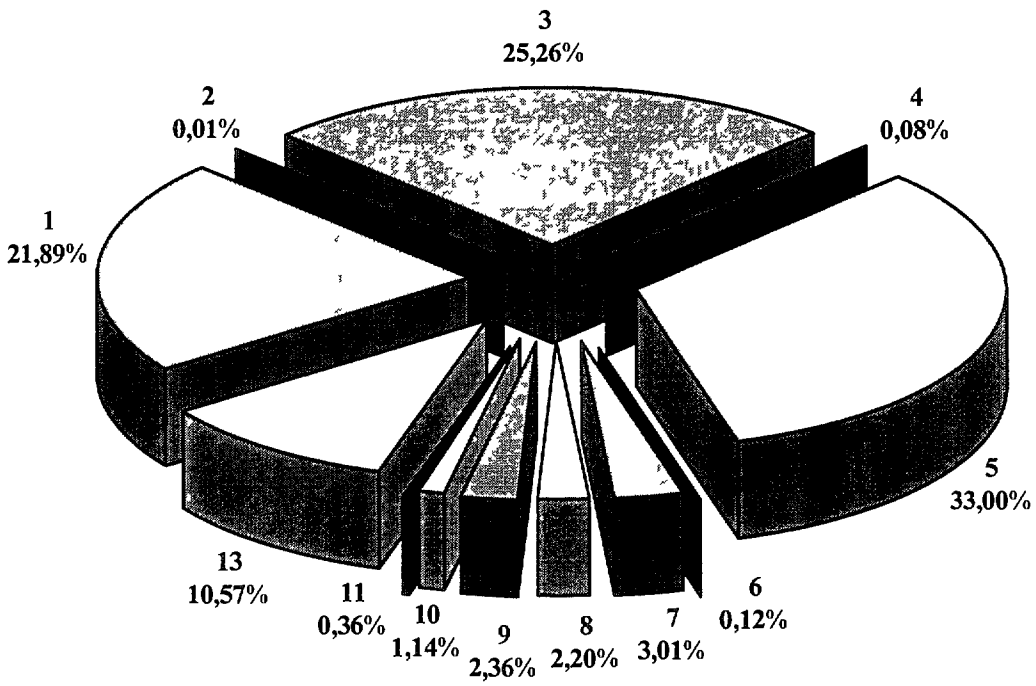


2 2 Recent production

The JSC UKRTATNAFTA puts out a wide range of oil products By the majority of indicators the refinery occupies the leading place at the Ukrainian market

#	Designation	Unit of measure	Output in 1997	Share in total output, %
1	Gasoline	1,000 tons	990 1	21 89
2	Aviation fuel	1,000 tons	0 5	0 01
3	Diesel fuel	1,000 tons	1142 4	25 26
4	Furnace oil	1,000 tons	3 4	0 08
5	Industrial fuel oil	1,000 tons	1492 8	33 0
6	Flotation reagent	1,000 tons	5 4	0 12
7	Lubricants	1,000 tons	136 1	3 01
8	Petroleum asphalt	1,000 tons	99 5	2 2
9	Petroleum asphalt materials	1,000 tons	106 9	2 36
10	Domestic gas	1,000 tons	51 6	1 14
11	Sulphur	1,000 tons	16 3	0 36
12	Low-viscosity marine fuel	1,000 tons	0	0
13	Other	1,000 tons	478 2	10 57
	TOTAL		**4523 2**	**100**

Breakdown of production output by types



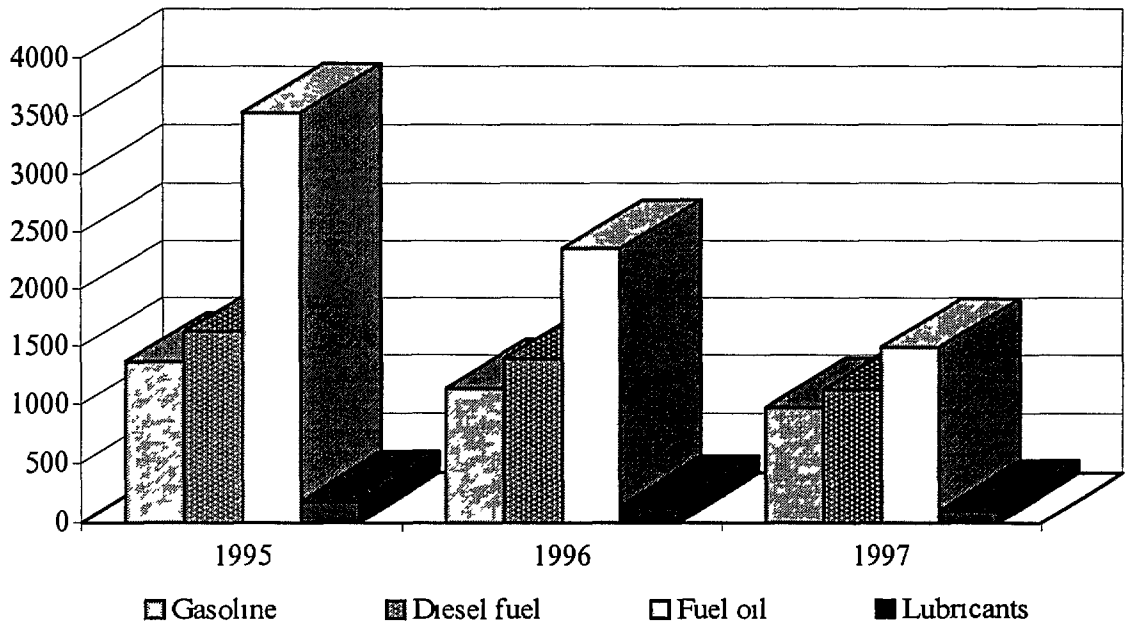
2 3 Significance of the sector for the national economy

Presently there are six oil refineries in Ukraine

- Kremenchug, Poltava region
- Lisichansk, Lugansk region
- Kherson
- Odessa
- Drogobich, Lviv region
- Nadvirna, Ivano-Frankivsk region

The primary customers of petroleum products in Ukraine are the agroindustrial complex, power generation enterprises, motor transport enterprises and motor vehicles

Sales of petroleum products manufactured by JSC UKRTATNAFTA
(1,000 tons)



The primary customers of the UKRTATNAFTA products are the following

- fuel supply departments, fuel storage facilities, fuel distribution facilities,
- farm supply organizations,
- steel works and rolling mills, metal structure works, coke works,
- ore concentration complexes,

- construction and installation enterprises, mobile construction units, construction mechanization departments,
- bakeries, grain elevators,
- sugar refineries, dairies, butter works,
- mining management departments,
- power generation plants,
- collective farms, forestries, agroindustrial companies and individual farms

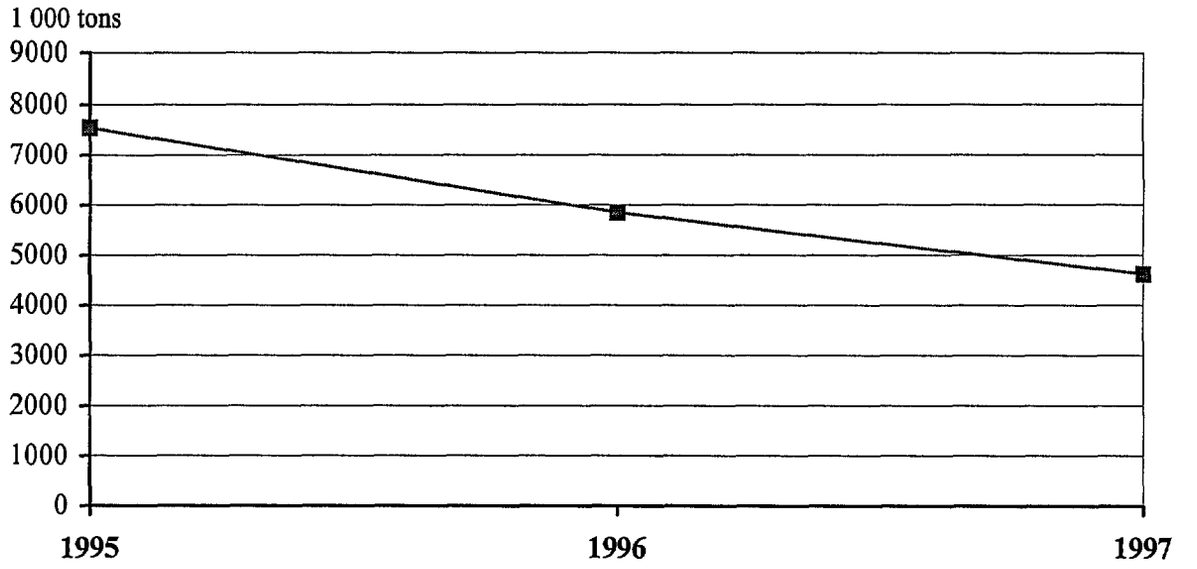
The dynamics of sales of the UKRTATNAFTA illustrates simultaneousness of the decrease of the share of outside owned raw materials which does not generate profit for the refinery and impaired financial results

3 0 CURRENT STATUS OF PRODUCTION

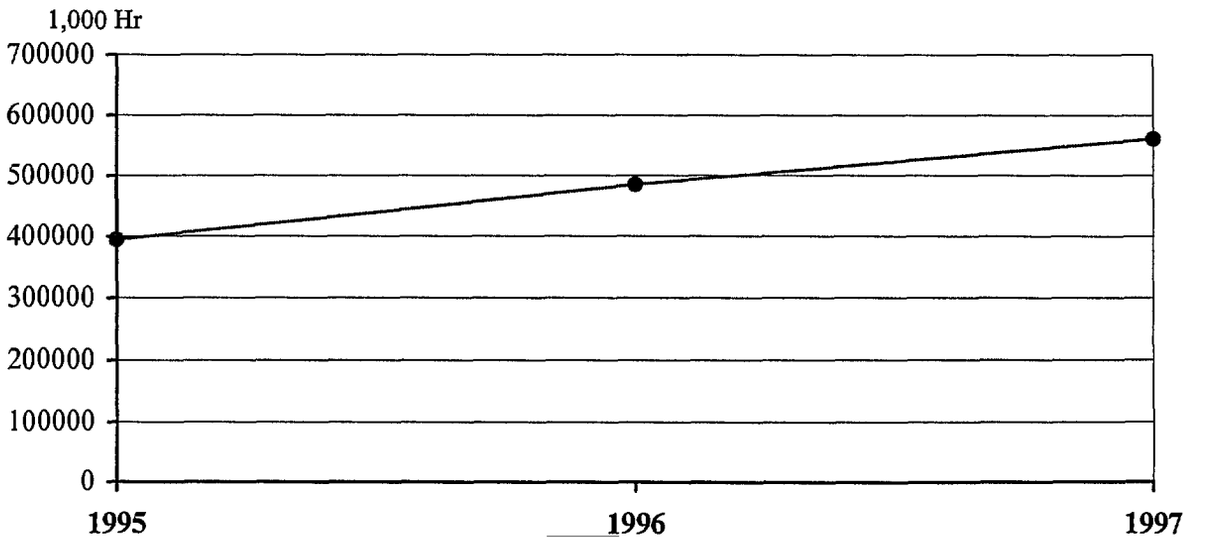
3 1 Production output

In 1995-1997 the refinery was underusing the capacities This was caused by the changes in the pricing policy and instability of the oil market

Production output changes



Output at current prices



3 2 Productivity of labor 1997 vs 1996

Productivity of labor in 1996 was 297,766 2 Hr
Productivity of labor in 1997 was 304,796 7 Hr,
which makes 102 4% vs 1996

3 3 Prospects of development

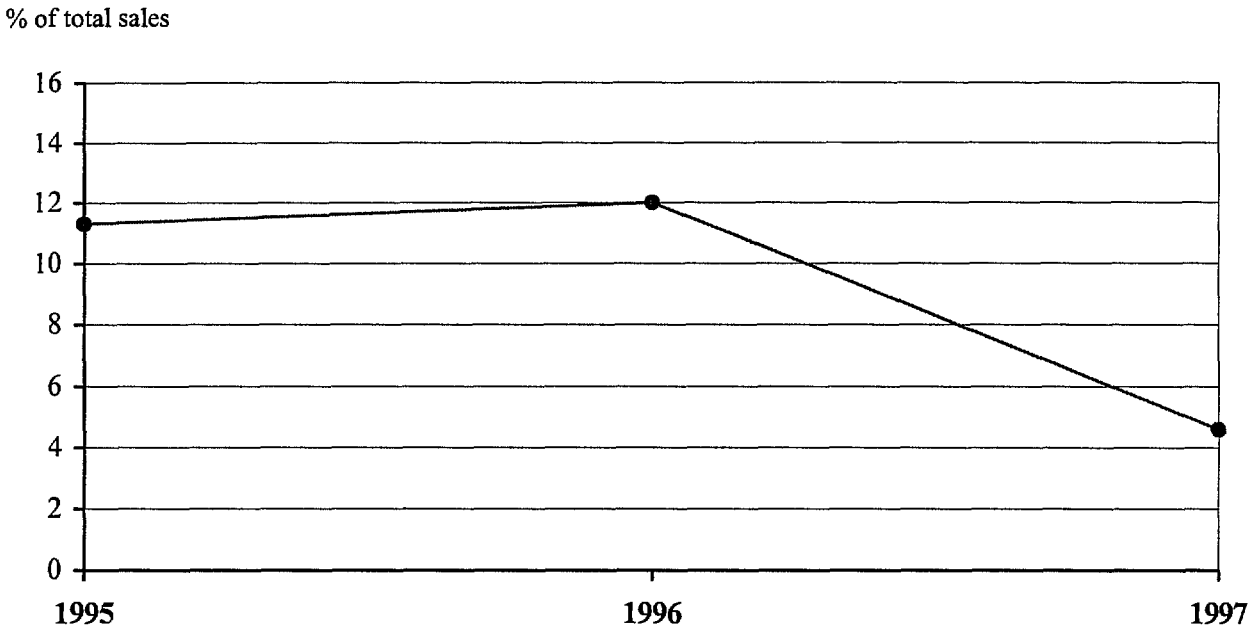
The marketing, production and technical services of the JSC work on the prospective development of the refinery In future the refinery plans to expand the selling market for the UKRTATNAFTA petroleum products by 5% The following factors will be employed

- in order to encourage the customers' demand a flexible price discount system has been developed which enables successful competition by attracting large wholesalers,
- it is planned to expand sales by attracting the state-owned joint-stock company "Khleb Ukrainy" which supplies petroleum products to agricultural enterprises, and to continue long-term co-operation with the Ukrainian Ministry of energy by supplying fuel oil to power stations,
- besides power sector fuel oil is purchased by other industries such as oil refining and petrochemical enterprises, sugar refineries with which long-term co-operation is planned,
- JSC UKRTATNAFTA plans to supply the petroleum products to ore concentration complexes, steel works and rolling mills, departments of the Ukrainian railroad company,
- according to publications only 30% of total consumption of light fuels (gasoline and diesel fuel) are sold via retail networks i e filling stations, therefore, it is planned to build further gas filling stations

3 4 Exports vs Domestic sales

JSC UKRTATNAFTA exports petroleum products

Share of exports in total sales in 1995-1997



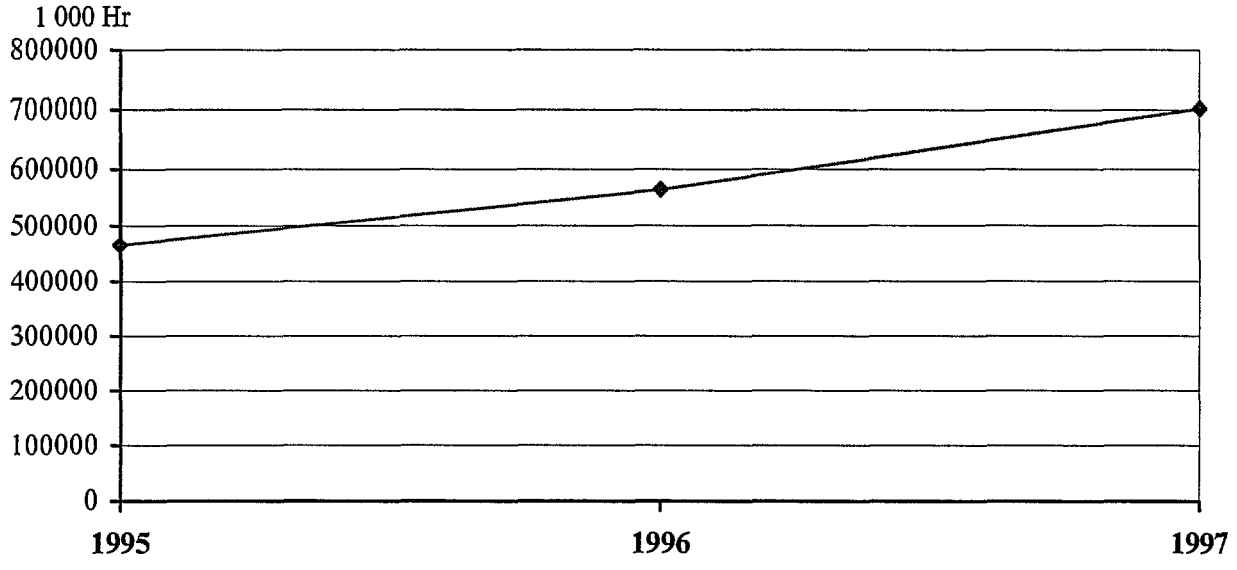
The chart shows that the export market were stable for the UKRTATNAFTA though the exports in 1997 decreased from 1996 by 7%

4 0 FINANCIAL STATUS

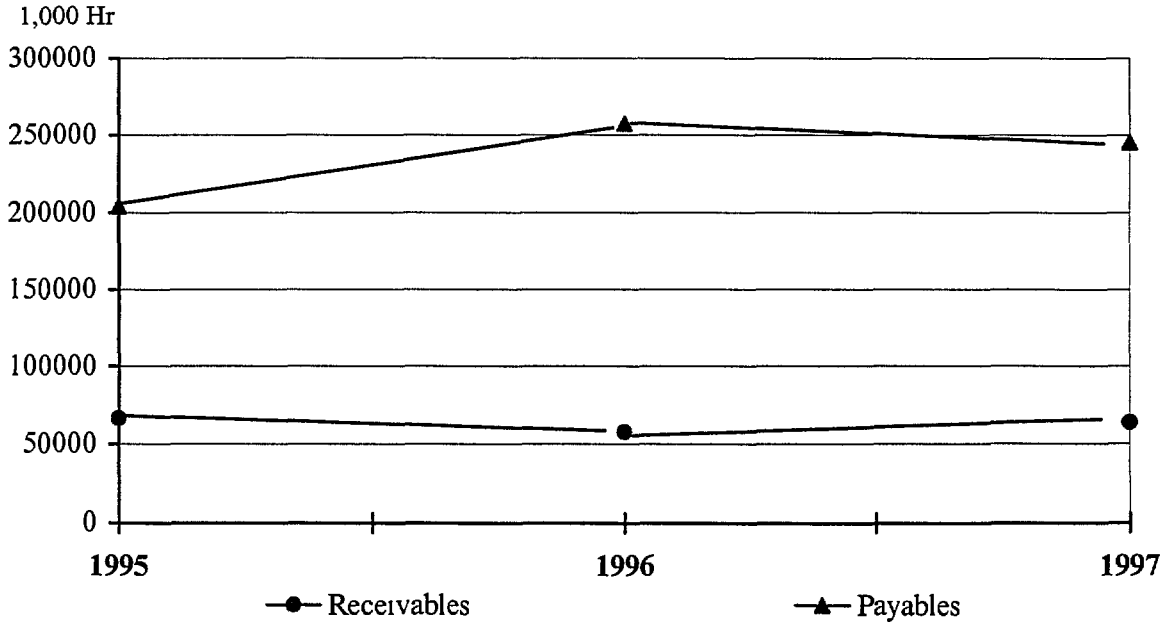
4 1 Currency vs Barter

In the business operations of the JSC UKRTATNAFTA barter operations constitute a significant part This is explained by the payment crisis in Ukraine

Gross income of the refinery in 1995-1997

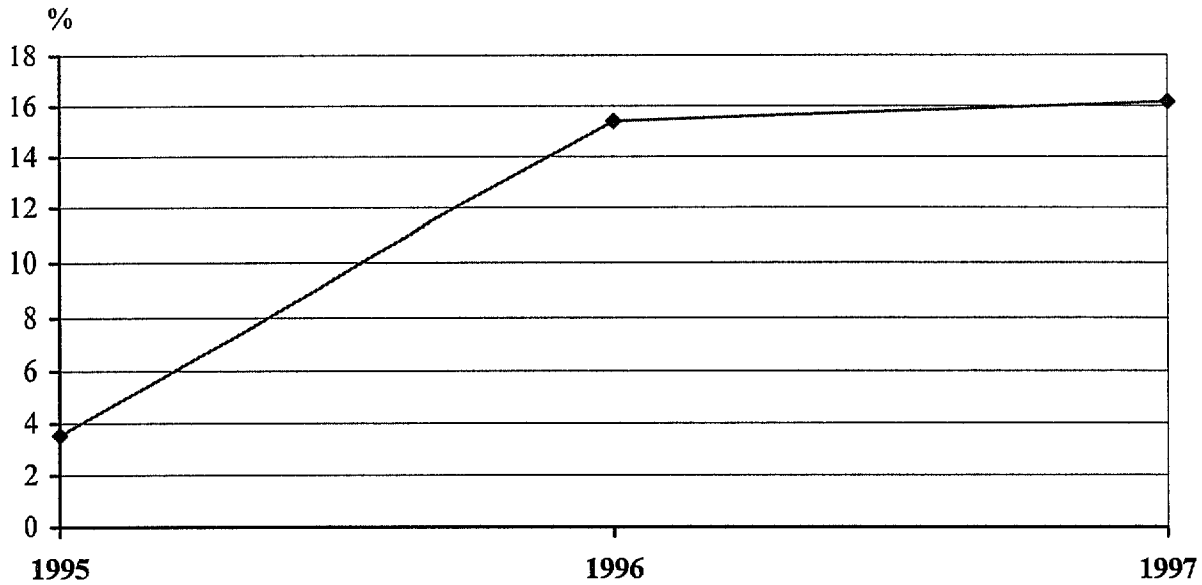


Receivables and payables in 1995-1997



The charts above show the main financial results of the refinery operations The analysis reveals that in spite of a significant rise in gross income in 1997 vs 1996 by 24 5%, the payables though dropped but negligibly Receivables increased in 1997 vs 1996 by 10 4%

Profitability of output in 1995-1997



The profitability of production 1997 vs 1996 continued to grow due to the transition to processing of own raw materials instead of outside owned

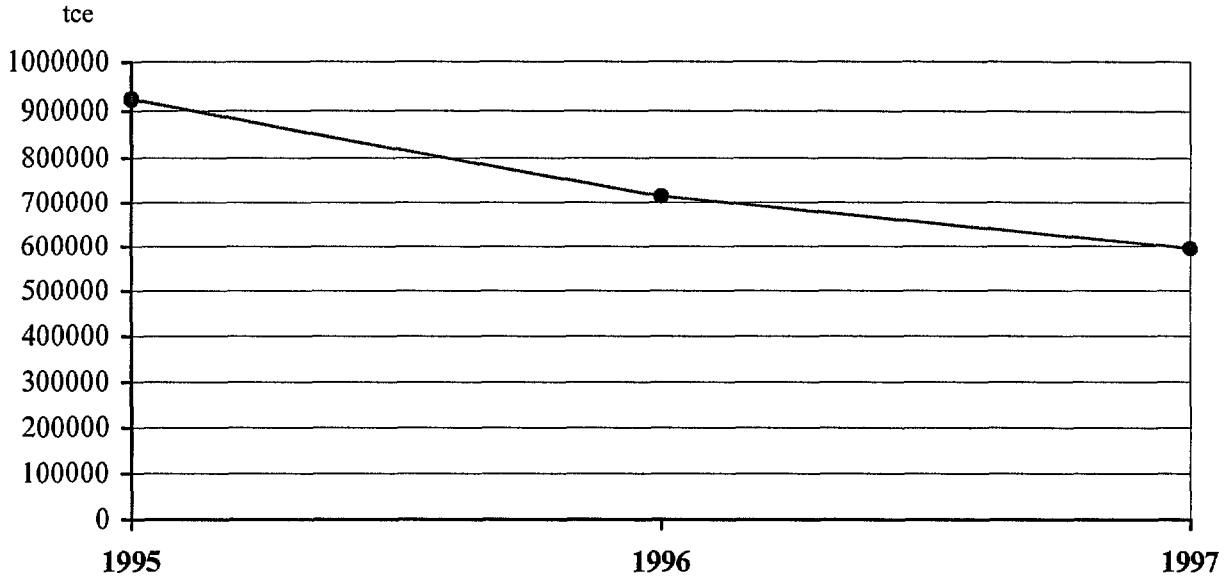
In general, the viability indicators have satisfactory values and show a stable status of the enterprise in the studied period

5 0 ANNUAL ENERGY CONSUMPTION AND COST

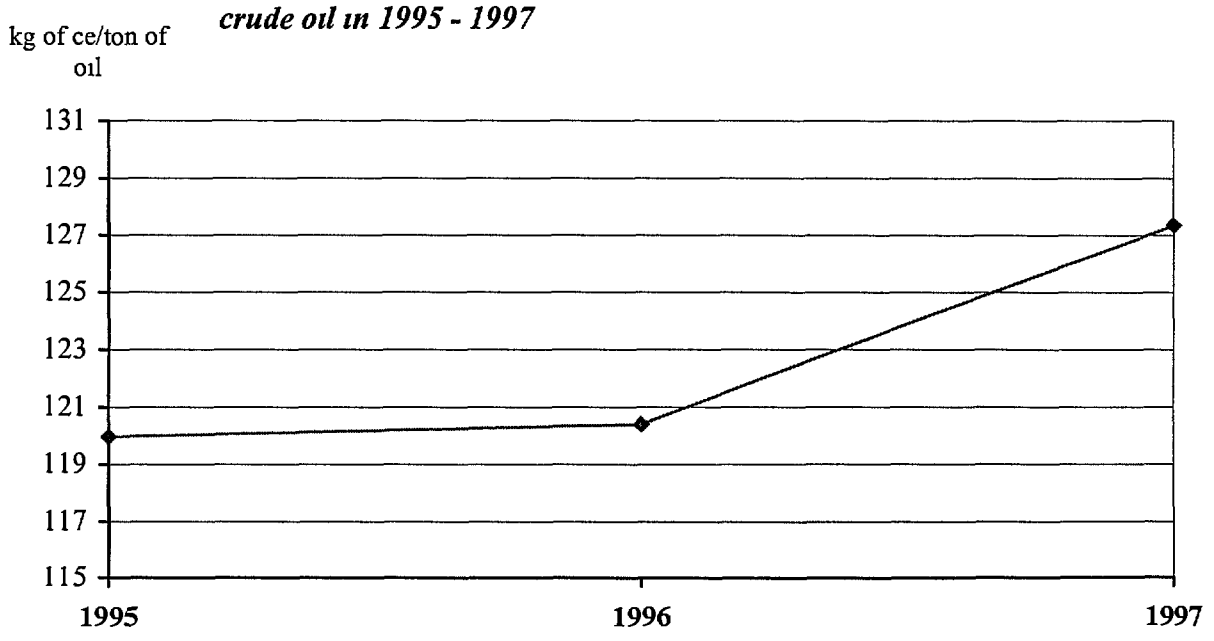
5 1 Annual consumption in 1995 - 1997

The JSC *UKRTATNAFTA* uses secondary types of energy purchased from the local utilities as electric power, various types of fuel, and thermal energy as technological steam

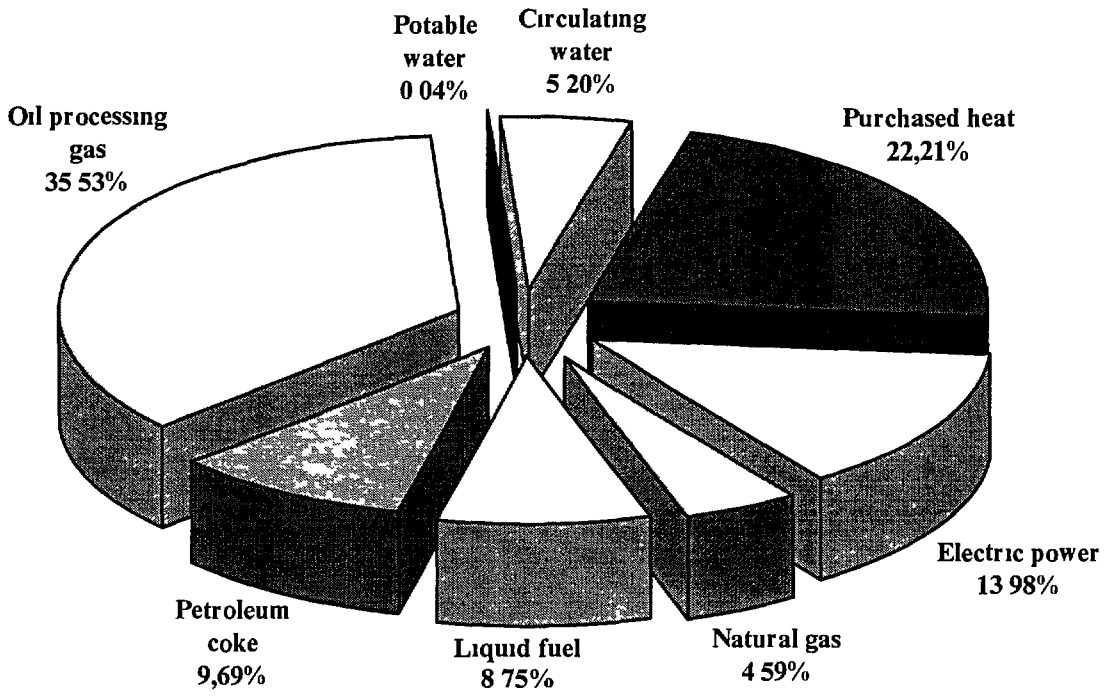
Fuel and energy consumption in 1995-1997



Specific consumption of fuel and energy for processing of crude oil in 1995 - 1997



Breakdown of total fuel and energy use in 1997



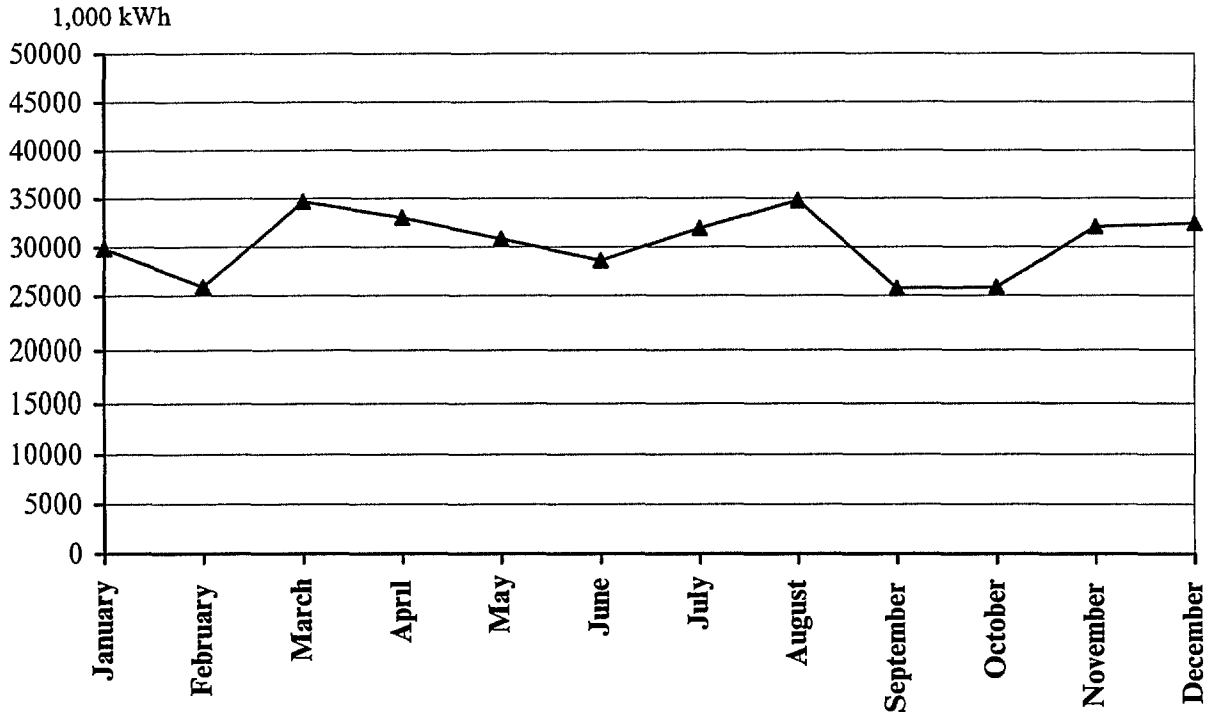
#	Fuel or energy	Annual consumption, tce	Share of total consumption, %
1	Electric power	87772 5	13 98
2	Natural gas	28844 4	4 59
3	Liquid fuel	54945 3	8 75
4	Petroleum coke	60796 5	9 69
5	Oil processing gas	223057 5	35 53
6	Potable water	226	0 04
7	Circulating water	32648 9	5 2
8	Purchased heat	139446 9	22 21
	TOTAL	**627738**	**100**

The above charts, diagram and table show annual consumption by types of energy and fuel Electric power, purchased heat and oil processing gas comprise *13 98* %, *22 21* % and *35 53*% of the total consumption respectively However, the cost structure is somewhat different (see Section 5 2) electric power - *20 67*%, purchased heat - *22 85* %, oil processing gas - *16 85* %

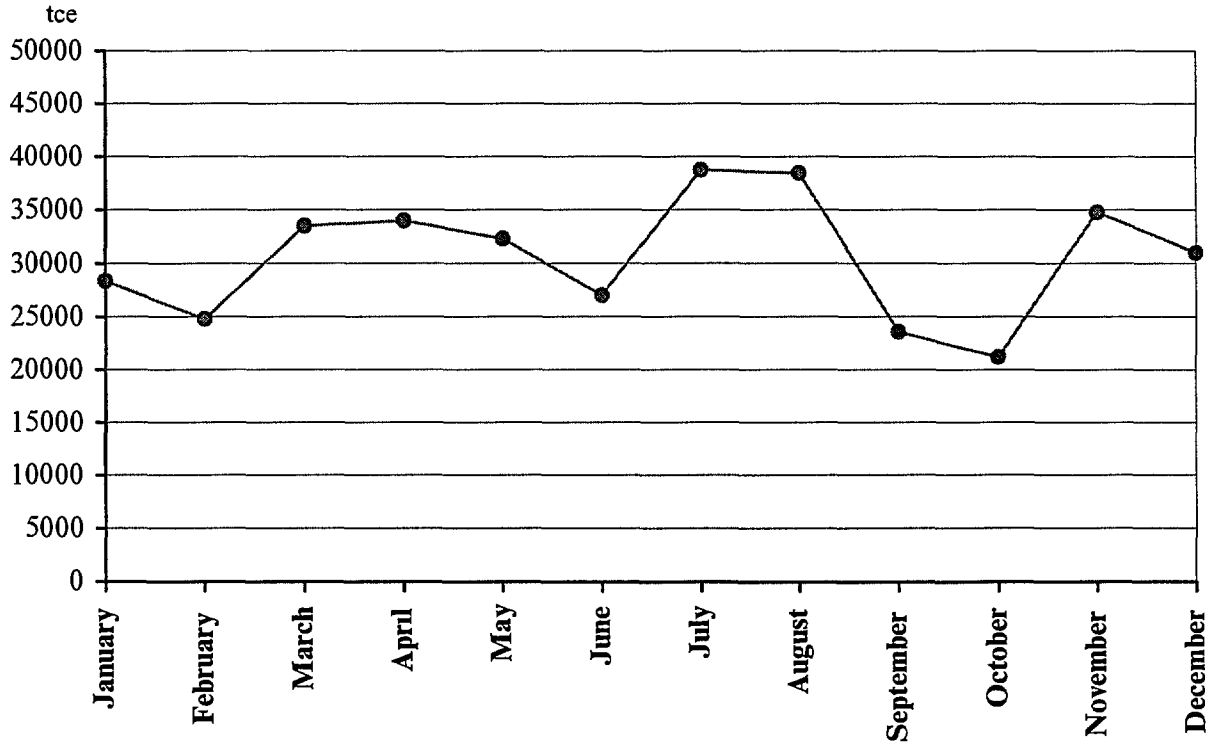
Upgrading and growth of production in combination with implementation of comprehensive energy conservation opportunities will reduce specific consumption of fuel and energy per ton of oil

Monthly fuel and energy consumption is shown on the graphs below

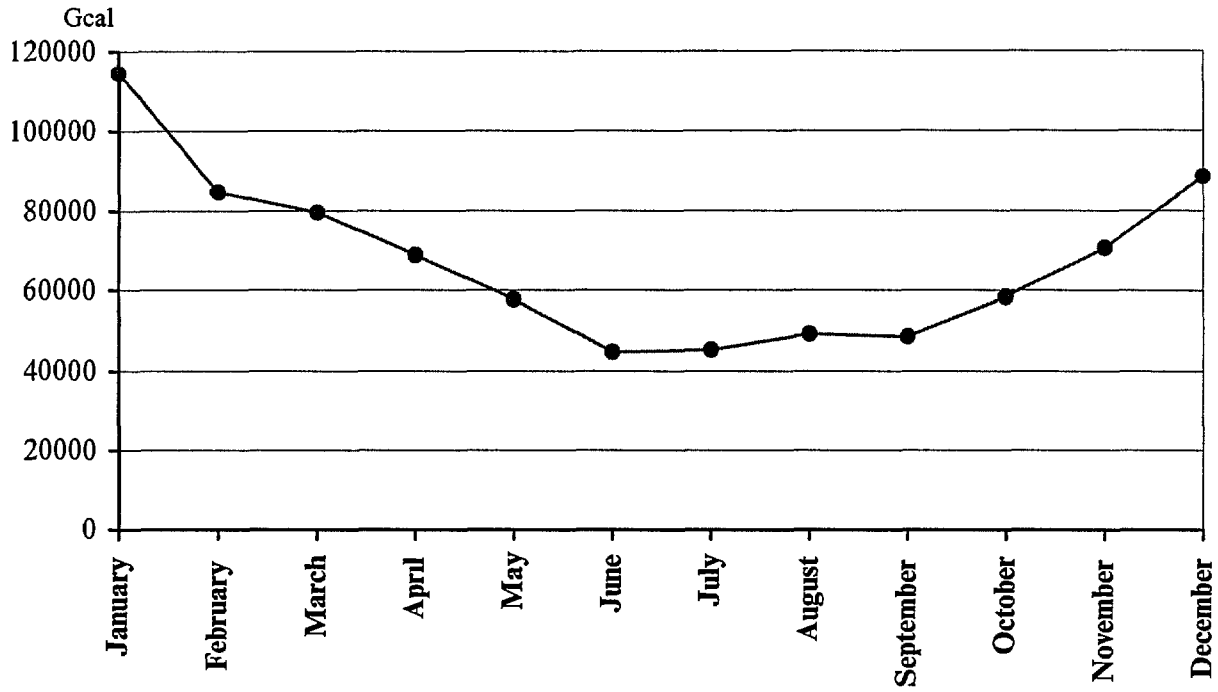
Electricity consumption in 1997



Fuel consumption in 1997



Thermal energy consumption in 1997



Total electricity consumption in 1997 was ***365,718 7*** thousand kWh, all types of fuel (natural gas, fuel oil, petroleum coke, oil processing gas) - ***367,644*** tce, steam - ***810,738*** Gcal Maximum steam consumption is in the winter months of December and January (***88,663*** and ***114,379*** Gcal respectively) Synchronous changes of parameters in the charts reflect the impact of production factors on the fuel and energy consumption

Fuel and energy consumption by the LCh-35/11-600-68 plant in 1997

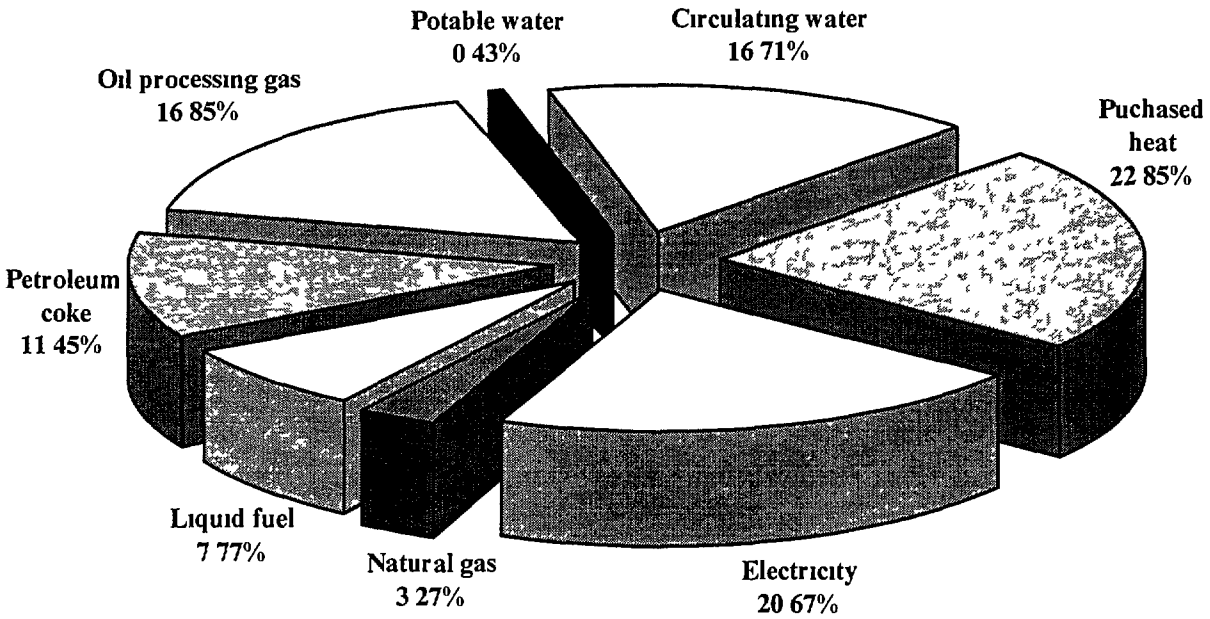
Time period	Production output tons	Electricity consumption, 1,000 kWh	Fuel consumption, tce	Heat consumption Gcal	Treated water use tons	Steam generation Gcal	Air consumption, 1,000 m³	Technological steam consumption, tons	Condensate recovery, tons	Circulating water, 1 000 m³
I quarter	60376	5539 2	6480	1984	6875	2679	449 2	2377	1242	1689 2
II quarter	30039	2910 4	3215	445	3641	1174	140 9	645	112	952 2
III quarter *)	0	0	0	0	0	0	0	0	0	730 1
IV quarter	63170	6122 6	6754	1510	6642	3166	410 5	1646	960	2162 4
1997	**123546**	**11661 8**	**13234**	**3494**	**13517**	**5845**	**859 7**	**4023**	**2202**	**4581 7**

*)In May - September 1997 the plant was undergoing major overhaul

5 2 Existing energy tariffs

In 1997 the JSC *UKRTATNAFTA* paid for energy and fuel $*54,252 thousand* According to the energy audit data the cost of energy used by the LCh-11/35-600-68 plant amounted to *47 2* % of all production costs Therefore, the energy conservation measures may have a significant impact on the financial results of the plant and entire refinery operations

Breakdown of energy costs in 1997



#	Fuel and energy	Annual costs, $	Share of annual costs, %
1	Electricity	13,531,592	20 67
2	Natural gas	2,141,795	3 27
3	Liquid fuel	5,087,045	7 77
4	Petroleum coke	7,499,805	11 45
5	Oil processing gas	11,032,368	16 85
6	Potable water	284,244	0 43
7	Circulating water	10,944,103	16 71
8	Purchased heat	14,959,589	22 85
	TOTAL	**65,480,541**	**100**

Average annual energy cost at the current tariffs was determined by the refinery operation results in 1997

- electricity - *0 037* $/kWh,
- natural gas - *89 03* $/1000 m^3

- fuel oil - *133 23* $/ton
- steam - *18 45* $/Gcal
- petroleum coke - *133 23* $/ton
- oil processing gas - *82 05* $/ton

5 3 Energy use profile

Distribution of energy among the JSC UKRTATNAFTA is carried out by 45 distribution and 65 transformer substations via cables laid in overpasses and in the ground

In 1997 the energy was supplied under direct contracts Annual electricity consumption was ***365,719*** thousand kWh The total capacity of capacitor units was – ***34,002*** kVAR, including the Kremenchug power station - ***5,955*** kVAR, the FAKEL substation - ***21,447*** kVAR, the ZARYA substation - ***6,600*** kVAR

Technological steam was used in 1997 by all UKRTATNAFTA facilities In 1997 the maximum daily average load of steam with 16 kg/cm^2 pressure received from the Kremenchug power station was 239 1 ton/hour given total maximum consumption from the external sources of 241 6 ton/hour

For plant, space and partial main oil pipeline heating the power station hot water is used Heating supply system supplies main oil pipeline heating systems and domestic hot water supply system

Overall length of steam, condensate, hot water chemically treated water and air piping operated by the thermal supply unit constitutes 474 km

In 1997 1,079,801 Gcal of thermal energy was used The thermal energy use includes 122,220 Gcal of heat generated by the heat utilizing equipment of the GK-3/1 No 1 and 2, G-36-37 , LCh-35/11-600, S-200 LK-6U, UPES plants In 1997 heat use for production purposes was 935,958 Gcal

Standard specific consumption for processing 1 ton of oil was 195 8 Mcal

Total actual heat consumption in 1997 from the Kremenchug power station with contracted amount of 1,853,000 Gcal was 897,437 Gcal, including via JV Phobos - 88,663 Gcal Consumption of the 16 kg/cm^2 steam from the industrial carbon works was 60,144 Gcal

The condensate recovery is carried out at six condensate stations The condensate recovery system is closed-circuit The condensate received at the condensate stations is cooled at the first-phase space heating system and is pumped to the central condensate station Condensate recovered at the central condensate station in 1997 amounted to 493,162 tons and was purified of oil products by settlement prior to return to the Kremenchug power station in conformity with the contract between the power station and JSC *UKRTATNAFTA* For the make-up of the space heating system and feeding the utilise boilers the power station supplied 142,111 tons of chemically treated water

Annual generation and consumption of compressed air was 137,5659 4 thousand cubic meters against the planned amount of 134,900 2 thousand cubic meters

In 1997 398,807 tce were used for production purposes comprising

- natural gas - 33,118 5 thousand normal m^3
- oil processing gas - 148,373 tons
- cracking gas - 52,293 tons
- diesel fuel - 37,605 tons
- boiler and oven fuel - 205 tons

including the following

for domestic purposes

- diesel fuel - 373 tons
- boiler and oven fuel - 205 tons

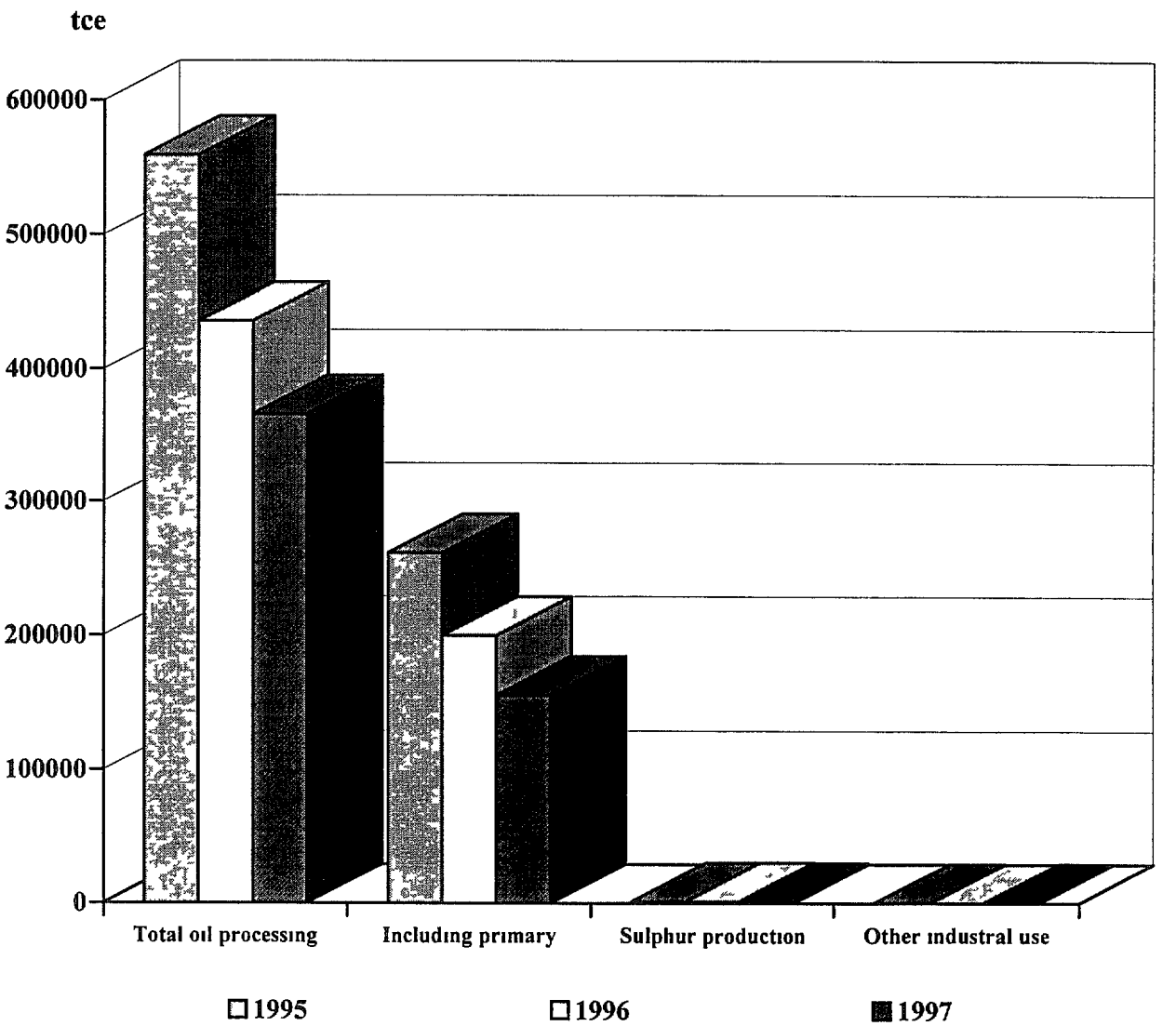
for outside sales

- natural gas - 9,061,698 normal cubic meters
- oil processing gas - 13,920 tons

At the refinery there is no technical submetering of natural gas and heat use by production units and types of products, therefore objective estimates of energy use distribution the indicated types of energy use Presently these estimates are drafted by the economic section of the refinery by calculations based on design specific consumption and production output The results of the energy use are reflected in the state statistics form No 11 MTP "Report on the results of fuel, thermal energy and electricity consumption"

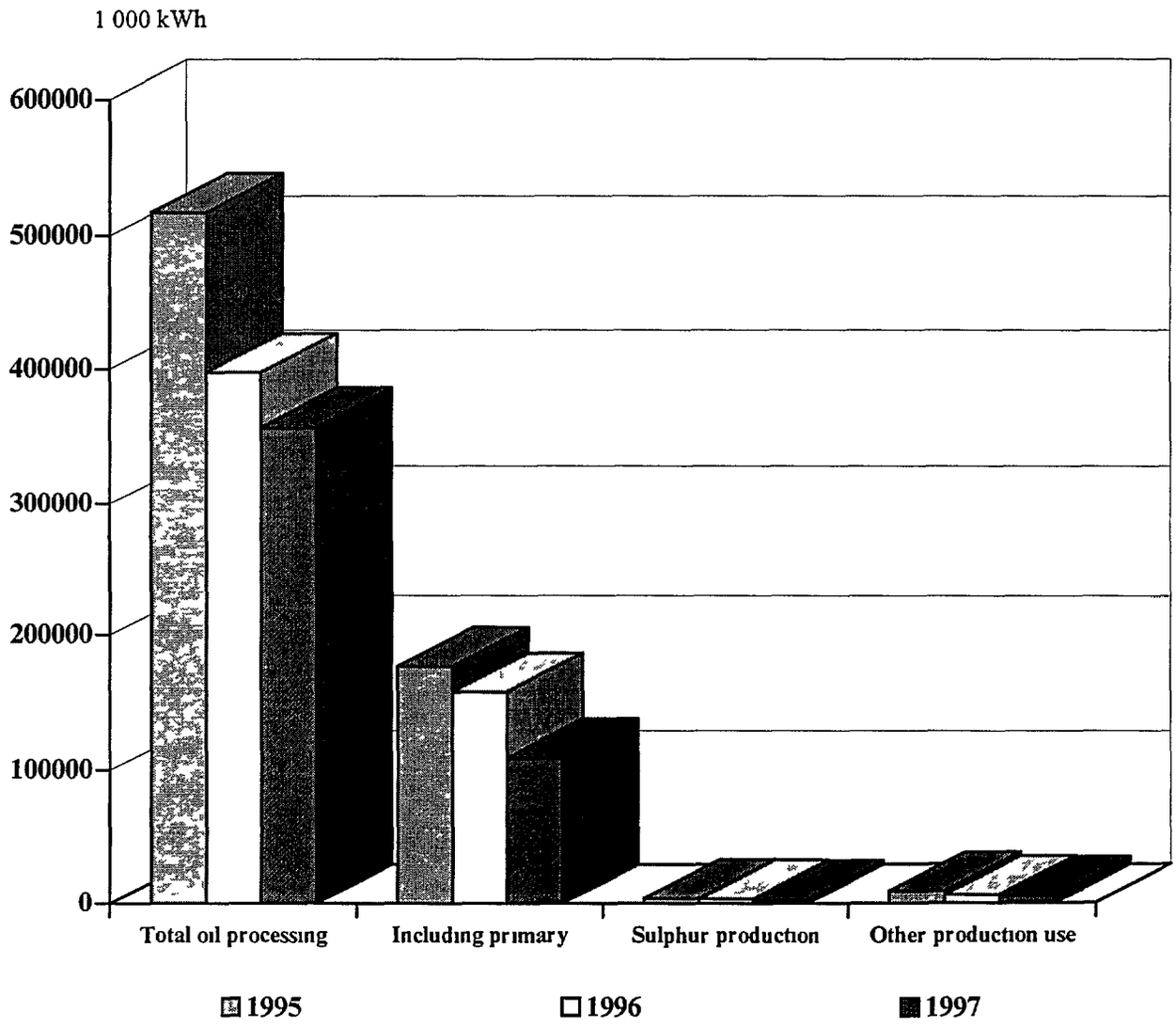
Fuel consumption by types of products and operations

Years	Total oil processing, tce	including primary processing, tce	Sulphur production, tce	Other production use, tce
1995	559,290	261,642	1,311	305
1996	435,682	199,849	1,214	0
1997	365,776	155,420	800	232



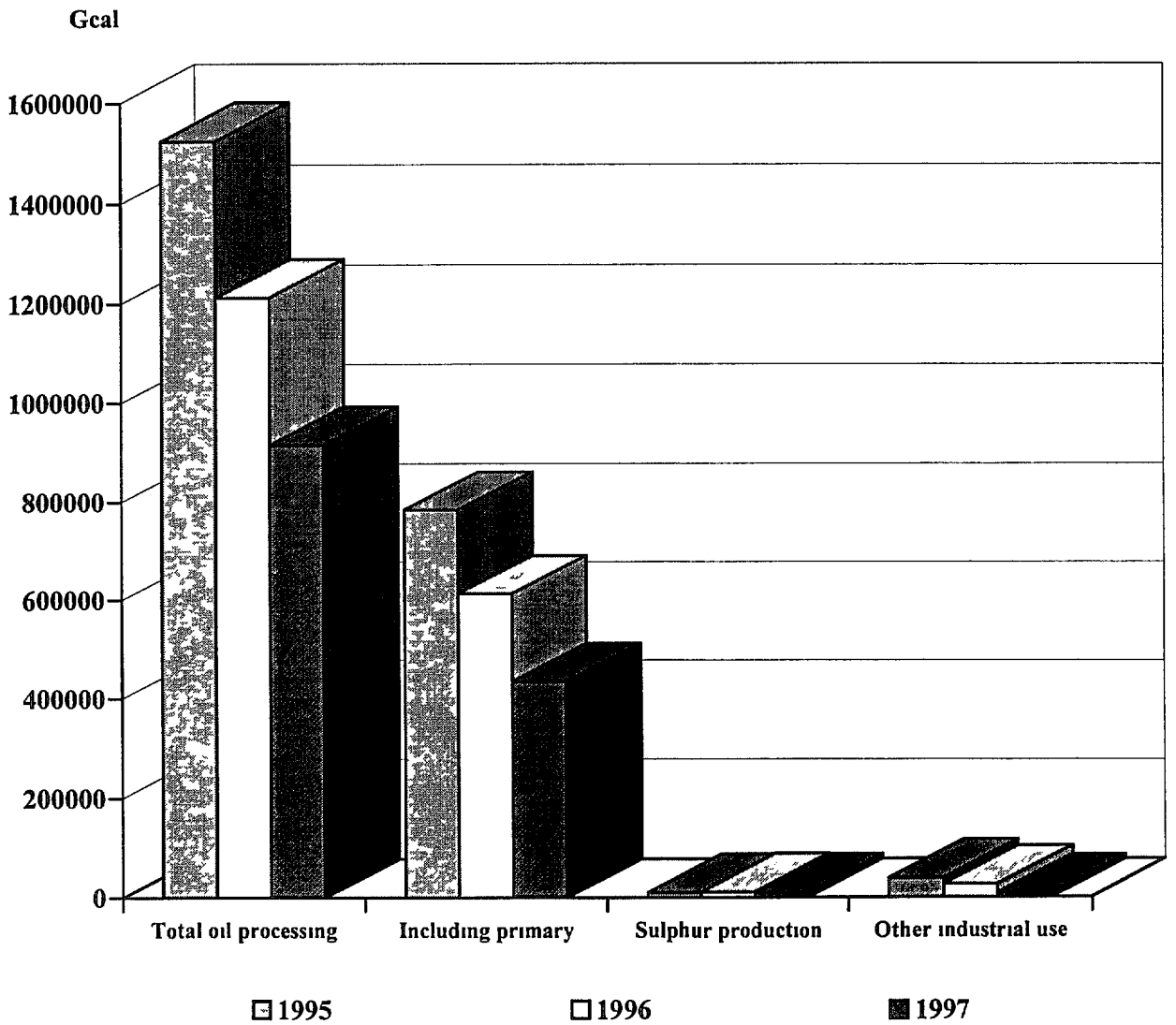
Electricity consumption by types of products and operations

Years	Total oil processing, 1,000 kWh	including primary processing, 1,000 kWh	Sulphur production, 1,000 kWh	Other production use, 1,000 kWh
1995	516 917	176 703	3 709	9 146
1996	397 513	157 611	3 337	6 204
1997	357 320	108 942	2 595	5 551



Thermal energy consumption by types of products and operations

Years	Total oil processing, Gcal	including primary processing, Gcal	Sulphur production, Gcal	Other production use, Gcal
1995	1 524 658	783 551	9 985	38 971
1996	1 211 482	612 191	10 735	26 491
1997	914 433	434 057	9 841	8 684



6 0 PREVIOUS ENERGY IMPROVEMENTS

Certain energy conservation effort was made at the JSC *UKRTATNAFTA* During the previous year the energy laboratory implemented the following

- review of the following plants S-200 LK-6U of the No2 production line, AVT and ELOU of the No 3 production line, AT-1 GK-3/1 of the No1 production line,
- review of the AT-1 GK-3/1 ovens of the No1 production line, AVT, S-200, S-300,
- review of electricity consumption, analysis of the electric supply of the refinery and development of measures to cut down losses in electric grids, optimization of operation of static capacitor batteries,
- preliminary study of the refinery liquid fuel system, system of registration of natural and oil processing gas consumption

The company is developing the concept of registration, control and management of the energy use on the basis of computer technology

At the LCh-35/11-600-68 catalytic reforming plant

- utilize boilers have been replaced,
- oven lining have been replaced,
- production parameter registration have been set up (temperature, pressure, flow),
- according to the retrofitting plan developed in conjunction with the Gas Institute the existing burners are being replaced with more modern ones

Refining technologies are being improved with the view of energy conservation

7 0 ENERGY AUDIT

The energy audit of the LCh-35/11-600-68 plant of the JSC UKRTATANAFTA resulted in a range of recommendations for energy efficiency improvement at the plant and the entire refinery The majority of the problems of the JSC *UKRTATNAFTA* are typical for the Ukrainian refineries, therefore addressing these problems can be replicated at these enterprises with similar type of energy use

Implementation of the proposals recommended by the energy auditors will reduce annual energy consumption

- electric power by 33,300 8 thousand kWh (9 1% of 1997 consumption)
- fuel by 36,039 thousand cubic meters (9 8% of 1997 consumption)
- thermal energy by 64,822 Gcal (8 05 of 1997 consumption)

ECO - 1 Institution of energy management

Energy management is the main avenue by which energy usage reduction and increase in consumption efficiency can be achieved Energy management is a system of enterprise management that promptly reveals and eliminates non-productive use of energy resources

We recommend to institute the energy management system at the JSC UKRTATNAFTA to full extent

Implementing an energy management activity typically would involve appointing a person responsible for institution of energy management at the enterprise - an energy manager In order to carry out continuous monitoring and analysis of energy consumption it is proposed to provide the enterprise with necessary measuring equipment

Implementation of this project will reduce

- electricity consumption by 18,285 thousand kWh/year,
- fuel consumption by 17,680 tce/year,
- thermal energy by 40,500 Gcal/year,
- energy costs by $2,700,000 per year

Simple payback will be 0 5 year
See details in Appendix A, ECO #1

ECO- 2 Automatic energy metering system

Presently the refinery energy laboratory is performing the study of energy efficiency of production plants For registration of energy traditional techniques are used when the service personnel records instrument readings and submits them for further processing Calculations of electricity, steam, heating water, liquid and gaseous fuel consumption by the refinery production units are carried out with the help of standard indicators and production output Instrument submetering presently does not meet actual requirements both from organizational and technological standpoints

We recommend to automate commercial and technical metering with the help of the ITEK technical instrument set manufactured by the R &D institute "Energiya" in Kiev These instruments are certified in Ukraine and are designed for continuous and periodical measurement/registration of physical values

Introduction of the ITEK-X1X allows consumers to pay their electric power bills by the one-rate tariff differentiated according to the daytime zone

We recommend to automate commercial and technical metering with the help of the ITEK technical instrument set manufactured by the R &D institute "Energiya" in Kiev These instruments are certified in Ukraine and are designed for continuous and periodical measurement/registration of physical values

Introduction of the ITEK-X1X allows consumers to register the resource use with high accuracy and pay the bills by the actual consumption but not proportionally to the occupied area or to other indicator

In order to implement this work it is planned to set up commercial electricity metering at 136 points, steam at 12 points, heating water at 4 points, liquid fuel at 2 points, gaseous fuel at 1 point

Technical electricity consumption metering can be implemented at 1,200 points, steam at 80 points, heating water at 28 points, compressed air at 130 points, liquid fuel at 34 points, gaseous fuel at 46 points

Judging from the global experience expected savings from introduction of the in-plant automatic metering and control and planning systems will be not less than 3%

Implementation of this project will save

- Electric power - 10,972 thousand kWh
- Natural gas - 721 7 thousand m^3 or 858 8 tce
- Steam - 24,322 Gcal

Simple payback is 0 9 year

See details in Appendix A, ECO #2

ECO - 3 Retrofitting of P-601 hydraulic purification oven with utilization of exhaust heat gas

At the L-Ch-35/11-600-68 reforming plant in order to hydraulically purify low-octane gasoline a P-601 cylindrical vertical heating oven is operated using the oil processing gas The experts using energy audit equipment have performed the study of the oven operation

The energy auditors see the opportunity to implement the following at the oven

- retrofitting burners,
- utilization of exhaust gas heat by using "gas-to-air" type equipment on the heat piping,
- automatic control of fuel to-air ratio by the combustion gas analysis, oven load depending on the temperature of raw materials,
- installation of fins on the radiator part of the oven,

that will save 30-32% 0f fuel used by the P-601 hydraulic purification oven

Implementation of this project will save

- 6,026 tce/year,

- $548,000 per year

Simple payback is 0 6 year
See details in Appendix A3, ECO #3

ECO - 4 Improvement of fuel combustion efficiency in P-602 reforming oven

The energy auditors studied the operation of P-602 unit of the LCh-35/11-600-68 plant The oven is designed for heating of the gas product mixture to 498-500°C The oven is equipped with 42 burners with combined gas and liquid fuel combustion capability Behind the oven there are two KU-601/1 2 waste-heat recovery boilers Exhaust gas analyses were taken at eight points along the flow of the flue gas

Overall efficiency of the oven is 83% If losses into the environment are taken into account the efficiency is 82%

The energy auditors recommend a set of measures for improvement of fuel efficiency at the oven that will save 8-10% of fuel

Implementation of this project will reduce

- fuel consumption by 2,040 tce/year,
- energy costs by $186,000 per year

Simple payback is 0 8 year

See details in Appendix A, ECO #4

ECO - 5 Retrofitting of heat exchange equipment of reforming plant and improvement of its operation efficiency

Reforming of low-octane gasoline into high-octane is connected with heating of raw materials undergoing hydraulic purification, gas catalytic cracking and ready product cooling on completion of the former processes Between heating the raw material and cooling of the ready product are heat exchanger units which heats raw materials from 45°C to 226°C before the hydraulic purification oven and cools the purified product from 310°C o 116°C In the cooling unit the product is cooled from 116°C to 38°C i e there are irretrievable heat losses

Performed analysis of the general operational parameters of the entire set of heat exchangers showed that there was a potential of reducing residual temperature difference 50% as a minimum This will increase the raw material temperature before the hydraulic purification and reforming ovens by 20-25% and through this to reduce fuel consumption for raw material heating in the ovens by 20-25%

For that purpose it is necessary to install additional high-efficiency equipment simultaneously with planned replacement of the equipment with expired life time

Implementation of this project will reduce

- fuel consumption by 2,040 tce/year,
- energy costs by $186,000 per year

Simple payback is 1 4 years

See details in Appendix A, ECO #5

ECO - 6 Improvement of LCh-35/11-600-68 reforming plant insulation

During the study of the plant the energy auditors revealed significant number of non-insulated surfaces of pipelines, heat exchangers, reactors, supports and other items with temperatures from 150^{0}C to 450^{0}C In order to calculate heat losses it is necessary to know the temperature and area of heat emitting surface

For the detailed analysis of heat losses it is advisable to carry out thermal survey of all equipment not only at this plant but at the entire refinery with further development of a special investment project of improvement of insulation on the refinery equipment and piping By the experts' estimate insulation of bare surfaces is attractive and efficient opportunity to reduce heat waste by 90-95% The energy auditors recommend to design and install easily dismantled thermal insulation permitting multiple use after overhauls

Implementation of this project will reduce

- fuel consumption by 248 tce/year,
- energy costs by $22,600 per year

Simple payback is 0 64 year

See details in Appendix A, ECO #6

ECO -7 Energy efficient plant lighting

The external and internal lighting system of the plant area consists of 45,756 lighting fixtures of various types including 1,000 searchlights on masts with incandescent lamps with 500-1000W , explosion-proof lamps for production area lighting, lighting fixtures with DRL - 250 (400) and DRL-400 (150) lamps for lighting of compressor rooms, pumping and ventilation stations, circulating water supply units and for external area lighting

The light flow of the DRL-400 lamp is 23,000 lumen and nominal service life is 6,000 hours, for DRL-250 lamp respectively 10,000 lumen and 2,400 hours

This recommends replacement of DRL -400 high pressure mercury lamps for external lighting of the plant area with the DNaT-250-3 high pressure sodium lamps and of DRL-250 with DNaT-100-3 using existing fixtures and replacing switching appliances with appropriate capacity The sodium lamps of the DNaT -250-3 type manufactured in the city of Poltava have a longer operation life - 12,000 hours with the light flow of 25,000 lumen and DNaT-100-3 respectively 6,000 hours with the light flow of 9,000 lumen

Implementation of this project will reduce

- electricity consumption by 389 1 thousand kWh/year,
- energy costs by $14,396 per year

Simple payback is 1 2 years

See details in Appendix A, ECO #7

ECO -8 Monitoring and optimization electric equipment capacities

Ninety nine per cent of total electricity consumption of the refinery was used for primary production purposes according to the 1997 data that constitute 365,466 thousand kWh per year for $13,522,242

Electric drives of production, pumping and ventilation equipment are main consumers of electric power

Historically, when electric motors went out of order the replacements were brought in irrespective of the nominally required capacity

Total rated capacity of 45 electric motors of the plant was 8,285 kW Total used capacity was 4,283 kW Measurements taken by the DRANETZ electric load analyzer testify to the low drive loads of electric drives

This recommends to introduce operational monitoring of actual electric parameters of electric equipment by a set of portable devices The recommended proposal will ensure monitoring of the actual electric equipment loads, analyse their efficiency and schedule replacement with more efficient equipment

Implementation of this project will save at least 1% of electricity used for production purposes each year

Implementation of this project will reduce

- electricity consumption by 3,654 7 thousand kWh/year,
- energy costs by $135,222 per year

Simple payback is 0 6 year

See details in Appendix A, ECO #8

8 0 ENVIRONMENTAL IMPACT OF RECOMMENDATIONS

The most efficient way of reduction of hazardous emissions into the atmosphere is decrease of fuel and electric power use Energy conservation and efficiency are extremely urgent from the ecological standpoint

The proposed project contains energy conservation measures aimed at saving fuel and electric power The main fuel used at the JSC UKRTATNAFTA is natural gas The harmful substance that forms in significant quantity during combustion of this fuel is nitrogen oxide (NO_X) The nitrogen oxides are harmful to the human health and can cause severe respiratory problems
Since combustion of natural gas results in the least emissions of the carbon dioxide CO_2 (that is the main gas responsible for setting "the green house effect"), saving natural gas will contribute to weakening of "the green house effect" Carbon monoxide (CO) is emitted after an incomplete combustion of fuel, it reacts with other substances and has various detrimental impacts Sulphur dioxide resulting from combustion destroys materials

Annual energy resource savings due to implementation of energy management will be as shown in the Table 1

1 Electricity savings	- 33,300,800 kWh
2 Fuel savings	- 36,039 8 tce
3 Thermal energy	- 64,822 Gcal

According to the data from the Ministry of Energy, in 1996 1 kW h of the electric power meant emitting into the atmosphere of 17 g of contaminating substances, including the following

- sulphur dioxide SO_2 9 9 g
- carbon oxide CO 0 5 g
- nitrogen oxides NO_x 2 2 g
- solid particles 4 4 g

Reducing electric consumption results in decreasing the amount of the emitted harmful substances that can be determined by the formula

$$h = h_n \quad E_{ps},$$

where

h - total emissions g/kWh, saved or not emitted into the atmosphere
h_n - the specific content of emissions, g/kW h
E_{ps} - electric power saving, kW h

Amounts of pollutants formed during generation of 33,300 8 thousand kWh

1) sulphur dioxide SO_2	h_1 = 9 9 x 33,300 8/10^3= 329 7 (t/year)
2) carbon oxide CO	h_2 = 0 5 x33,300 8/10^3 = 16 65 (t/year)
3) nitrogen oxides NO_x	h_3 = 2 2 x 33,300 8/10^3 = 73,26 (t/year)
4) solid particles	h_4 = 4 4 x 33,300 8/10^3 = 146,0 (t/year)

The amount of prevented emissions into the atmosphere as the result of fuel and purchased heat savings can be calculated based upon the European standards of industrial emissions

For the light oil fractions used in the power plants of 5 MW capacity the standards are as follows

- carbon oxide CO = 171 mg/kWh or 171 kg/thousand kWh
- nitrogen oxides NO_x = 250 mg/kWh or 0 25 kg/kWh

Total fuel savings by implementing ECO #1 - #6 considering that for generation of 1 Gcal of heat 0 172 tce is used will be 47,189 2 tce which is equal to 33 032 Gcal (390,773 8 thousand kWh) of thermal energy

Reduction of emissions into the atmosphere will be

- carbon oxide CO M_{CO} = 0 171 x 390,773 8/10^3 = 66 82 (ton/year)
- nitrogen oxides NO_x M_{NOx} = 0 25 x 390,773 8/10^3 = 97 69 (ton/year)

TABLE OF POLLUTANT EMISSION REDUCTION

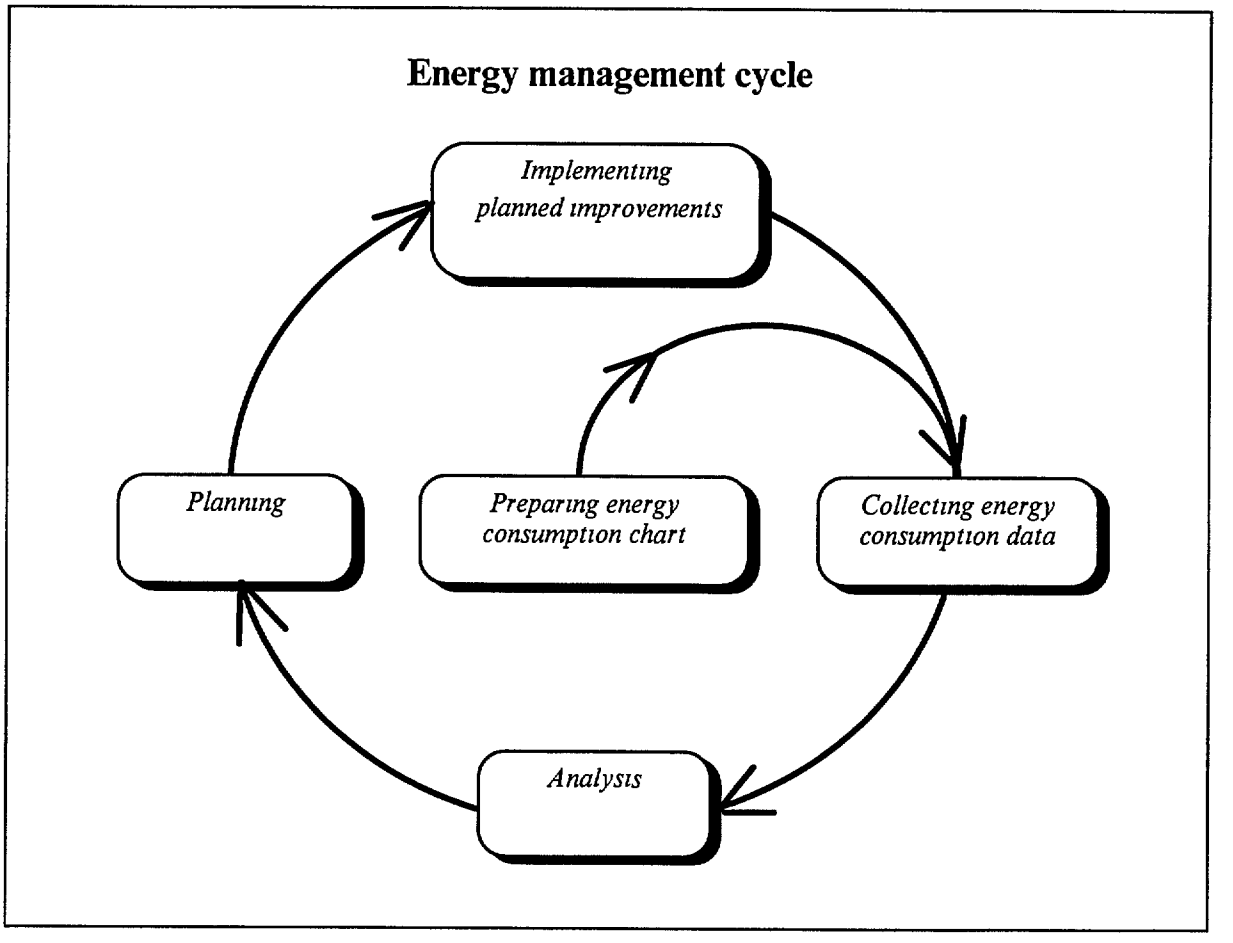
Description	**Unit of measure**	**Reduction in emissions as result of the energy savings, t/yr**		
		Electric power	**Natural gas**	**TOTAL**
Hard particles		146	-	146
Sulphur dioxide		329 7	-	329 7
Carbon oxide		16 65	66 82	83 47
Nitrogen oxides		73 26	97 69	170 95
Total emission reduction				730 12

APPENDIX A ENERGY CONSERVATION OPPORTUNITIES (ECOs)

ECO #1 Institution of energy management

ECO description

Energy management is the main avenue by which energy usage reduction and increase in consumption efficiency can be achieved This management strategy is based on conventional measurements and documentation and provides operating conditions that facilitate minimal energy consumption needed for the technology This is also a management tool which comprises a continuous research allowing precise knowledge on facility's energy distribution and consumption, as well as on best energy utilization for production, district heat and other non-productive purposes



Implementation of energy management program will result in having more detailed energy consumption records Such system will allow comparison of the energy usage to that of other enterprises for precise evaluation of energy saving projects that are considered by the facility

Implementing an energy management activity typically would involve appointing a person responsible for institution of energy management at the enterprise - an energy manager For the JSC *UKRTATNAFTA* the energy auditors see it advisable to institute the energy manager position at each production line and at each energy consumption system (fuel, electricity, air, heat and water)

The main duties of an energy manager

- Preparing facility's energy consumption chart (probably in collaboration with an outside consultant, energy auditor),
- Collecting fuel and energy consumption data using measuring and testing equipment,
- Preparing a plan for implementing additional measuring and testing equipment,
- Collecting data on raw materials and energy consumption and on production output,
- Making key calculations on improving energy efficiency - for overall facility as well as specific production lines,
- Implementing new technologies on existing and new energy systems to improve energy efficiency of operation,
- Encouraging the personnel to indicate potential energy conservation opportunities
- Keeping informed on current energy policy trends and neighboring issues, (e g , such as new tax legislation, existing consumption restrictions, subsidies, environmental aspects etc)

In order to implement permanent energy consumption monitoring and analysis we recommend to institute energy management system at the plant and to provide required measuring equipment The set of equipment that will be useful for the plant should include

- three phase energy analyzer,
- tachometer,
- hot-wire anemometer,
- combustion analyzer,
- non-contact thermometer,
- ultrasonic leak detector,
- digital contact thermometer,
- light meter,
- power factor meter,
- portable temperature/humidity/ dew point meter,
- computer with printer

Implementation of this ECO will result in considerable energy savings

Annual energy savings

Currently the works use annually on average 365,718,700 kWh of electric power, 24,057,000 m^3 of natural gas, 810,738 Gcal of steam, 38,138 tons of fuel oil and 190,746 tons of other fuel (petroleum coke and oil-processing gas)

Typically, combustion efficiency improves by 2 5% from utilizing the combustion analyzer Electric power use efficiency can be linked to a wide range of factors i g power factor correction, improvement of equipment load control (shutting off idling equipment), optimization of motor loads, optimization of pump operation, improvement of compressor load control, etc On average improvement of electric power use can ensure from 3 to 10% savings of total electric power consumption

The global experience and practice show that in case of institution of full-time energy management ensures 10% of fuel and energy consumption savings with 5% energy conservation implementation cost

Presently the refinery management is purposefully addressing energy conservation issues by setting up an energy laboratory with the concrete action program The laboratory plans to develop and implement energy efficiency improvements and introduce consistent energy conservation effort

At a cautious estimate of the laboratory efficiency which with the proper instrumentation can be transformed into an energy management section at the refinery we can assume that at the expenditure of 2 5% of energy costs the energy savings will amount to

- Electric power - 365,718,700 x 0 05 ~ 18,285,000 (kWh)
- Natural gas - 24,057,000 x 0 05 ~ 1,202,000 (m^3) or 1,430 tce
- Steam - 810,738 x 0 05 ~ 40,500 (Gcal)
- Fuel oil - 38,183 x 0 05 ~ 1,900 (tons) or 2,750 tce
- Petroleum coke - 56,293 x 0 05 ~ 2,800 (tons) or 3,000 tce
- Oil processing gas - 134,453 x 0 05 ~ 6,700 (tons) or 10,500 tce

Annual cost savings estimate

1 At the average annual price of $0 037 per 1 kWh of electric power the cost savings will be
18,285,000 x 0 037 ~ $676,500

2 At the average annual price of $89 03 per 1,000 m^3 of natural gas the cost savings will be
1,202 x 89,03 ~ $107,000

3 At the average annual price of $18 45 per 1 Gcal of steam the cost savings will be
40,500 x 18,45 ~ $747,000

4 At the average annual price of $133 23 per 1 ton of fuel oil the cost savings will be
1,900 x 133 23 ~ $253,000

5 At the average annual price of $133 23 per 1 ton of petroleum coke the cost savings will be
2,800 x 133 23 ~ $373,000

6 At the average annual price of $82 05 per 1 ton of oil processing coke the cost savings will be
6,700 x 82 05 ~ $549,000

TOTAL energy cost savings will be
676,500 + 107,000 + 747,000 + 253,000 + 373,000 + 549,000 ~$ 2,700 000
including fuel costs
107,000 + 253,000 + 373,000 + 549,000 ~ $1,282,000

Implementation Costs

According to the world practice, expenses on implementing energy management are planned in advance and constitute 5% of energy costs These expenses include costs of improving energy consumption record system, management costs, costs of consulting company services, which will produce

- facility's energy flow survey,

- energy consumption charts,
- energy consumption balance,

and will also

- work out energy efficiency recommendations,
- implement energy management program,
- provide assistance in purchasing energy efficient equipment

At average annual energy costs of $54,252,000 total implementation costs of energy management program should be planned at

54,252,000 x 0 025 ~ $1,356,300

Simple payback

Implementation costs - $1,356,300
Annual cost savings - $2,700,000
Simple payback period will be

1,356,000/2,700,000 ~ 0 5 (year)

ECO-#2 Automatic energy metering system

ECO description

Presently the refinery energy laboratory is performing the study of energy efficiency of production plants With this purpose the energy use registration and operation modes of energy intensive equipment of the production plants are checked step by step followed by the analysis and evaluation of the energy efficiency The measurements will result in development of proposals for energy efficiency improvements

Energy metering is carried out by 674 instruments used for metering

- electric power - 562 electric meters,
- steam 52 meters,
- heating water - 17 meters,
- liquid fuel - 17 meters,
- gas fuel - 27 meters

For measuring non-electric parameters the following measuring instruments are used

- pneumatic measuring converters with output signals of 0 2 - 1 0 kg/cm^2,
- measuring converters with electric output signals of 4-20 mA,
- differential flow ink plotters

Electric power is supplied to the refinery from the GRU-6 main distribution device of the power station via two five-cable, one four-cable and ten three-cable feeders through 24 node distribution points of the refinery, from the FAKEL 150/6-kV substation via three four-cable, eight three-cable, sixteen two-cable and twelve single-cable feeders through 45 node distribution points

Heat supply for the JSC UKRTATNAFTA comes from the Kremenchug power station with the following steam parameters

- pressure 16 kg/cm^2 , temperature 300^{0}C via five steam pipelines of 500 mm diameter,
- pressure 40 kg/cm^2 , temperature 350^{0}C via one steam pipeline of 200 mm diameter,
- pressure 40 kg/cm^2 , temperature 350^{0}C via one steam pipeline of 350 mm diameter,

and via heating water network with the temperature schedule of 130-70^{0}C

Industrial carbon utilizer boilers are the second source of heat supply for the refinery supplying the steam with 16 kg/cm^2 pressure, 300^{0}C temperature via a 500 mm pipeline

Twenty two utilizer boilers are the third heat source

Compressed air for production and testing is supplied by four compressor stations

- VK-1 air compressor unit equipped with one 5G-100/8 and two 3NV-4K-315/520 and three UOV-100 air dehumidifiers with 100 m^3/min capacity each
- VK-2 air compressor unit equipped with three 5G-100/8 and one 43BTz-160/9 compressors and three UOV-100 air dehumidifiers with 100 m^3/min capacity each

- VK-3 air compressor unit equipped with two German-made VMTS-8037 and one 43BTz-160/9 compressors and three UOV-100 air dehumidifiers with 100 m^3/min capacity each
- Air compressor unit of production line No4 equipped with four 305 VP-30/8 and one PK-5/25 compressors and three UOV-100 air dehumidifiers

The primary fuels are oil processing gas and fuel oil of own production The fuels for G-24, G-36-37, UPES, petroleum asphalt and UIG plants are natural gas supplied by the city utility

Besides, the catalytic cracking plants use as their technological fuel petroleum coke generated during catalytic cracking process

Detailed study of the refinery showed that for energy registration traditional techniques are used when the service personnel makes rounds of meters, flow meters and other instruments, records their readings and takes them to the computer center for further processing Calculations of electricity, steam, heating water, industrial hot water, liquid and gaseous fuel consumption by production units if the refinery are made with the help of standard indicators and actual production output Energy submetering inside the refinery does not meet current requirements both from organizational and technological standpoints

We recommend to automate commercial and technical metering with the help of the ITEK technical instrument set manufactured by the R &D institute "Energiya" in Kiev These instruments are certified in Ukraine and are designed for continuous and instantous measurement/registration of physical values

Introduction of the ITEK-X1X allows consumers to pay their electric power bills by the one-rate tariff differentiated according to the daytime zone which in conjunction with the measures of reduction of the maximum hour consumption provides a considerable cost effect that has been proven by more than annual operation at numerous Ukrainian facilities

ITEK-210 and ITEK-310 are intended for commercial and technical metering of electric power (differentiated by time) and build-up of automatic metering and control systems of electric power use (AMCSEPU) in combination with electric meters of three-phase induction type equipped with pulse generation devices (E440, E870, UP-1, UP-2, UP-3, SU-500) or electronic (Siemens, Landis and Gyr, Alpha-ABB, etc) with pulse output They support 64 (for ITEK-210) or 12 (for ITEK-310) metering channels, 4 tariff zones, day schedule for all metering channels is a 5 days' minimum, 2 independent data interfaces

ITEK-210 can be used in combination with or instead of the installed TsT-5000 systems by connection to the existing matrix of primary measurement converters The ITEK-210 is included in the State register of measurement devices of Ukraine

The ITEK-410 is designed for 4 metering channels and is similar to the above devices Additionally it supports tariffs differentiated by peak consumption and demand, and provides monitoring and control over consumption process Daily schedules from 4 channels are stored for not less than 1 month

Introduction of ITEK-X2X allows consumers to meter resources with high accuracy and pay the bills for actual consumption but in proportion to the area

ITEK-220 and ITEK-320 are designed for automatic commercial metering and telemetric control of supply and consumption of liquids, gases, steam and thermal energy in combination with any primary measurement converters of consumption, temperature, pressure and pressure drop with standardized output parameters at supplier's (thermal power plant, district heat, boiler houses) and consumer's sites (industrial enterprises, public utility facilities) The ITEK-X20 devices are designed in conformity with requirements of RD-50-213-80, PR34 -70-010-85, State standard 6651-84 and recommendations of the Ministry of health

The ITEK-X20 devices are intended for the facilities of the first metering group (up to 4 facilities) with a complex configuration of supply and recovery piping (ITEK-220), and for the facilities of the first or second metering groups (one facility) (ITEK-320)

In order to implement this work it is planned to set up commercial electricity metering at 136 points, steam at 12 points, heating water at 4 points, liquid fuel at 2 points, gaseous fuel at 1 point

Technical electricity consumption metering can be implemented at 1,200 points, steam at 80 points, heating water at 28 points, compressed air at 130 points, liquid fuel at 34 points, gaseous fuel at 46 points

Annual energy savings

Judging from the global experience expected savings from introduction of the in-plant automatic metering, control and planning systems will be not less than 3% In 1997 the plant used approximately 7,530,000 kWh of electric power, 2,530,000 m^3 of natural gas
Therefore, based on the 1997 energy consumption data energy savings at the works will be

- Electric power - 10,972 thousand kWh
- Natural gas - 721 7 thousand m^3 or 858 8 tce
- Steam - 24,322 Gcal

Annual cost saving estimate

Currently the refinery pays for energy $54 25 million Therefore, the energy cost savings will be
54,250,000 x 0 03 = $1,627,500

Implementation Costs

Commercial metering of electricity, steam, heating water, liquid and gaseous fuels -$400,000
Technical metering of electricity, steam, heating water, compressed air,

liquid and gaseous fuels	- $800,000
Installation and commissioning	- $200,000
TOTAL cost	- $1,400,000

Simple payback

Implementation costs - $1,400,000
Annual cost savings - $1,627,000
Simple payback period will be

1,400,000/1,627,000 ~ ***0 9*** (year)

ECO # 3 Retrofitting of P-601 hydraulic purification oven with utilization of exhaust heat gas

ECO description

At the L-Ch-35/11-600-68 reforming plant in order to hydraulically purify low-octane gasoline a P-601 cylindrical vertical heating oven is operated using the oil processing gas The experts using energy audit equipment have performed the study of the oven operation

The exhaust gas analysis at the balance point after the convection tube bank showed the following

- temperature at the oven output is 578^{0}C,
- excess air α = 1 99-2 03,
- incomplete CO combustion = 3-39 PPM,
- efficiency is 57 4 - 58 3%

The energy auditors see the opportunity to implement the following at the oven

- retrofitting burners for improved fuel combustion with less excess air and eliminating incomplete combustion will save 5-5=6% of fuel,
- utilization of exhaust gas heat by using "gas-to-air" type equipment on the heat piping will save 20-22% of fuel,
- automatic control of

- fuel to-air ratio by the combustion gas analysis,
- oven load depending on the temperature of raw materials before the P-601 reactor will save 3-5% of fuel,

- installation of fins on the radiator part of the oven to increase heat utilization in the combustion chamber and reduction of heat load on the oven lining will save 0 5-1% of fuel

The oven efficiency improvement measures will save 30-32% of the fuel used by the P-601 hydraulic purification oven

Annual energy savings estimate

During the study of the L-Ch-35/11-600-68 reforming plant the P-601 hydraulic purification oven was running to the full capacity of 110 m^3 of raw materials per hour which was heated to the temperatures from 225-226^{0}C to 310^{0}C

Thirty per cent savings will result from implementation of the energy conservation measures

If the L-Ch-35/11-600-68 reforming plant is operated 7,200 hours per year as set forth by the Regulations fuel savings will be

2,790 x 0 3 x 7,200/1,000 ~ 6,026 (tce)

Annual cost savings estimate

At the current average $91 04 cost of 1 tce at the refinery cost savings will be
6,026 x 91 04 ~ $548,000

Implementation cost

Design and consulting - $30,000
Equipment and components (heat utilizing equipment, burners, fan, air ducts, insulation, automatic controls) - $200,000
Installation and turnkey commissioning - $70,000
Contingencies and overheads - $30,000
TOTAL cost - $330,000

Simple payback

Implementation cost - $330,000
Annual cost savings - $548,000
Simple payback will be

33,000/548,000 = ***0 6*** (year)

ECO #4 Improvement of fuel combustion efficiency in P-602 reforming oven

ECO description

The energy auditors studied the operation of P-602 unit of the LCh-35/11-600-68 plant The oven is designed for heating of the gas product mixture to 498-500°C The oven is equipped with 42 burners with combined gas and liquid fuel combustion capability Behind the oven there are two KU-601/1 2 waste-heat recovery boilers

During the visit the energy auditors used US-made equipment BACHARACH combustion analyzer, HeatSpyDHS-24X non-contact infra-red thermometer, KURZ thermoanemometer

Exhaust gas analyses were taken at eight points along the flow of the gases

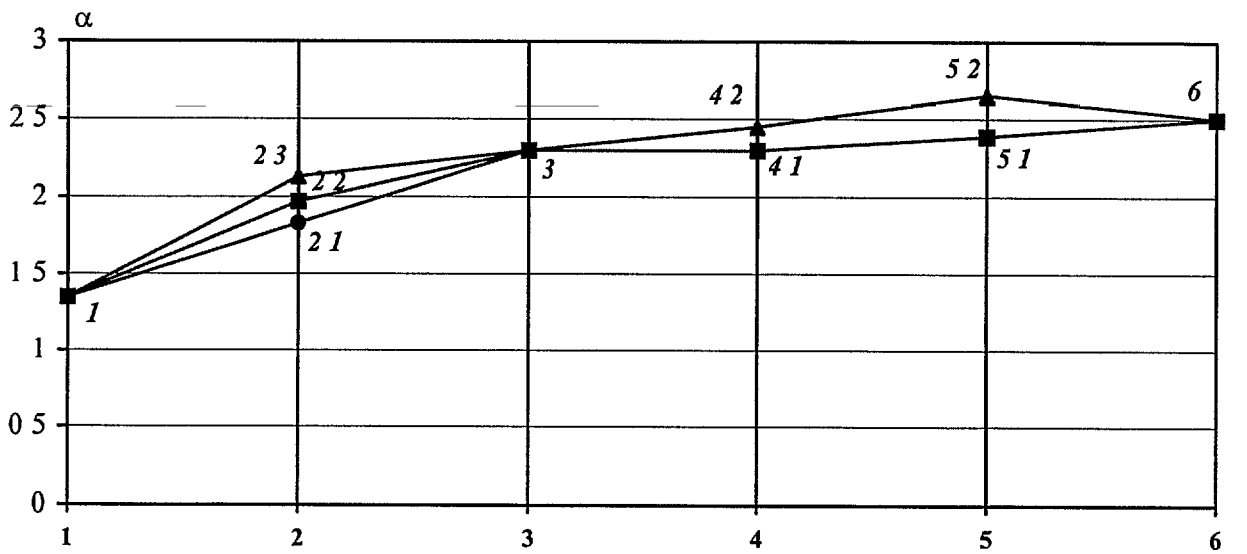
- top of the convection part of the oven
- center of the convection part of the oven
- bottom of the convection part of the oven
- general oven outlet
- before No1 waste-heat recovery boiler
- before No2 waste-heat recovery boiler
- behind No1 waste-heat recovery boiler
- behind No1 waste-heat recovery boiler

Overall efficiency of the oven is 83% If losses into the environment are taken into account the efficiency is 82%

Inferior efficiency for this equipment composition is caused by the following factors

- uneven distribution of air among the burners Spot air flow measurements showed that for the upper burners (21) air consumption is twice as much as for the lower burners (21) i e 30,700 m^3 /hour and 14,400 m^3/ hour respectively Therefore, total excess air in the exhaust gas in the radiating part of the oven is α = 1 35-1 36 Despite the presence of the excess air incomplete combustion was observed,
- lack of air and fuel pressure control at the burners, position indicators of air dampers the number of which, by the way, is insufficient for air flow control for all the oven burners,
- low quality of oven lining of the convection part of the oven During measurement with the non-contact infra-red thermometer zones of 7-8 m^2 area with surface temperatures of 200-220°C were observed,
- existence of air infiltration shown on the chart below

Measurement points	Name of P-602 part along the smoke flow	Excess air α
1	Radiation part	1 35
2 1	Convection part (bottom)	1 83
2 2	Convection part (center)	1 97
2 3	Convection part (top)	2 13
3	General exhaust gas outlet	2 3
4 1	Before KU-1 waste heat recovery boiler	2 3
4 2	Before KU-2 waste heat recovery boiler	2 45
5 1	Behind KU-1 waste heat recovery boiler	2 39
5 2	Behind KU-2 waste heat recovery boiler	2 65
6	Before exhaust fan	2 5



As the chart shows with the standard α = 1 4 excess air surplus in the combustion chamber was 30% and 100-110% for the entire oven

It is evident from the above mentioned that the efficiency improvement potential of fuel combustion at this oven constitutes 8-10%

In order to improve the operation efficiency of the oven it is recommended to implement the following measures

- retrofit oven burners and install parameter control instruments Fuel savings will be 1 5%
- eliminate air5 infiltration along the smoke gas flow Fuel savings will be 1 5%
- retrofit thermal insulation of the oven convection part Fuel savings will be 1-1 5%

Annual energy savings estimate

By the accurate estimate of the experts implementation of the above measures will save 6-7% of fuel

With the oven fuel consumption ~ 4,730 tce per hour and operation during 7,200 hours per year fuel savings will be

4,730 x 7,200 x 0 06 ~ 2,040 (tce)

Annual cost savings estimate

With the current average fuel cost at the refinery of $91 04 per 1 tce cost savings will be

2,040 x 91 04 ~ 186,000 ($)

Implementation cost

By the experts' estimate the cost will be

- burner units - $42,000
- control equipment - $20,000
- installation of burners and instruments - $10 000
- insulation retrofitting - $50,000
- ESCO services

(contract supervision, adjustment, servicing, management) - $20,000

TOTAL cost - $142,000

Simple payback

Implementation cost - $142,000

Annual cost savings - $186,000

Simple payback will be

142,000/186,000 = ***0 8*** (year)

ECO #5 Retrofitting of heat exchange equipment of reforming plant and improvement of its operation efficiency

ECO description

The LCh-35/11-600-68 plant during processing both heats the raw material and cools ready products

Between heating the raw material and cooling of the ready product there heat exchanger units which heats raw materials from 45°C to 226°C before the hydraulic purification oven and cools the purified product from 310°C o 116°C In the cooling unit the product is cooled from 116°C to 38°C i e there are irretrievable heat losses

The temperature difference underused during processing is
$\Delta t = 116^0 - 45^0 = 71^0C$

During reforming the residual temperature difference between the initial raw material before the heat exchangers and the finished product before the cooling units is
$\Delta t = 138^0 - 83^0 = 55^0C$

The limited term of the audit precluded to perform careful analysis of operations of each heat exchanger unit Performed analysis of the general operational parameters of the entire set of heat exchangers showed that there was a potential of reducing residual temperature difference 50% as a minimum This will increase the raw material temperature before the hydraulic purification and reforming ovens by 20-25% and through this to reduce fuel consumption for raw material heating in the ovens by 20-25%

For that purpose it is necessary to install additional high-efficiency equipment simultaneously with planned replacement of the equipment with expired life time

Annual energy savings estimate

At the time of the energy audit the LCh-35/11-600-68 plant was running at the nominal capacity Fuel consumption was

- by the hydraulic purification oven approximately 2 8 tce/hour
- by the reforming oven approximately 4 7 tce/hour

Total fuel consumption was 7 5 tce/hour With annual operation of 7,200 hours fuel consumption is

7 5 x 7 200 = 54,000 (tce/year)

If we take into account that prior to the implementation of energy efficiency improvements of heat exchanger operation the ECOs No3 and 4 for performance improvement of heating ovens will have been carried out fuel consumption will be

54,000 - 6,026 -2,040 = 45,934 (tce/year)

where 6,026 tce/year is fuel savings of ECO No3

2,040 tce/year is fuel savings of ECO No4

Then, fuel savings by implementing this ECO will be

45,934 x 0 2 = 9,187 (tce)

Annual cost savings estimate

At the current price of 1 tce of $91 04 cost savings will be

9,187 x 91 04 ~ $846,000

Implementation cost

By the experts' estimate implementation cost will be

survey, design and business planning	- $50,000
equipment	- $1,000,000
installation	- $50,000
contingencies and overheads	-$50,000
TOTAL cost	- $1,150,000

Simple payback

Implementation cost	$1,150,000
Annual cost savings	$846,000
Simple payback	

1,150,000/846,000 = *1 4* years

ECO #6 Improvement of LCh-35/11-600-68 reforming plant insulation

ECO description

During the study of the plant the energy auditors revealed significant number of non-insulated surfaces of pipelines, heat exchangers, reactors, supports and other items with temperatures from 150°C to 450°C In order to calculate heat losses it is necessary to know the temperature and area of heat emitting surface Temperature measurements on the surfaces of the production equipment and piping were taken by the non-contact infra-red thermometer The surfaces were determined based on the geometrical sizes of the equipment and pipelines

Limited term of the audit precluded detailed analysis of the insulation, nevertheless we consider it necessary since at several places of the outer surfaces of insulation at several places the temperature reached 80°C and higher

For the detailed analysis of heat losses it is advisable to carry out thermal survey of all equipment not only at this plant but at the entire refinery with further development of a special investment project of improvement of insulation on the refinery equipment and piping

By the experts' estimate insulation of bare surfaces is attractive and efficient opportunity to reduce heat waste by 90-95%

The energy auditors recommend to design and install easily dismantled thermal insulation permitting multiple use after overhauls

Annual energy savings estimate

By the experts' estimate (though not complete and not finalised) the area of non-insulated surfaces at the plant was

$F_1 = 5 - 5\ 2\ m^2$ with $t = 450^0C$
$F_1 = 20\ m^2$ with $t = 280 - 320^0C$
$F_1 = 15\ m^2$ with $t = 230 - 280^0C$
$F_1 = 60 - 65\ m^2$ with $t = 180 - 200^0C$
$\Sigma F \sim 100\ m^2$

Thermal waste is calculated by the formula

$$Q = K \times F \times \Delta t \times n \times 10^6,$$

where $K = 10$ Ccal/m^2 x hour x C^0 thermal conductivity of structures
F - heat exchange surface area
$\Delta t = (t_{sur} - t_{air})$ - temperature difference
t_{sur} - surface temperature
t_{air} - ambient air temperature
n = 7,200 - annual working hours

Total losses by non-insulated surfaces ~ 1,600 GCal/year

Savings of 90% of heat after insulation will be

$$1{,}600 \times 0\ 9 \sim 1{,}440\ (GCal)$$

At the specific consumption standard of 0 172 tce/ GCal fuel savings will be

1,440 x 0 172 ~ 248 (tce)

Annual cost savings estimate

At the current price of 1 tce of $91 04 cost savings will be

248 x 91 04 ~ $22,600

Implementation cost

By the experts' estimate implementation cost will be

survey and design	- $5,000
equipment	- $5,000
installation	- $2,000
contingencies and overheads	-$2,500
TOTAL cost	- $14,500

Simple payback

Implementation cost	$14,500
Annual cost savings	$22,600
Simple payback	

14,500/22,600 = ***0 64*** year

ECO #7 Energy efficient plant lighting

ECO description

The external and internal lighting system of the plant area consists of 45,756 lighting fixtures of various types including 1,000 searchlights on masts with incandescent lamps with 500-1000W, explosion-proof lamps for production area lighting, lighting fixtures with DRL - 250 (400) and DRL-400 (150) lamps for lighting of compressor rooms, pumping and ventilation stations, circulating water supply units and for external area lighting The light flow of the DRL-400 lamp is 23,000 lumen and nominal service life is 6,000 hours, for DRL-250 lamp respectively 10,000 lumen and 2,400 hours

This recommends replacement of DRL -400 high pressure mercury lamps for external lighting of the plant area with the DNaT-250-3 high pressure sodium lamps and of DRL-250 with DNaT-100-3 using existing fixtures and replacing switching appliances with appropriate capacity The sodium lamps of the DNaT -250-3 type manufactured in the city of Poltava have a longer operation life - 12,000 hours with the light flow of 25,000 lumen and DNaT-100-3 respectively 6,000 hours with the light flow of 9,000 lumen

Calculation of annual electric power savings

The electric power use of the DRL - 400 mercury lamp is

$P_{F1} = (P_{L\,1} + P_{SW,\,1})\ x\ cos\phi,$

where $P_{L\,1}$ = 400 VA is the capacity of DRL - 400 mercury lamp,
$P_{SW\,1}$ = 85 VA is capacity of switching appliances,
$cos\phi = 0\ 98$

$$P_{F1} = (400 + 85)\ x\ 0\ 98 = 475 \text{ Wh} = 0\ 475 \text{ kW}$$

Amount of the power used by 150 lighting fixtures over 1 year at average 10-hour use is

$$P_1 = P_{F1}\ x\ n\ x\ F$$

where $n=150$ is the number of lighting fixtures,

$F = 10\ x\ 365 = 3{,}650$ hours - annual time of lighting operation
$P_1 = 0\ 475\ x\ 82\ x\ 3{,}650 = 260{,}062$ kWh

The electric power use of the SZPR-250 lighting fixtures with DNaT -250-3 lamp

$$P_{F2} = (P_{L\,2} + P_{SW\text{-}2})cos\phi$$

where $P_{L\,2} = 250\ VA$ is the capacity of DNaT - 250-3 lamp,
$P_{SW\,2}$ = 34,7 VA is capacity of switching appliances,
$cos\phi = 0\ 98$

$$P_{F32} = (250 + 34\ 7)\ x\ 0\ 98 = 279 \text{ W} = 0\ 279 \text{ kW}$$

Power used by 150ghting fixtures over 1 year at average 10-hour use is

$$P_e = P_{F2} \times n \times F = 0\ 279 \times 150 \times 3{,}650 = 152{,}752 \text{ kWh}$$

Annual energy savings by using DNaT-250-3 lamps

$$S_{E_E} = P_1 - P_2 = 260{,}062 - 152{,}752 = 107{,}310 \text{ kWh}$$

The electric power use of the DRL - 2500 mercury lamp is

$$P_{F3} = (P_{L\,3} + P_{SW,\,3}) \times \cos\phi$$

where $P_{L\,3} = 250$ VA is the capacity of DRL - 250 mercury lamp,
$P_{SW\,3} = 54\ 1$ VA is capacity of switching appliances,
$\cos\phi = 0\ 98$

$$P_{F3} = (250 + 54\ 1) \times 0\ 98 = 298 \text{ Wh} = 0\ 298 \text{ kW}$$

Amount of the power used by 400 lighting fixtures over 1 year at average 10-hour use is

$$P_1 = P_{F1} \times n \times F$$

where $n = 400$ is the number of lighting fixtures,
$F = 10 \times 365 = 3{,}650$ hours - annual time of lighting operation

$$P_3 = 0\ 298 \times 400 \times 3{,}650 = 89{,}191 \text{ kWh}$$

The electric power use of the lighting fixtures with DNaT -100-3 lamp

$$P_{F4} = (P_{L\text{-}4} + P_{SW\,4)} \cos\phi$$

where $P_{L\text{-}4} = 100W$ is the capacity of DNaT - 100-3 lamp,
$P_{SW\,4} = 7$ W is capacity of switching appliances,
$\cos\phi = 0\ 98$

$$P_{F1} = (100 + 7) \times 0\ 98 = 105 \text{ W} = 0\ 105 \text{ kW}$$

Power used by 400 lighting fixtures over 1 year at average 10-hour use is

$$P_4 = P_{F4} \times n \times F = 0\ 105 \times 400 \times 3{,}650 = 153{,}300 \text{ kWh}$$

Annual energy savings by using DNaT-100-3 lamps

$$S_{E_E} = P_3 - P_4 = 435{,}080 - 153{,}300 = 281{,}780 \text{ kWh}$$

TOTAL electric power savings at the refinery will be
107,310 + 281,780 = 389,090 (kWh)

Annual cost savings estimate

Cost savings at the price of electric power of US$0 037 per 1kWh

$$S_M = S_{EE} \times 0\ 037 = 389{,}090 \times 0\ 037 = US\$14{,}396 \text{ per year}$$

Implementation costs

Cost of DNaT -250-13 lamps with appliances ($35 x 150) - = US$*5,250*
Cost of DNaT -100-13 lamps with appliances ($30 x 400) - = US$*12,000*

TOTAL cost - $*17,250*

Construction and installation costs not included since the work will be carried out by the plant personnel

Simple payback estimate

Implementation costs - US$17,250

Annual cost savings - US$14,396

Simple payback

$$SP = 17{,}250/14{,}396 = 1\ 2 \text{ years}$$

Since the service life of selected lamps is longer than that of the existing lamps actual payback period can be less than one year

ECO #8 Monitoring and optimization electric equipment capacities

ECO description

Ninety nine per cent of total electricity consumption of the refinery was used for primary production purposes according to the 1997 data that constitute 365,466 thousand kWh per year for $13,522,242

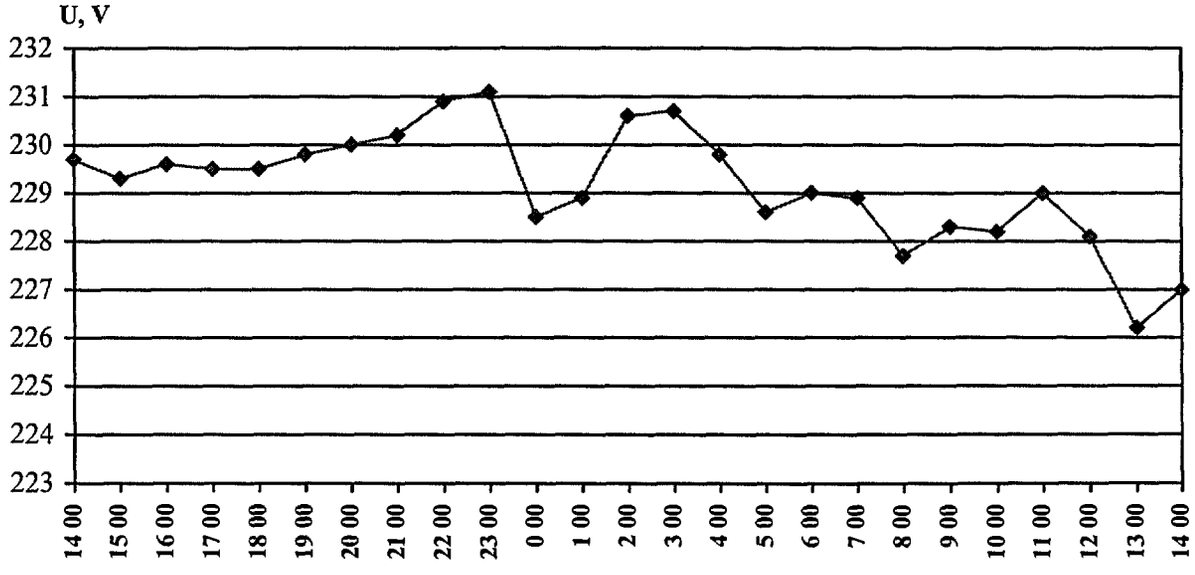
Electric drives of production, pumping and ventilation equipment are main consumers of electric power

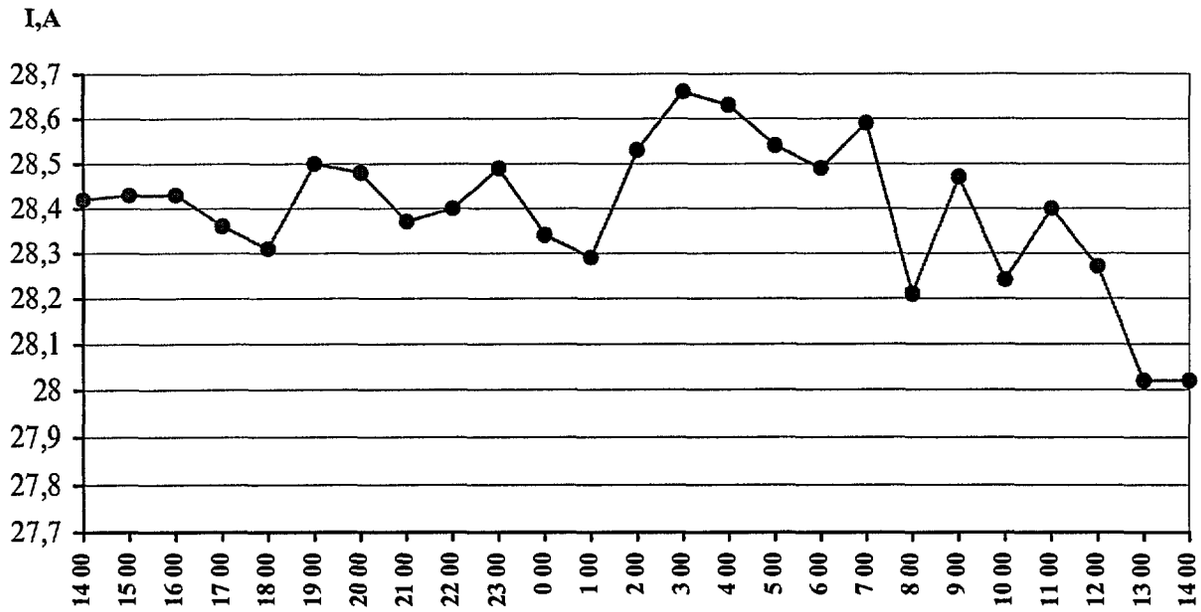
Historically, when electric motors went out of order the replacements were brought in irrespective of the nominally required capacity As the measurements at the LCh-35/11-600-68 plant on May 12, 1998 showed the N-605a pump motor capacity was used by 38%, N-1 pump electric motor by 53%, V-6156 blower drive by 51% The TK-601 compressor motor of 5790 kW was used by 58,7%

Total rated capacity of 45 electric motors of the plant was 8,285 kW Total used capacity was 4,283 kW

Measurements taken by the DRANETZ electric load analyzer testify to the low drive loads of electric drives Daily chart of electric parameter changes (voltage -U, full power -S, active power -P, reactive power - Q, power factor - cosϕ) of the H-602-13 air cooler with AYM-811006T motor of 17 kW taken on May 12 and 13, 1998 illustrate uniform character of the load with capacity use of 58 8% Low cosϕ ~ 0 51 is explained by underuse of static capacitor batteries on the 0 4kV side

Daily chart of electric parameter changes of the H-602-13 air cooler

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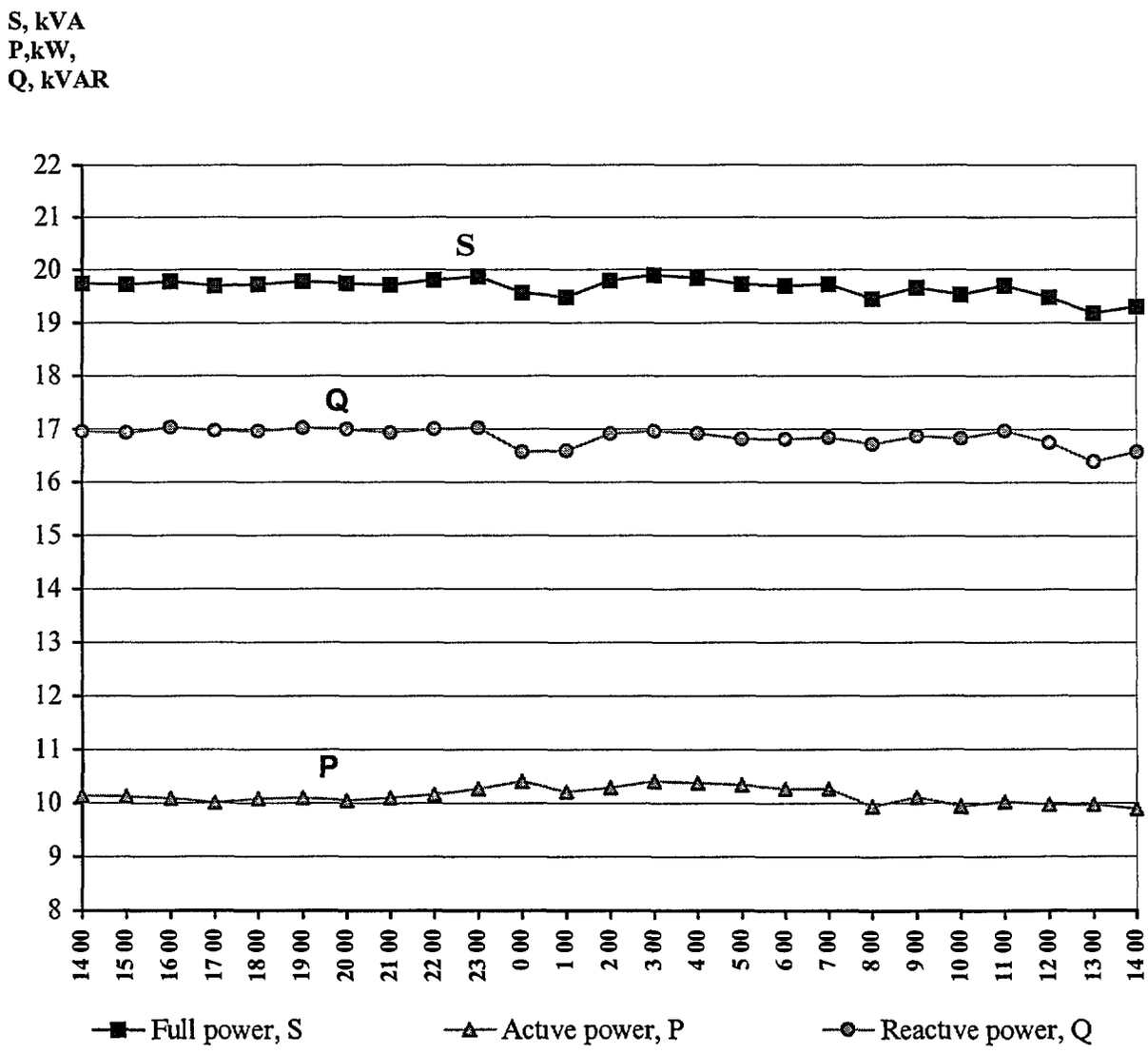
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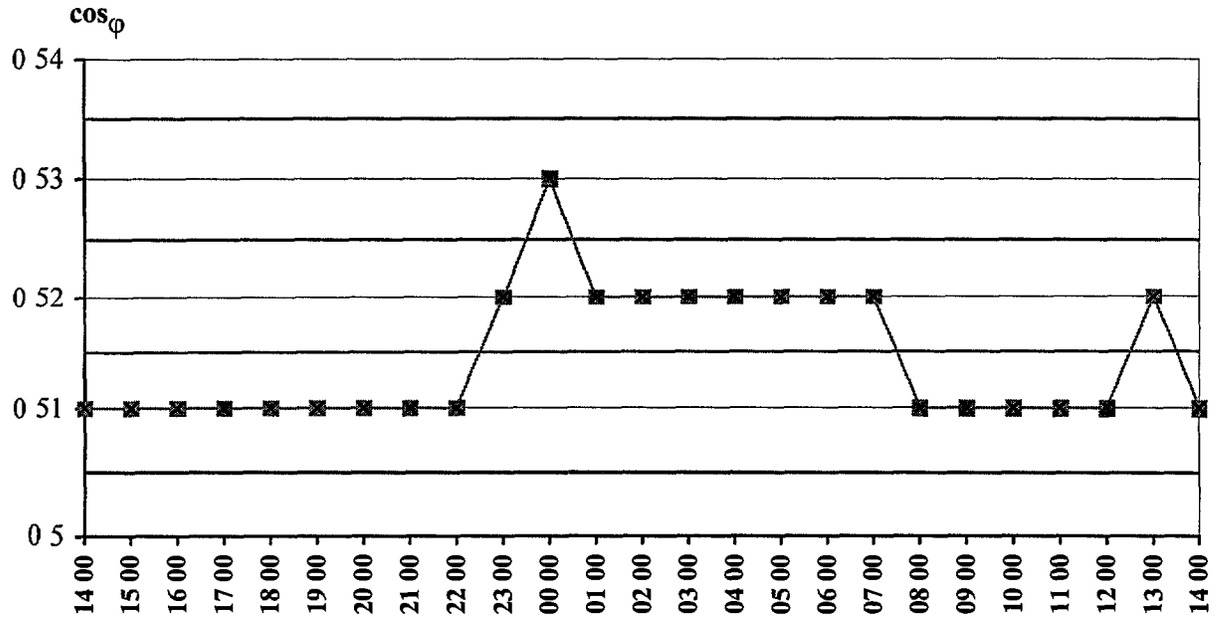


In general, the total rated capacity of 7,345 electric motors was 288,924 kW, total capacity of 6 electric generators was 167 kW Non-motor electric load is represented by 54 electric welding units of 1,275 kW total rated capacity and 45,756 lighting devices

The electric power supply system includes 241 power transformer of 307,620 kVA

This recommends to introduce operational monitoring of actual electric parameters of electric equipment by a set of portable devices The recommended proposal will ensure monitoring of the actual electric equipment loads, analyse their efficiency and schedule replacement with more efficient equipment

Implementation of this project will save at least 1% of electricity used for production purposes each year

Annual energy savings estimate

Annual electricity consumption by 1997 data is 365,466 thousand kWh
Expected reduction of electricity use by 1%,
365,466 x 0 01 = 3,654 66 (thousand kWh)

Annual cost savings estimate

At $37 per 1,000 kWh of electricity cost savings will be
3,654 66 x 37 = $135,222

Implementation cost

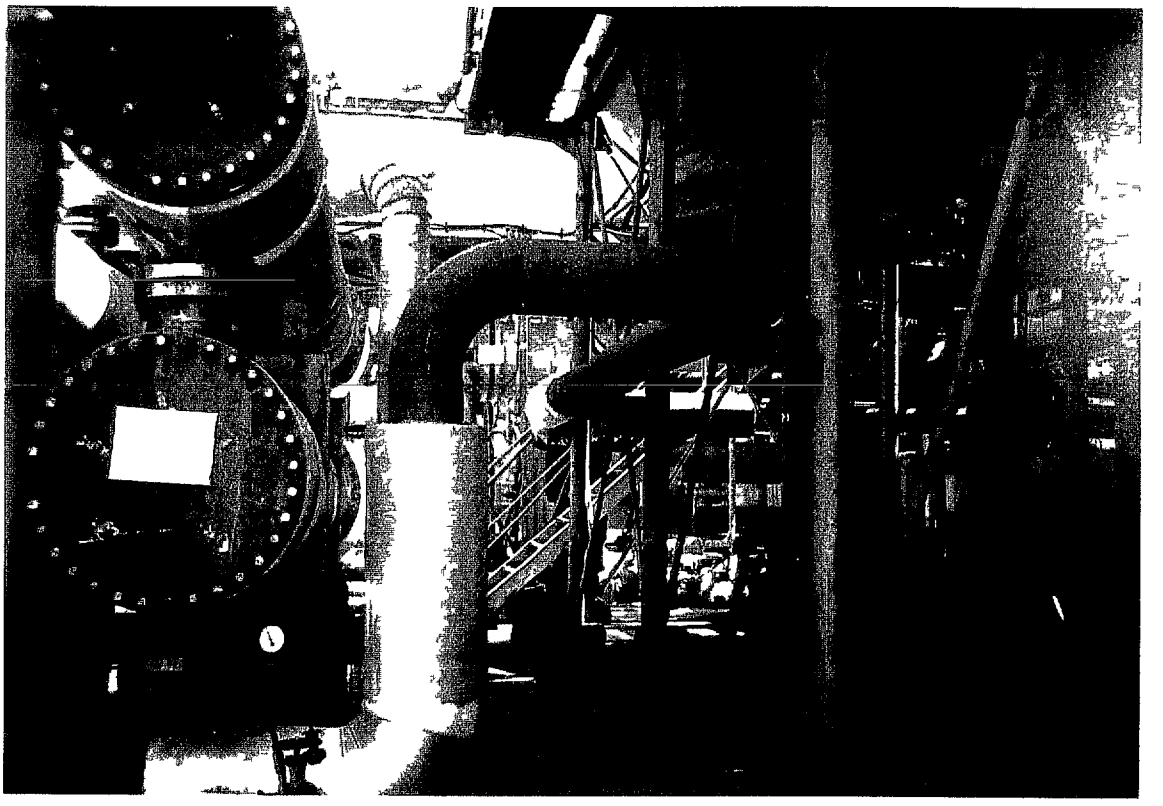
One set of portable instruments of 2000A Wattprobe, DRANETZ, Power factor meter, TIF 2300 with overheads and contingencies	$20,000
Monitoring and analysis of equipment load efficiency (assumed)	$55,000
TOTAL cost	$75,000

Simple payback

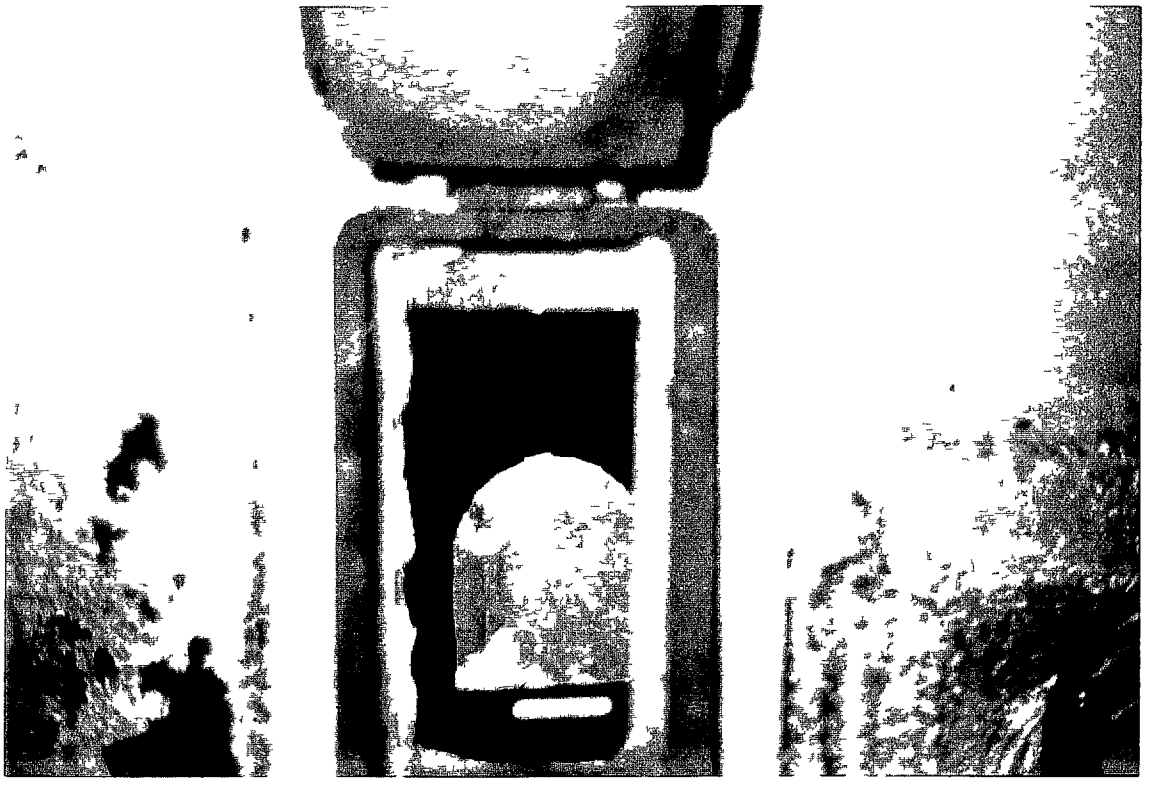
Implementation cost	$75,000
Annual cost savings	$135,222
Simple payback	

75,000/135,222 = ***0 6*** year

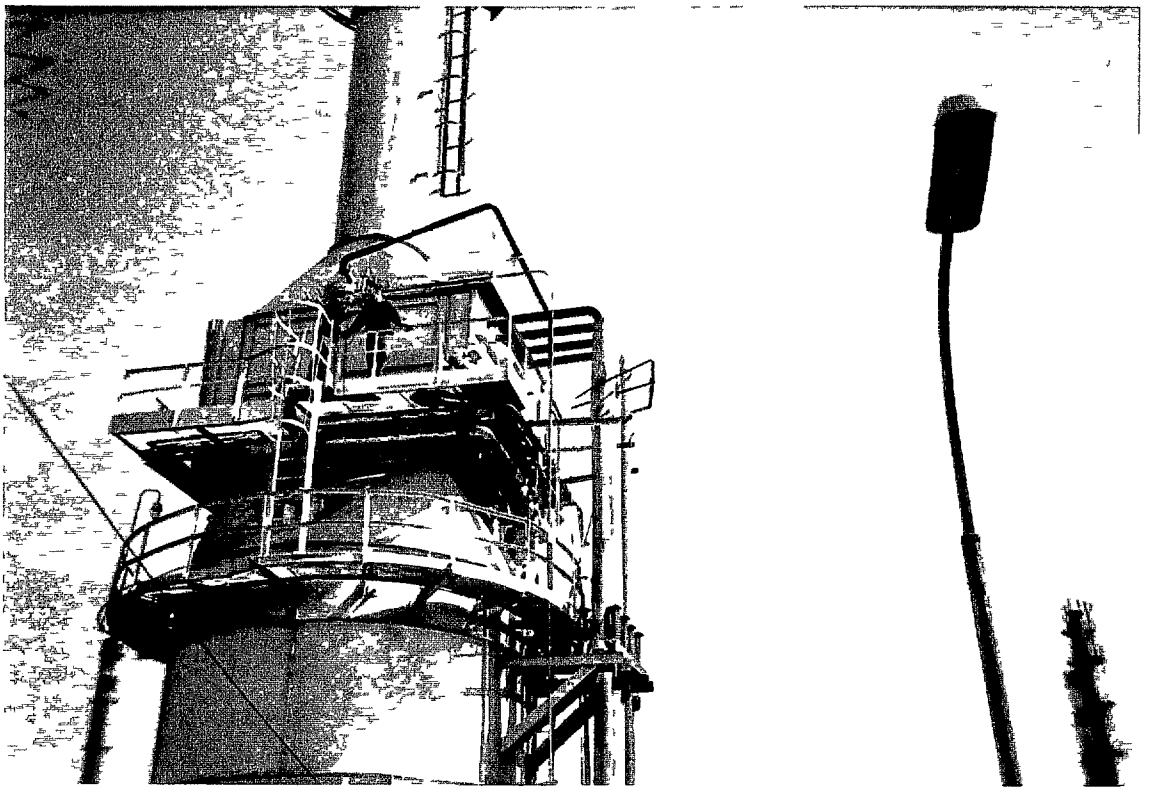
APPENDIX B PHOTOGRAPHS OF THE PLANT



Неизолированный участок трубопровода
Non-insulated piping section

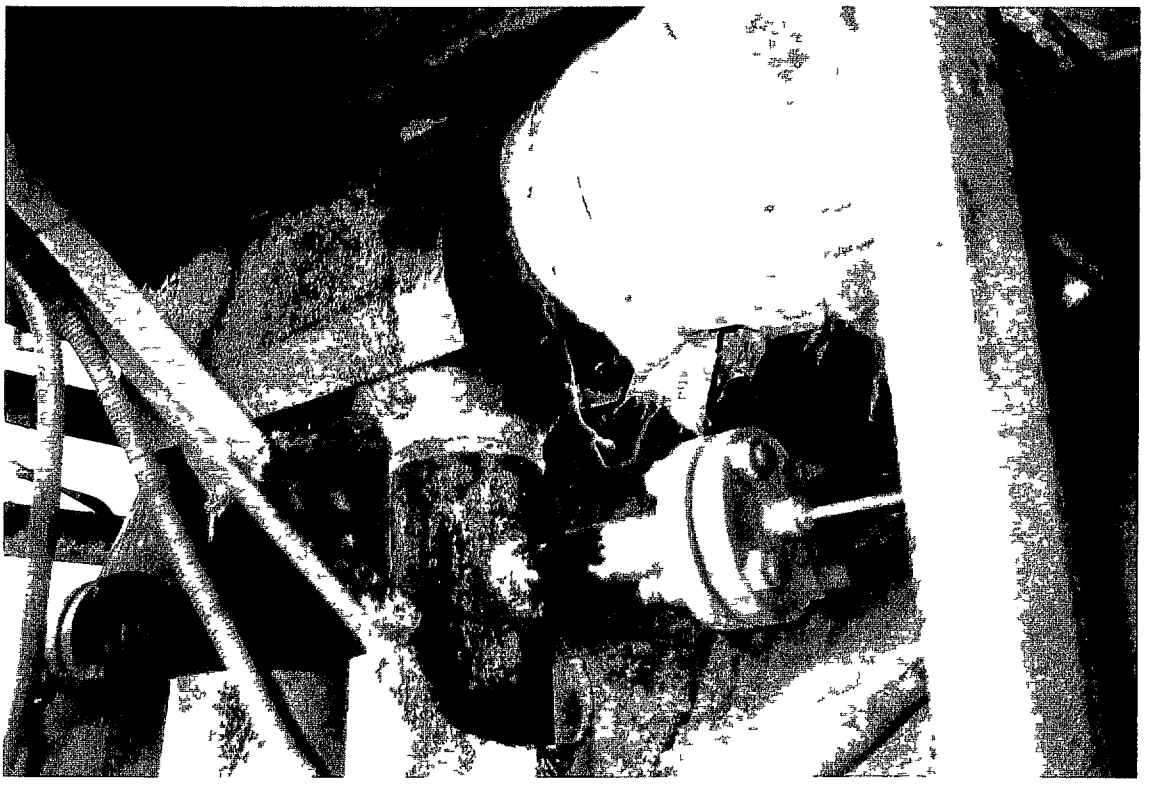


Следы химического недожега наблюдались визуально
Traces of incomplete combustion observed visually



Печь гидроочистки установки риформинга ЛЧ 35/11-600-68

Hydraulic purification oven of LCh-35/11-600-68 reforming plant

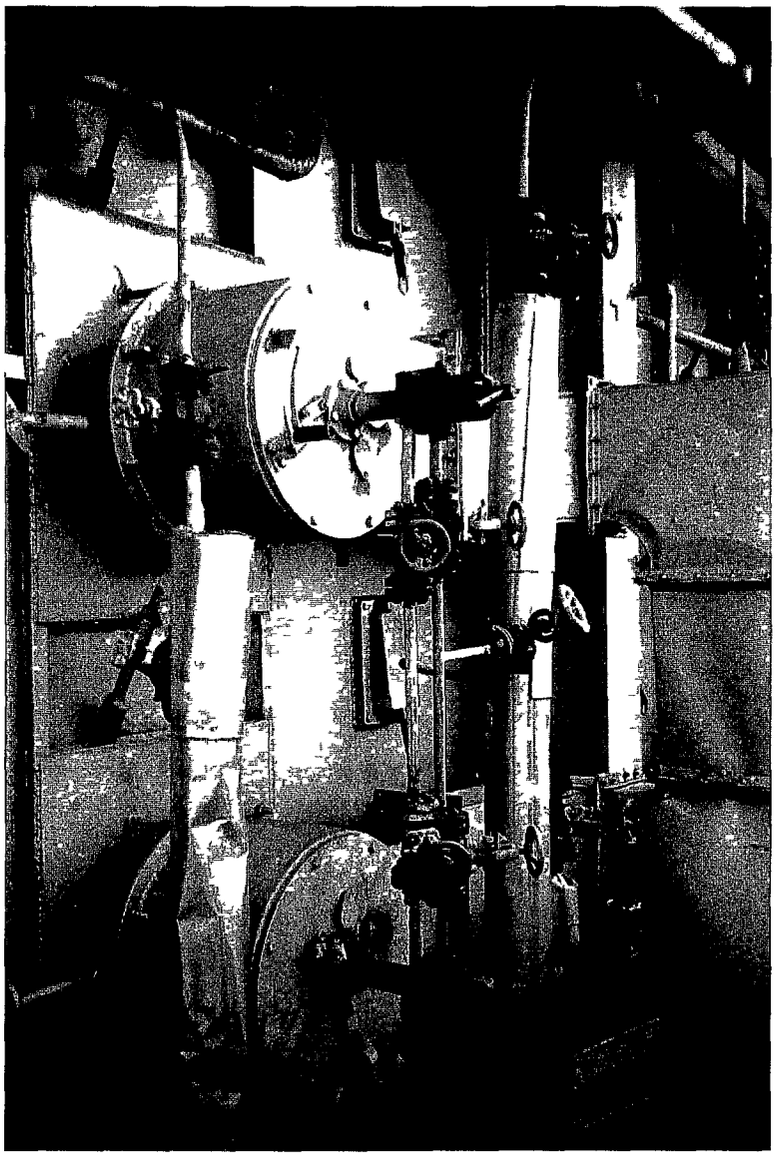


Выходной коллектор печи гидроочистки

Outlet manifold of hydraulic purificattion oven

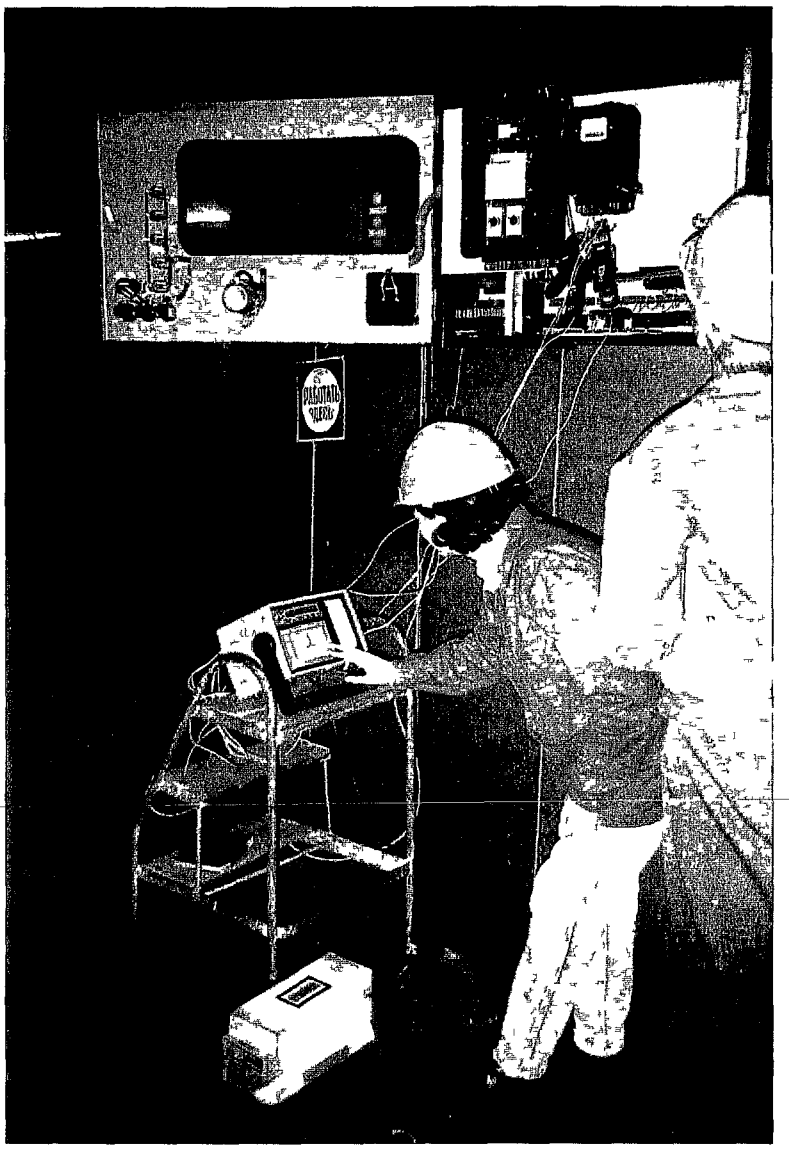
Температура на неизолированной поверхности 263 ^{0}C
Temperature of non-insulated surface is 263^{0}C

Неизолированные поверхности реакторов установки
Non-insulated surfaces of the plant reactors



Горелки технологической печи установки риформинга
ЛЧ 35/11-600-68

Burners of LCh-35/11-600-68 reforming plant oven



Измерение параметров электрических электрических величин с помощью прибора *DRANETZ*

Electric measurements by the *DRANETZ* instrument

APPENDIX C CONVERSION FACTORS

Currency rates of exchange

1 hrivnia - local currency unit
1hrivnia = US$0 54 as of December 1997

Conversion factors

Heat

1 cal = 4 187 J
1 kcal = 4 187 kJ = 3 968 BTU
1 Gcal = 4 187 x 10^3 = 4 187 GJ
1 BTU = 1055 J = 1 055 kJ = 1 055 x 10^3 MJ
1 tce (tonne of coal equivalent) = 7,000 kcal x 3 968 BTU = 27,78 x 10^6 BTU = 27,78 MBTU

Power

1 W = 3 6 x 10^3 J = 3 6 kJ
1 kW = 3 6 x 10^3 kJ = 3 6 MJ = 860 kcal
1 MW = 3 6 x 10^3 MJ = 860 kcal
1 kcal = 1 163 x 10^3
1 Gcal = 1163 kW = 1 163 MW
1 kW = 1 36 HP
1 kW = 1 34 hp

Pressure

1 kg/cm^2 = 1 atm
1 atm = 101 325 kPa = 0 1 MPa
1 bar = 10^5 Pa = 100kPa = 0 1 MPa

Length

1 mm =0 03937 in = 0 00328 ft
1 cm = 0 3937 in = 0 0328 ft
1 m = 3 937 in = 3 281 ft

Weight

1 gram = 2 2046 x 10^3 lb
1 kg = 2,2046 lb
1 t = 1000kg = 2 2046 x 10^3 ft

Area

1 cm^2 = 0 155 square in = 1 076 x 10^3 square ft
1 m^2 = 1 55 x 10^3 square in = 10 76 square ft

Volume

1 m^3 = 35 31 cu ft = 1000 l
1l = 35 31 x 10^3 cu ft
1l = 0 264 US gal

Heat content

1 kJ/kg = 0 43 BTU/lb
1 kJ/m^3 = 26 84 x 10^3 BTU/cu ft
1 MJ/m^3 = 26 84 BTU/cu ft
1 kcal/m^3 = 4,187 kJ/m^3 = 0 112 BTU/cu ft

Temperature

^{0}C = 0 56 (^{0}F-32)

ABBREVIATIONS

CIS - Commonwealth of Independent States
ECO - energy conservation opportunity
ESCO - energy service company
etc - et cetera
Hr - hrivnia
i d - id est
JSC - joint-stock company
mln - million
TACIS - Technical Assistance to CIS countries
tel - telephone
thou - thousand
US - United States
USAID - United States Agency of International Development

BTU - British thermal unit
^{0}C - degrees Celsius
cm^2 - centimeter squared
^{0}F - degrees Fahrenheit
g - gram
Gcal - gigacalory
GJ - gigajoule
h - hour
kcal - kilocalory
kg - kilogram
kgf - kilogram-force
kV - kilovolt
kV-A - kilovolt-ampere
kW - kilowatt
kW h - kilowatt hour
Lm - lumen
m - meter
m^2 - meter squared
m^3 - meter cubed
min - minute
MJ - megajoule
mm H_2O - millimeters of the water column
MW - megawatt
t - tonne
tce - tonne of coal equivalent
t/h - tonnes per hour
W - watt

APPENDIX D ABBREVIATIONS

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