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

REPORT

ON ENERGY AUDIT

AT OPEN JOINT-STOCK COMPANY

"MARKOKHIM"

City of Mariupol, Donetsk Region, UKRAINE

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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 (USAID) This project, referred to as Delivery Order #30, consisted of performing twenty four industrial energy audits throughout Ukraine The purpose of this project was to develop Ukrainian energy service company (ESCO) capabilities To accomplish this task Burns and Roe Enterprises (the prime 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

These audits consisted of a one week site visit by a team of engineers, normally two or three individuals Since these industries are generally very large, a one week site visit is not sufficient to adequately audit the entire facility The site visit was restricted to one week due to other project considerations However, the engineering staff were trained to identify improvements that would be representative of the entire plant In many cases it was necessary to focus the auditing efforts on one system or only on a portion of the plant Therefore 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

The current report describes the findings of the energy efficiency audit performed by Burns and Roe at the "Markokhim" plant in the city of Mariupol Presently the JSC "Markokhim" produces 2,126,900 tons of coke with 6% moisture content including metallurgical coke, coke breeze, bean coke Total production output in 1997 was $57,430 thousand The products meet the highest quality standards The share of energy cost in total production costs is 16%

Presently JSC "MARKOKHIM" has at its disposal large production area and capacities Presently the following production units are operated coking unit, trapping units, coal preparation unit, desulphurisation unit, sodium thiocyanate unit, auxiliary units

The number of personnel is 2,246

The "Markokhim" products are in demand at the domestic market and constitute 14% of total Ukrainian output

The tasks of the energy audit were as follows

- to conduct informal training in the energy management practices
- to create an institutional awareness of energy management
- to recommend specific steps in order to improve energy efficiency including management actions and low-cost/no-cost opportunities
- to recommend of medium-cost and capital investment actions reflecting large-scale energy conservation opportunities

The energy audit team made up of three Ukrainian specialists performed the energy audit March 16 through 21, 1998 In compliance with the objectives of the Project the energy audit team prepared the following preliminary report

1 2 Brief survey

The JSC "Markokhim" is a rather energy-intensive enterprise Consumption of energy resources in 1997 was as follows

- electric power - 98,529 5 thousand kWh,
- blast furnace gas - 1,050,100 thousand m^3

The energy audit team has discovered many attractive opportunities of improving energy efficiency at the current energy and fuel prices Presently the energy efficiency improvements are cost effective though difficult to implement due to high interest rate for bank credit and general economic challenges connected with the bartering settlement system and mutual non-payments

The "Markokhim" plant is considered fairly successful by Ukrainian standards but it has to use bartering as well to pay for the blast furnace gas end electric power

The plant staff approved procurement of portable combustion analyzers and other measuring instruments included in the audit team equipment

Energy efficiency is deteriorating due to mismatching of design capacity and current electric power use Electric power distribution system capacity exceeds the needs by 280%

Since the primary fuel is coking gas of in-plant generation and blast-furnace gas of the "Azovstal" steel works, implementation of energy conservation opportunities requires consideration of production specifics and mutual settlement system of the steel works

The "AzovStal" has debts for coke and coking gas to the "Markokhim" The "Markokhim" is ready to pay ESCOs with the "AzovStal" promissory notes which can by sold by commercial institutions at a discount The "AzovStal" debt settlement will require debt discounting at 20-30% that should be taken into account in ECO economic calculation

The proposal envisages further implementation of suggested long-term measures by the plant itself together with private Ukrainian energy servicing companies One of the objectives of an ESCO is acquisition of long-term (2-3 years) financing to implement energy conservation projects

One of the team members - Mr M Tarnovsky found several opportunities of space heating improvements outside the USAID project The purpose of the future contract will carry out implementation of ECOs designated "turnkey" in this report

1 3 Recommendations

The following table is a summary of energy conservation opportunities at the facility These opportunities are recommended for implementation as soon as possible The plant management is encouraged to consider implementing other items as soon 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

Typically an 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 that the plant manager should be aware of energy conservation potential

The major part of the proposed measures can be implemented with minor adjustments at other industrial plants i e they are the standard solution of a common problem

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

- electric power by - 25,397,000 kWh (26%)
- blast-furnace gas by - by 251,105,000 m3 (20%)
- thermal energy - by 2,027 Gcal (16%),

and will result additionally in reduction of pollutant emissions

1 Solid particles - 111 7 tons/year
2 Sulfur dioxide - 251 4 tons/year
3 Carbon oxide - 298 3 tons/year
4 Nitrogen oxide - 402 1 tons/year

The recommendations listed in Table 1 will improve energy efficiency of the plant, cut costs and improve the competitiveness of the plant The Table lists several energy conservation opportunities with short payback periods

Capital investments of $1,803,200 into the improvement of energy efficiency (ECO#1 through ECO#7) will result in annual savings of $1,774,660 later

List of Energy Conservation Opportunities (ECO)

Table No1

ECO #	Description	Electricity, 1,000 kWh	Blast-furnace gas 1,000 m^3	Annual savings, US$	Project cost, US$	Payback, years
1	**Institution of energy management** This ECO will ensure energy use management and reduce energy costs by 10%	4,900	52,505	620 400	310 200	0 5
2	**Energy metering system upgrading** This ECO will monitor on-line energy consumption, prevent excessive energy use and improve energy efficiency at the enterprise	1,960	21,000	243,000	500 000	2
3	**Use of variable speed drives at the dust-free coke-pushing fans** With periodical operation of fans there are energy losses during idling With variable speed drive power consumption from frequency converter will be lost only in the drive unit i e 10-15% of the nominal capacity	876		35 000	81,000	2 3
4	**Use of steam turbines for co-generation of electric power at the boiler house** This ECO will reduce the purchases of power from utilities	17,520		700,000	850 000	1 2
5	**Improvement of thermal and hydraulic conditions of thermal supply networks** This ECO is required for reduction of thermal energy use for space heating and electricity consumption by water circulating pumps	141		148,000	39 000	0,3

6	**Monitoring of combustion modes in gas consuming units** This ECO will ensure efficient fuel combustion in steam boilers and oil-heating oven with optimum fuel-to-air ratio and periodical checks and adjustments		174,300	9,760	7,000	0 7
7	**Conversion of the works boiler house to uniform type of fuel - coke-oven gas** This ECO will improve boiler efficiency and operation time between overhauls		3,300	18,500	16,000	0 9
	TOTAL	25,397	251,105	1,774,600	1,803 200	1

2 0 GENERAL BACKGROUND

Chairman of the board Oleg N Litvinov
Chief power manager Vladimir V Dvornik
Phone (0629) 33-93-30
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Naberezhnaya str Mariupol 341005

2 1 Enterprise history

Open-type joint-stock company "MARKOKHIM", previously known as the Mariupol coke and chemical works was commissioned in 1935 (1st complement) comprising 4 coke-oven batteries No 1 through 4, chemical and auxiliary units In 1951 through 1955 the 2nd complement of the works started operation comprising four more coke-oven batteries No 5 through 8

In 1984 the first phase of the works renovation started with the shut-down of two batteries of the first complement and with the construction of one heavy-duty battery No 1-bis of 910,000 tonnes of 6% moisture content stock coke capacity (which was commissioned in December 1989)

Since 1990 the second phase of renovation has been initiated including construction of No 2-bis coke-oven battery and rearrangement of No 3 battery

Currently the following units are operating
- coking unit of 5 coke-oven batteries (No 1 and 5 through 8)
- gas trapping units No 1 and 2
- coal preparation unit
- desulphurisation unit
- sodium thiocyanate unit
- auxiliary units

The age of coke ovens of No5-8 batteries is over 40 years but they are kept up normal operational condition

Primary energy consumers
- gas trapping units, desulphurisation unit,
- coal preparation unit, coking unit,
- boiler house

Presently JSC "MARKOKHIM" has at its disposal large production areas and capacities

2 2 Recent production

Currently the works produce 2,126,900 tons of 6%-moisture content coke including metallurgical coke, coke breeze, bean coke

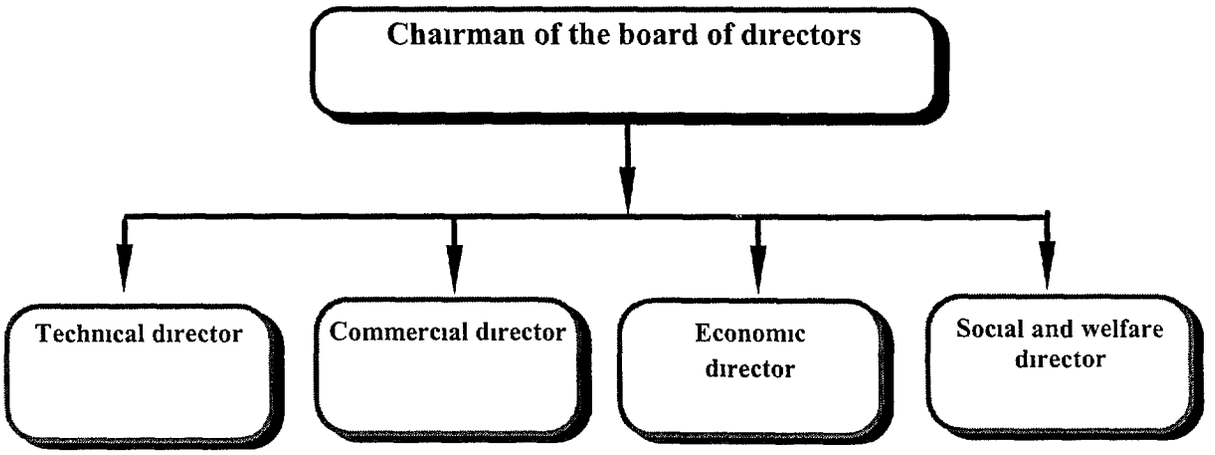
Below is the table reflecting the production output of the "MARKOKHIM" works in 1997

#	Production items	Unit of measure	Annual output
1	Crude benzene	tonnes	22,500
2	Coal tar	tonnes	98 000
3	Industrial sulphur	tonnes	4 500
4	Sodium thiocyanate	tonnes/month	~ 60
5	Ammonia sulphate	tonnes	2,300
6	Coke-oven gas	1,000 cu meters	901,626

2 3 Number of employees

The production process of generation and purification of coke-oven gas is continuous entailing three-shift operation of primary production units
The number of industrial personnel at the works is 2,246

Organisational management structure of JSC "MARKOKHIM"



2 4 Number of similar enterprises in Ukraine

The Mariupol coke and chemical works is one of the largest enterprises in Ukraine
Presently there are 14 works in the country making similar products

The output of the JSC "MARKOKHIM" amounts to 14% of the total domestic coke production

2 5 Significance of this sector for the national economy

The products of the Mariupol coke and chemical works are in demand at the domestic market and abroad

The primary consumers of the of the works' products are the following

• blast furnace coke	-"AzovStal" steel works
• coke-oven gas	-"AZOVSTAL" steel works
• coal tar	- coke and chemical works
• benzene	- exports to the CIS countries
• industrial sulphur	- Eastern ore concentration complex (Zheltiye Vody)
• ammonia sulphate	- exports

The quality of the production complies with the existing state standards and regulations

3 0 CURRENT STATUS OF PRODUCTION

3 1 Total production output of the works

The analysis of the total output over 1995 through 1997

#	Year	Unit of measure	Production at comparable prices
1	1995	thousands of hrivnas	112,544
2	1996	thousands of hrivnas	102,878
3	1997	thousands of hrivnas	106,248

3 2 Productivity of labor 1997 vs 1996

The analysis of labor productivity over 1996 and 1997

#	Year	Unit of measure	Productivity per employee
1	1996	thousands of hrivnas	152
2	1997	thousands of hrivnas	173

As seen from above labor productivity in 1997 grew by 13 4%

3 3 Prospects of development

The present economic situation is characterized by the production slump as compared to 1995 This is explained by the demand for the main product of the "AZOVSTAL" works which in its turn supplies the JSC "MARKOKHIM" with blast furnace gas Hence, the settlements between the two technologically linked enterprises are made by mutual clearing

Today all profit received from production of industrial sulphur, benzene and other by-products of coke-oven gas purification goes to the production line renovation The result of construction of No 1-bis heavy-duty battery was considerable reduction of pollutant emission into the atmosphere

3 4 Exports vs Domestic sales

The products of the Mariupol coke and chemical works are sold primarily at the domestic market Exports amount to 5-6% of the sales

4 0 FINANCIAL STATUS OF THE ENTERPRISE

4 1 Currency vs Barter

There exist barter settlements with the customers due to the lack of currency with them This led to the fact that monetary operations make up 45% of total sales Bartering is carried out by JSC "MARKOKHIM" with suppliers of raw materials, auxiliary production materials

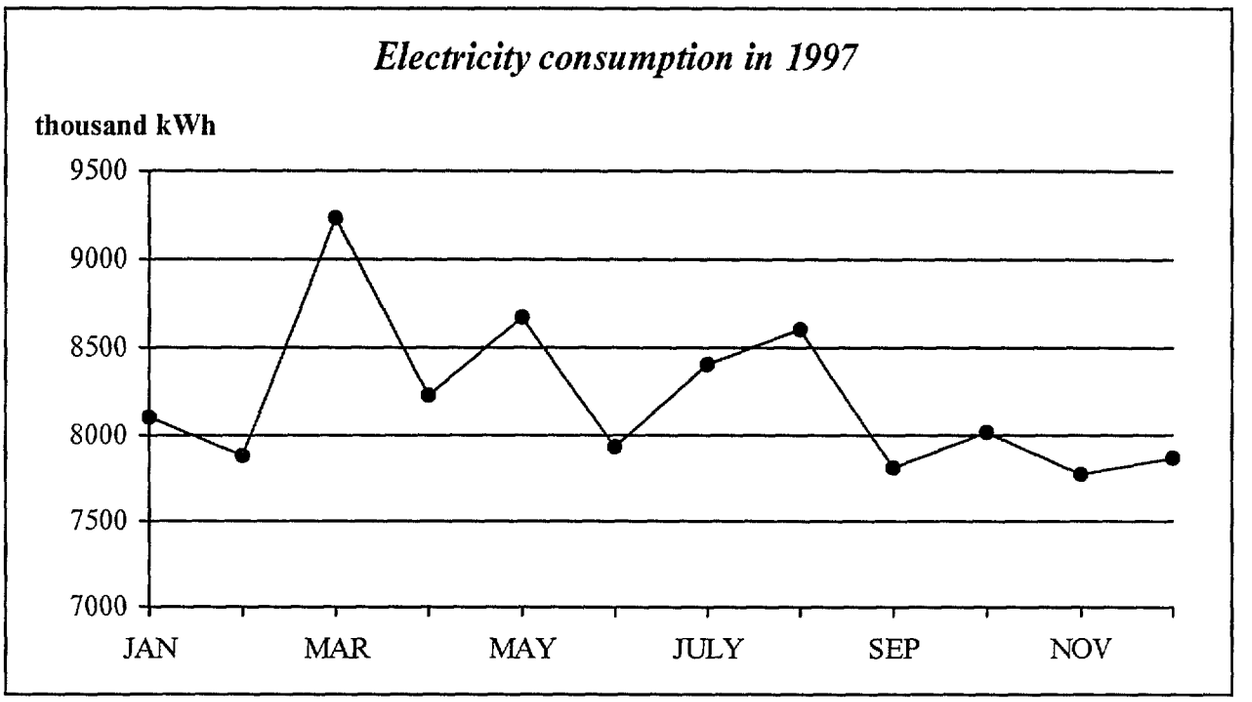
4 2 Viability of enterprise

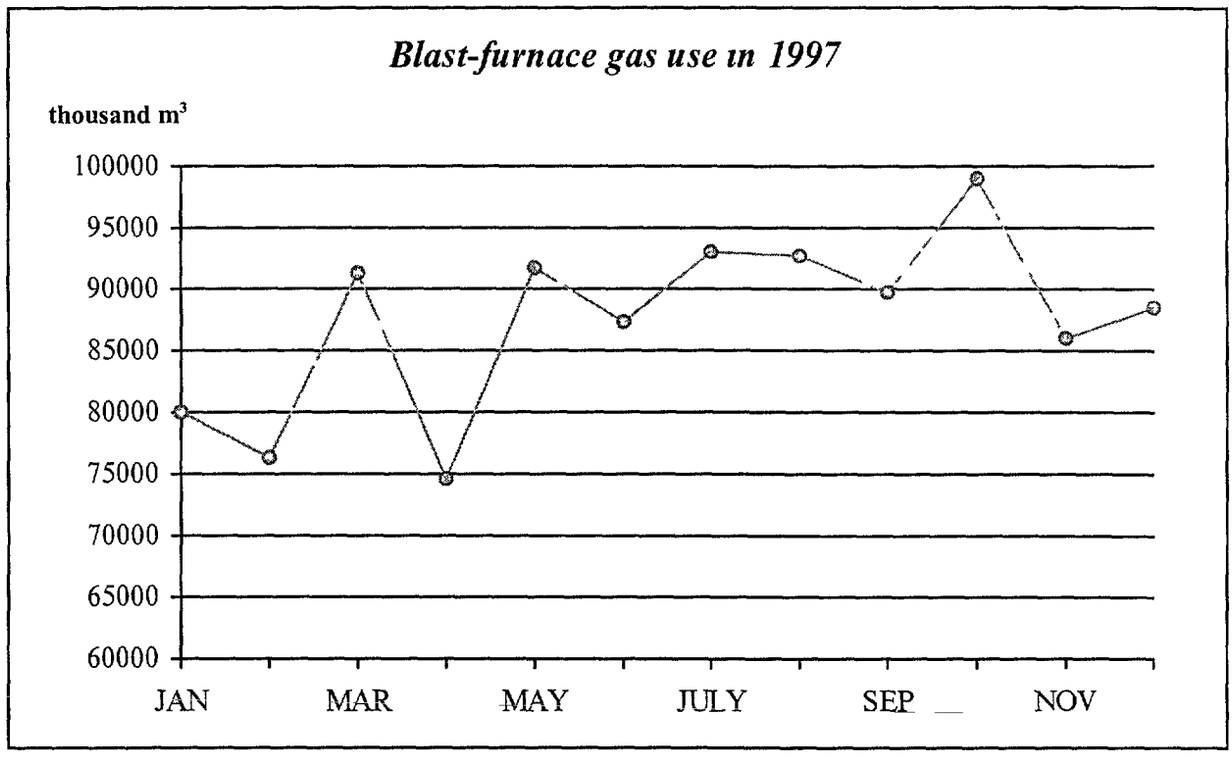
Despite a rather complicated economic situation in the country the enterprise has a fairly high rating This implies solvency and credit standing with slight deviations from the standard Debts receivable and accounts payable are at the same level Production profitability in 1997 was 27%

5 0 ANNUAL ENERGY CONSUMPTION AND ENERGY COSTS

5 1 Annual energy consumption in 1997

Total annual electricity consumption in 1997 amounted to 98529 5 thousand kWh
Breakdown of electricity consumption by months characterizing the workload on the equipment and stability of the plant operation can be seen on the chart below





As seen from the charts the plant operation was unstable which lead to the fall in coke and coke-oven gas production In its turn this leads to the increase of low-calorie blast-furnace-gas consumption

5 2 Current energy and fuel prices

Electricity

The works pay its electricity bills by two-part tariffs
1 Negotiated demand
2 Amount of consumed electricity by electric meter readings

The contract for electric power supply was concluded with the JSC "AzovStal" at the following prices

• 1 kW of negotiated demand	3 3$
• 1 kWh of consumed electricity	0 03$
Negotiated demand	14 MW
Payment for negotiated demand	14,000 × 3 3 = 46,200 ($)
Average monthly electricity consumption	8,300,000 kWh
Payment for actual electricity consumption	8,300,000 × 0 03 = 249,000 ($)
Total payments	46,200 + 249,000 = 295,200 ($)
Actual price for 1 kWh	295,200 / 8,300,000 = 0 036 ($)

The main distribution substation is located on the "Azovstal" territory and electricity bills are paid by the substation meter readings

Fuel

For fuel the works use blast-furnace gas from JSC "AzovStal" and coke-oven gas of own production Settlements for energy are made by mutual clearing between the "Markokhim" and "AzovStal"

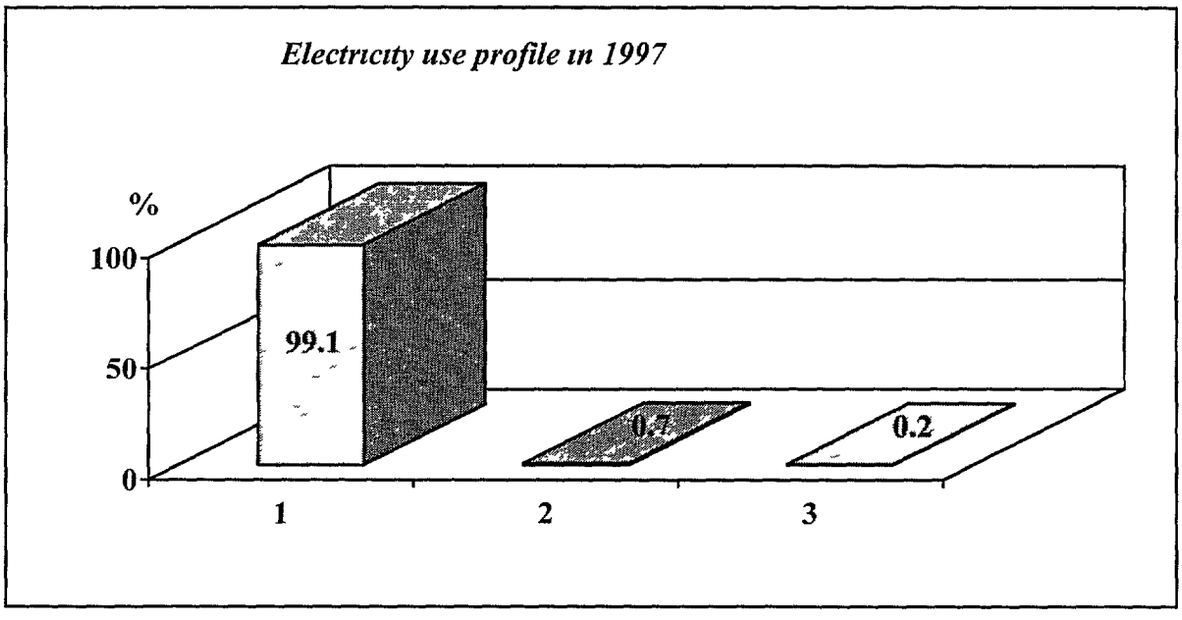
The cost of 1000 m^3 of blast-furnace gas – 5 6$
For calculations we used the cost of coke-oven gas per 1000 m^3 of 10$ by the plant data

5 3 Energy use and cost structure

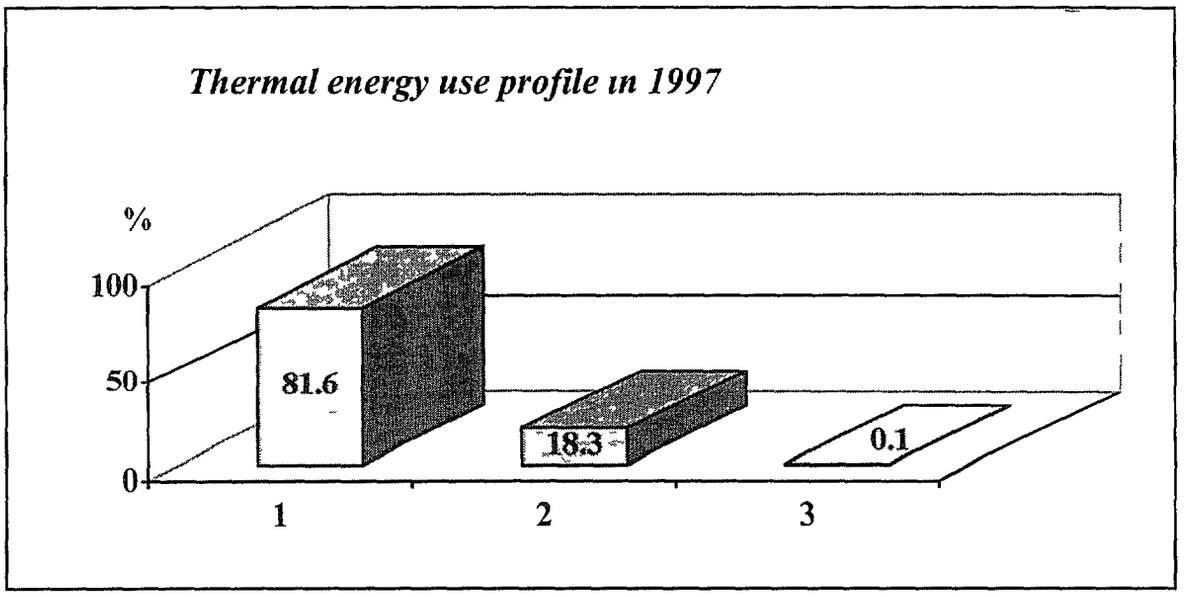
Energy use and cost structure

#	Type of energy	Unit	Consumption	Cost, US$1,000
1	Electricity	MWh	98,259 5	3,700
2	Blast-furnace gas	m^3	1,050,100	5,500
	TOTAL			9,200

5 4 Energy use profile



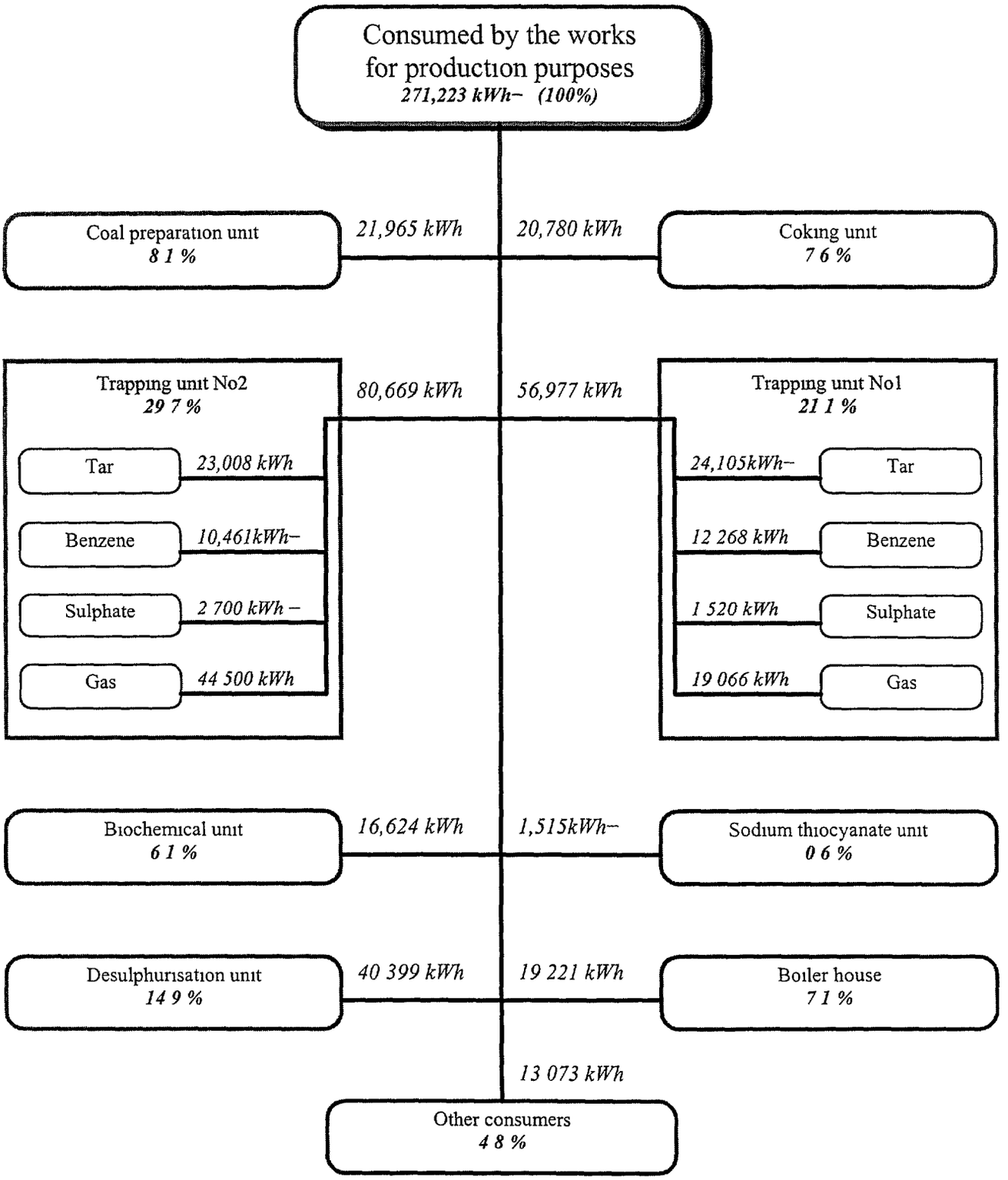
#	Electricity consumption	thousand kWh	%
1	Production use	97,655	99 1
2	General use	642	0 7
3	Domestic use	232	0 2
	TOTAL	98,529	100



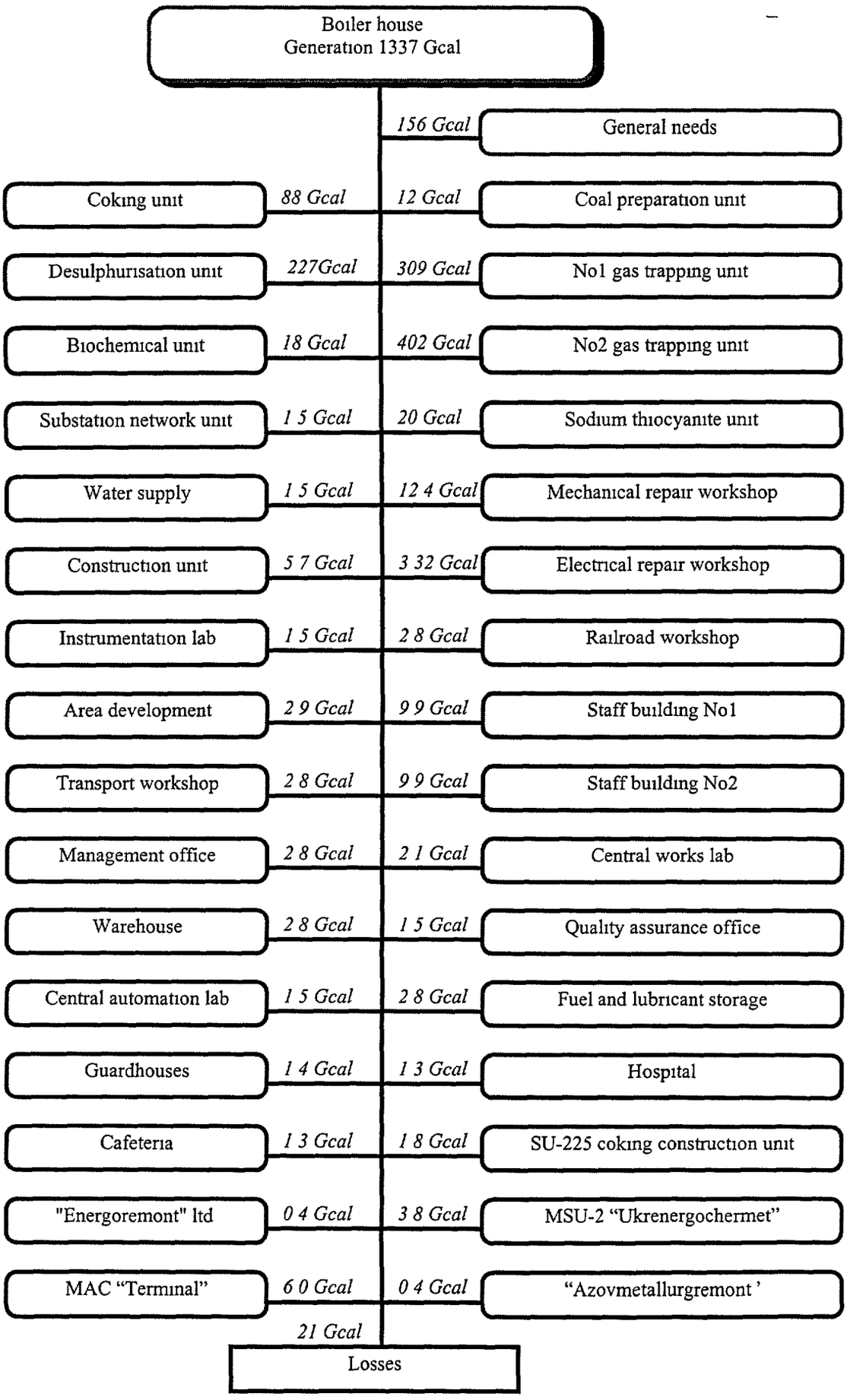
#	Thermal energy consumption	GCal	%
1	Production use	402,255	81 6
2	General works use	90,099	18 3
3	Domestic use	559	0 1
	TOTAL	492,913	100

Coke-oven gas production and consumption balance - for February 1998

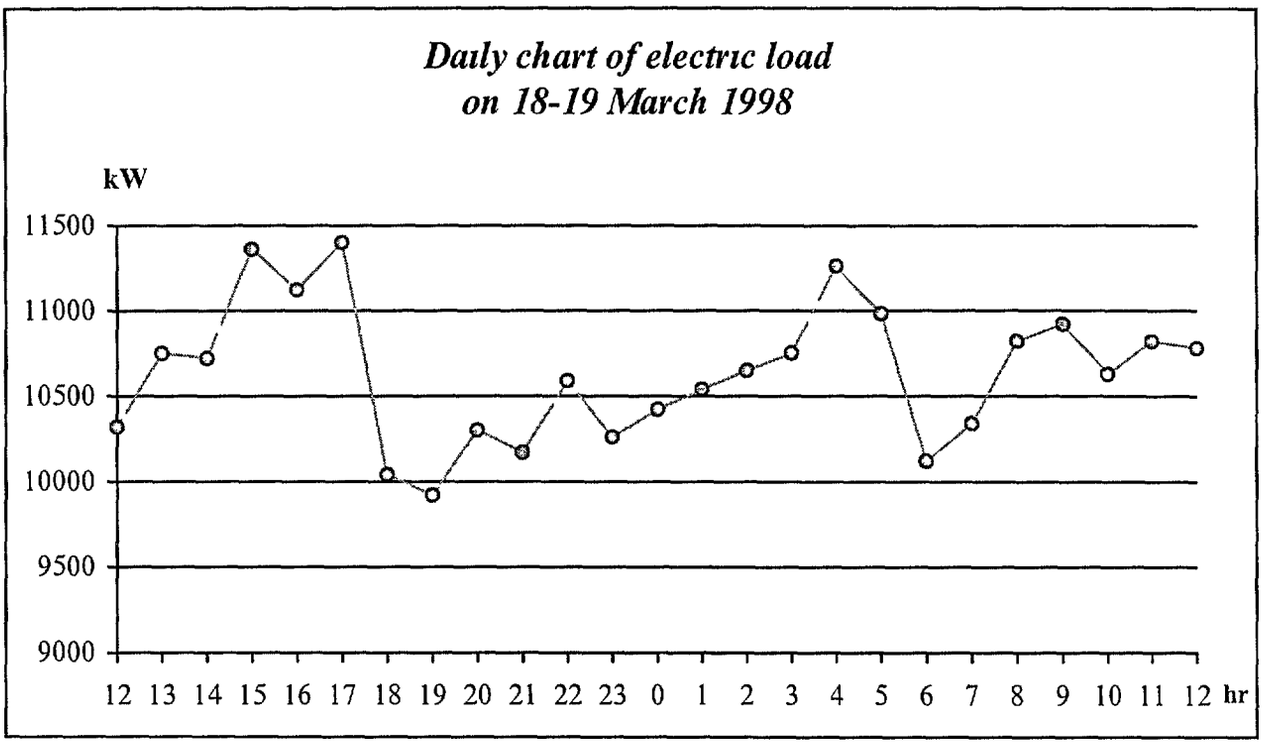
Electricity consumption balance on 03.02.1998

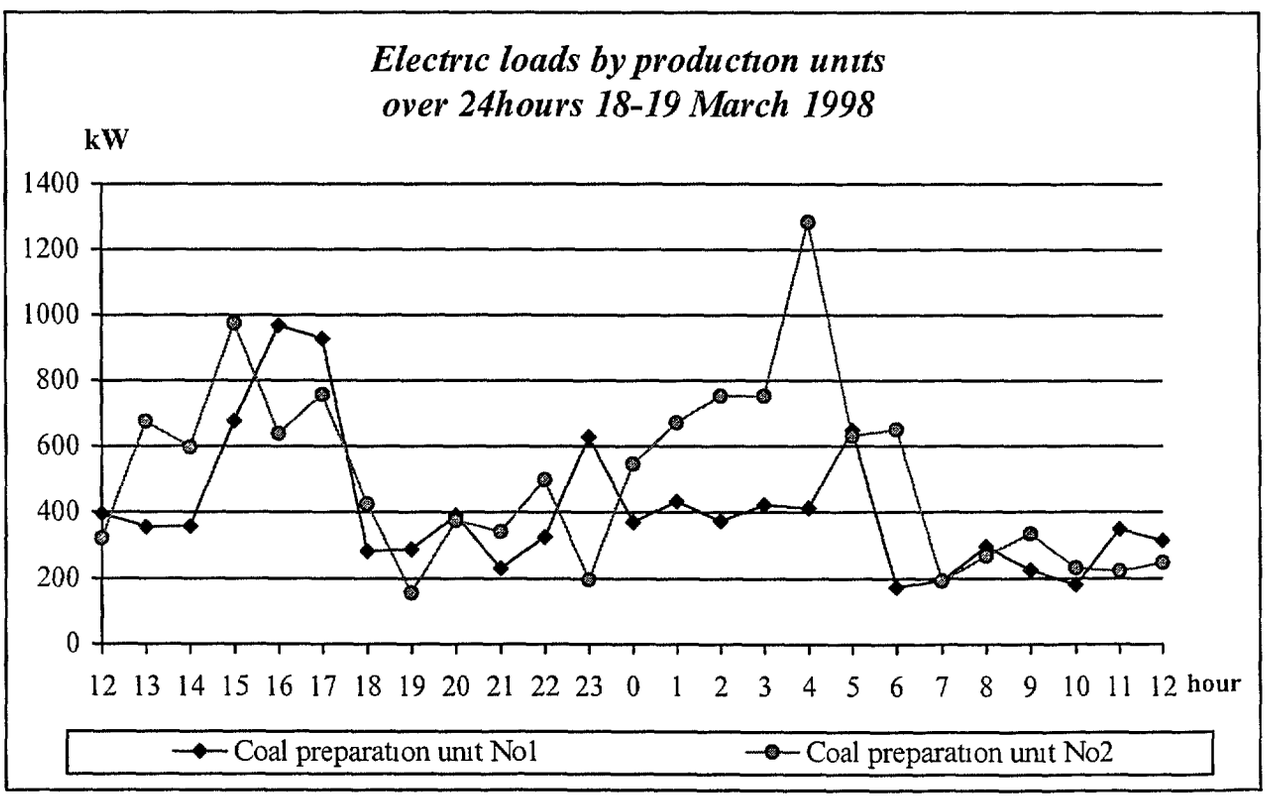


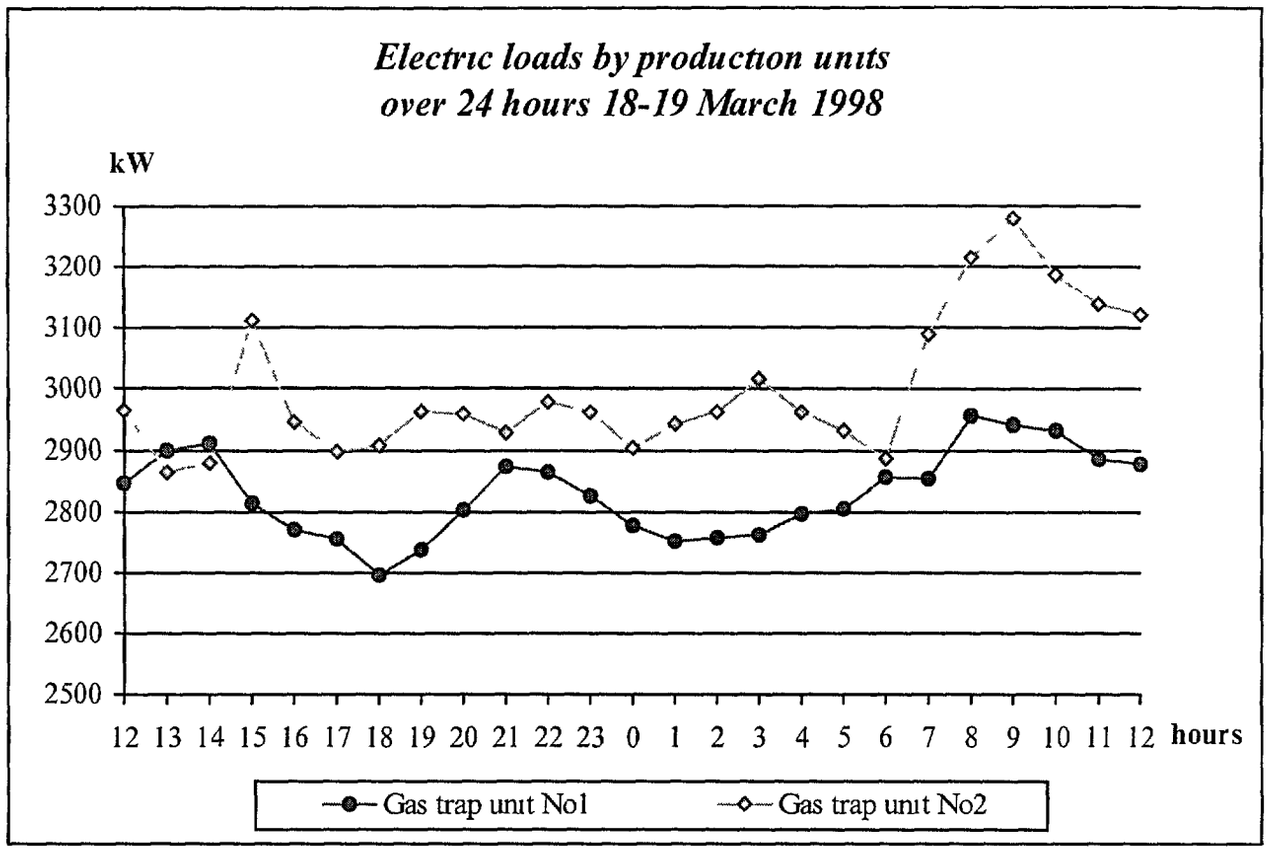
Thermal energy consumption balance on 03.02.1998

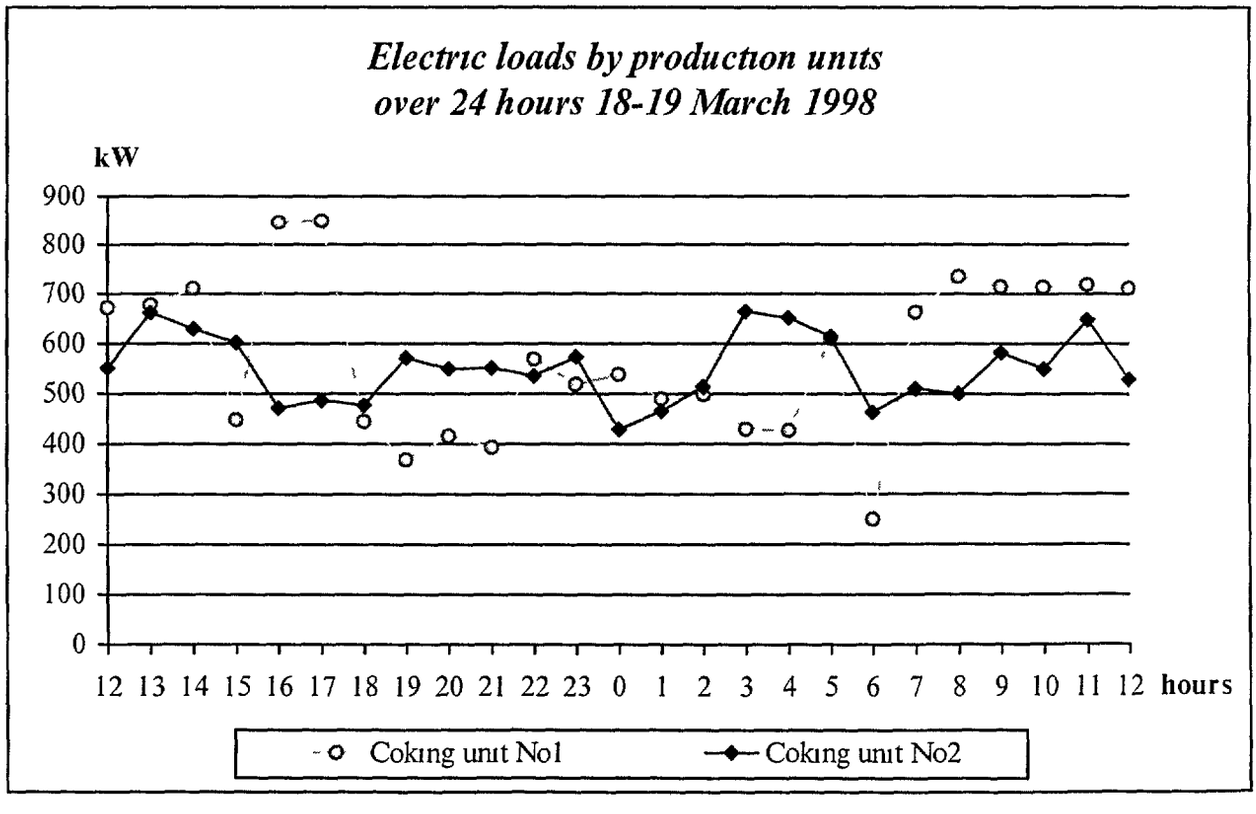


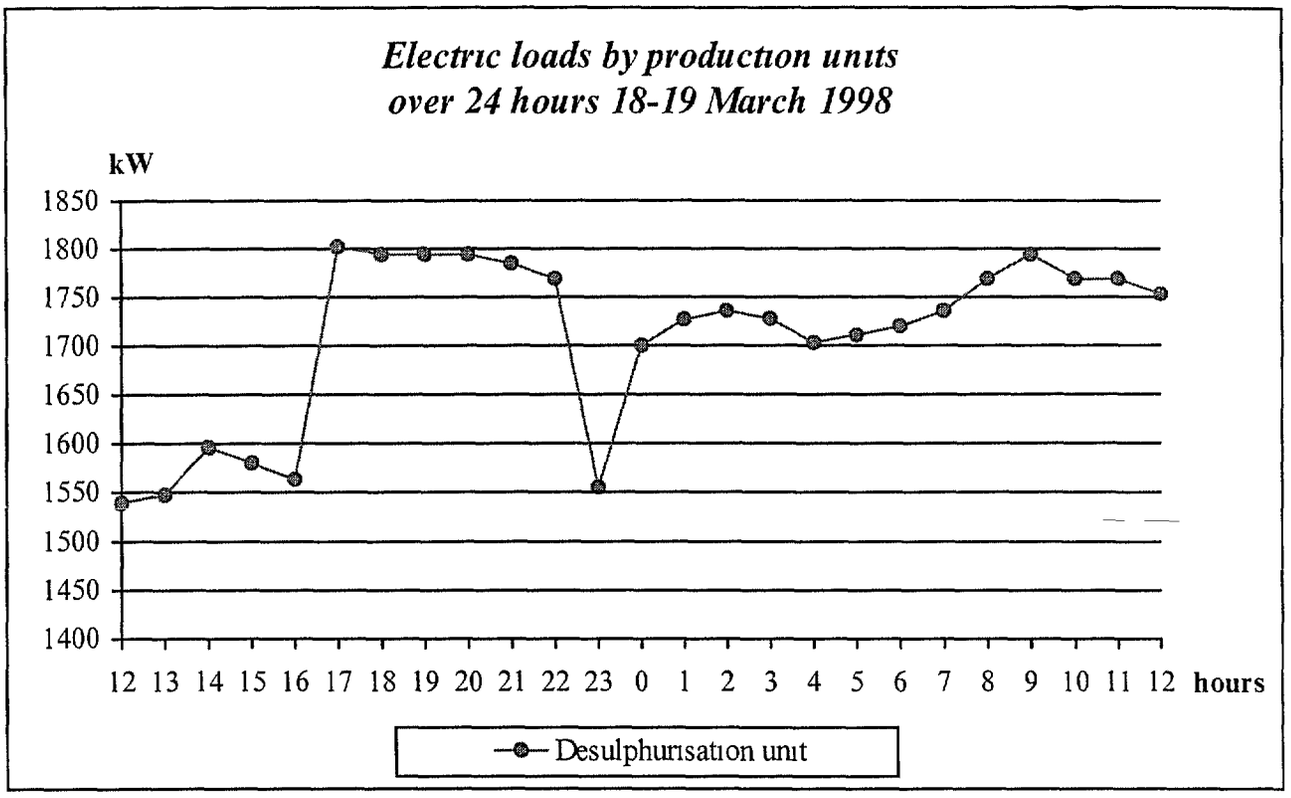
The above balances of thermal energy and coke-oven gas consumption are made by the works' data and are subject to further review while instituting energy management Below are the charts of electric loads at the entire works and separate production units at 1 hour intervals within the period from 12^{00} of 18 March to 12^{00} of 19 March 1998 received on the basis of the data of the works power supply services

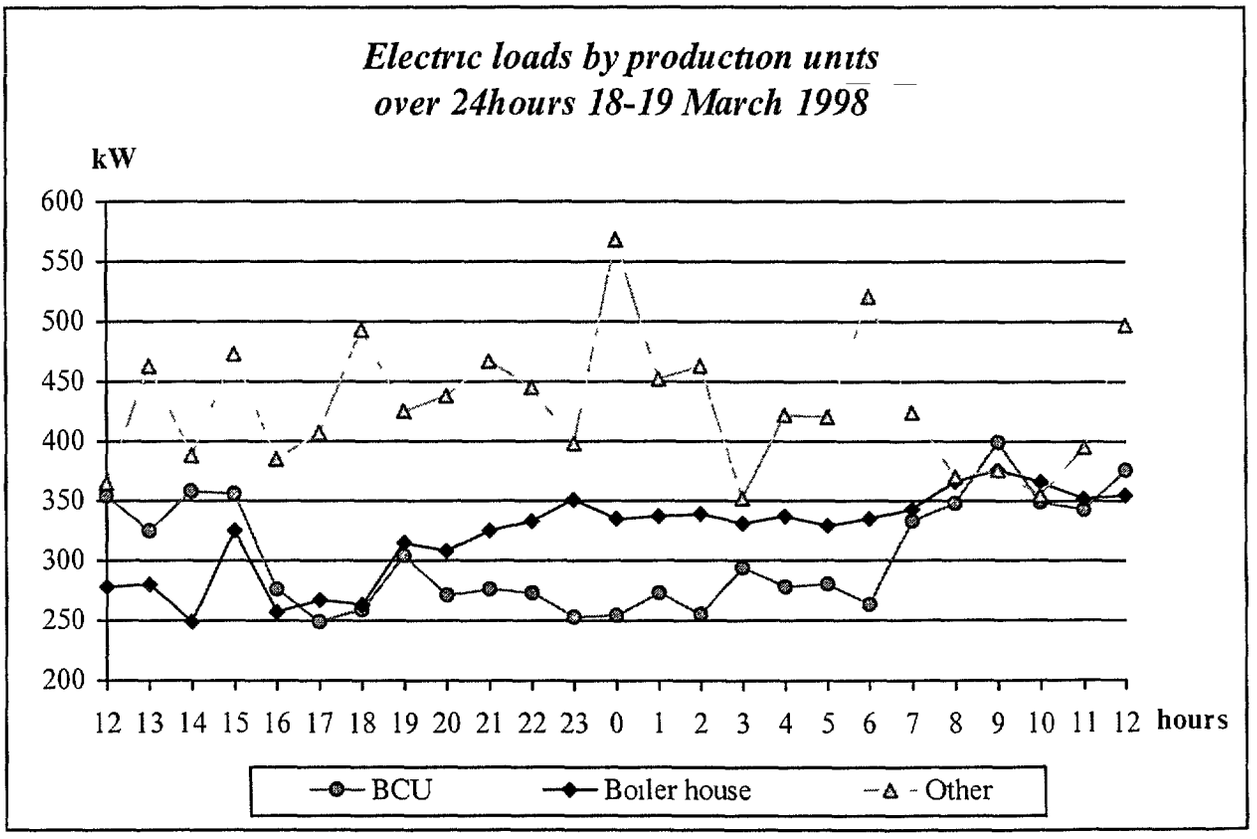





Electric loads by production units
over 24 hours 18-19 March 1998
kW
3300
3200
3100
3000
2900
2800
2700
2600
2500
12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 hours
Gas trap unit No1
Gas trap unit No2


Electric loads by production units
over 24 hours 18-19 March 1998
kW
900
800
700
600
500
400
300
200
100
0
12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 hours
Coking unit No1
Coking unit No2





Comparative analysis of electric power consumption shows non-rhythmical operation of separate production units which means that there are opportunities of reducing

electricity consumption Lack of data on production output and coke-oven battery loads within this period precludes acquisition of full picture in regard to efficiency of electric load on the equipment

Institution of energy management described in Appendix A (ECO #1) will allow to obtain a realistic picture of production unit efficiency and work out specific measures for reduction of electricity consumption Energy audits at this enterprise should be continued

6.0 PREVIOUS ENERGY IMPROVEMENTS

The energy audit team was furnished with the 1997 energy conservation program of the Mariupol coking and chemical works drafted by the power management staff Fifty per cent of of measures reflect technical maintenance and overhaul of the equipment which do not correspond to energy conservation

The measures of fuel and energy use reduction for 1997 planned by the "MARKOKHIM" staff which seem to be attractive are given below

1 Introduction of variable speed drives at the crashers of the coal preparation unit, at water supply pumps, phenol- and waste-water pumps (electric power supply unit) Savings estimate - 1,100 thousand kWh/$41,600 per year
2 Improvement of use of compressed air oxygen for treatment solution regeneration from 2 5 g/m^3 to 3 g/m^3 (desulphurisation unit) Savings estimate - 60 thousand kWh/$2,270 per year
3 Installation of variable speed drive at the BCU 2-A water supply pump to the coking unit (gas trapping unit No2) Savings estimate - 160 thousand kWh/$605,340 per year
4 Due to the design capacity underuse - replacement of final cooling pump (gas trapping unit No1) Savings estimate - 360 thousand kWh/$13,500 per year
5 Introduction of variable drive at the dust-free coke-pushing fan (coking unit) Savings estimate - 110 thousand kWh/$41,620 per year
6 Due to underuse of production line capacities - replacement of seven 22- kW pumps in the absorption line with lower capacity 15-kW pumps (sodium thiocyanate unit) Savings estimate - 16 thousand kWh/$610 per year
7 Installation at boiler draught and blower fans of variable speed drives (boiler house) Savings estimate - 265 thousand kWh/$10,300 per year
8 Installation of exhaust gas oxygen content meters at No6 and 7 boilers (boiler house) Savings estimate - 166 thousand kWh/$6,280 per year
9 Insulation of the No1, 2 and 3 reactors with frame mixers, tanks of the second line of polysulphide cycle in the absorption production line (sodium thiocyanate unit) Savings estimate - 750 Gcal/$8,110 per year
10 Development and introduction of automatic temperature control system for the network water at the heater plant (boiler house) Savings estimate - 320 Gcal/$3,460 per year
11 Introduction of the "Izotek" and "Izover" insulation at the thermal piping Savings estimate - 810 Gcal/$8,720 per year
12 Introduction and, with positive outcome, assimilation of recovered steam utilization from the melting and crystallizing production line for absorbent solution heating in sulphur plant No 3 and indirect heating of steam traps and instrument cabinets (desulphurisation unit) Savings estimate - 840 Gcal/$9,080 per year
13 Insulation of 3 tar storage facilities (gas trapping unit No2) Savings estimate - 1410 Gcal/$1,520 per year
14 Recovery of condensate from oil/steam heat exchangers of sulphate production line (gas trapping unit No2) Savings estimate - 13,245 tonnes/$20,160 per year
15 Recovery of not less than 35% of used steam as condensate (desulphurisation unit) Savings estimate - 6,040 tonnes/$9,200 per year

The proposed measures reflect the existing reserves of energy conservation The works have been and are implementing various organizational and technical energy saving measures dictated by the need to reduce production costs Several issues have not been dealt with due to the lack of proper technical solutions and because of changes in technology and absence of sufficient funds

Unfortunately, the "MARKOKHIM" energy conservation program lacks implementation data and economic results

7.0 ENERGY AUDIT

As the result of the energy audit at the JSC "Markokhim" the audit team recommended several proposals for improvement of energy efficiency at the plant The majority of the problems are typical for Ukrainian enterprises so the solutions of these problems can be replicated for enterprises with similar systems of energy use

Introduction of the recommended measures will reduce annual energy consumption

1 Electricity by 25,397,000 kWh (26%)
2 Coke-oven gas by 15,000,000 m^3 (5%)
3 Blast-furnace gas by 251,105,000 m^3 (20%)

The results of technical and economic calculations of energy conservation opportunities are given below

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 This management strategy is based on conventional measurements and documentation and provides operating conditions that facilitate minimal energy consumption needed for the technology Implementation of energy management program will result in having more detailed energy consumption records that 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

We recommend to introduce on the Facility the energy management program at full extent The implementation of this ECO will result in reducing annual energy consumption by 10% In order to institute energy management it is necessary to equip the works with a comprehensive energy metering system, the elements of which are proposed in Appendix A

Implementation of this project will permit to reduce energy costs by $620,400 per annum Payback period will be 0 5 year

See details of the proposal in Appendix A, ECO #1

ECO #2 Energy metering system upgrading

In order to implement energy management and introduction of cost-accounting within the works production units it is necessary to upgrade the existing energy metering system As one of upgrading options we recommend the ITEK technical instrument set which possesses metrological characteristics and is designed for continuous and periodical (express analysis) 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 peak hour consumption provides a

considerable cost effect that has been proven by more than annual operation at numerous Ukrainian facilities

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)

Implementation of this project will allow to reduce energy costs by $243,000 per annum Payback period will be 2 years

See details of the proposal in Appendix A, ECO #2

ECO #3 Use of frequency regulated variable speed drive for the fans of dust-free coke pushing system

In order to reduce electric power consumption it is suggested to regulate the motor speed by frequency with the damper fully opened The source of electric power savings is total absence of power losses while operating with the damper closed With variable speed regulation the fan speed can be reduced to 5-10% of the nominal And the power required by the load from the frequency converter (FC) output will be conditioned only by the losses in the drive mechanism in idling mode i e 5-10% of the nominal

In order to implement variable speed regulation we recommend to utilize frequency converters of the REN series manufactured by the International Consortium "Energosberezhenie" (city of Kharkiv)

Implementation of this project will allow to reduce energy costs by $35,000 per annum Payback period will be 2 3 years

See details of the proposal in Appendix A, ECO #3

ECO #4 Steam turbines for co-generation of electric power at the works boiler house

The boiler house generates steam with the parameters $P = 14$ kg/cm^2 and $T_{st} = 350^0$C necessary for production processes at the steam ejectors of the coking unity and benzene traps of the gas trapping units The rest of consumers require the steam with the following parameters $P = 3\text{-}6$ kg/cm^2 and $T_{st} = 170 - 190^0$C The energy auditors see it expedient to use steam turbine plants in the works boiler house of 2 MW total capacity This will permit to reduce the volume of purchased power and lower energy costs

Implementation of this project will allow to reduce energy costs by $700,000 per annum Payback period will be 1 2 years

See details of the proposal in Appendix A, ECO #4

ECO #5 Optimization of the Hot Water Supply System

In order to reduce heat consumption for space heating down to the standardized values and decrease of electric power consumption for network water pumping it is necessary to implement the following measures

- to determine using the installed instruments the actually connected heat load,
- to calculate hydraulic parameters of hot water networks,
- after the hydraulic calculations orifice plates should be installed at each consumption site before each space heating system In this case the entire space heating system will be hydraulically stable,
- it is necessary that the resistance of the internal systems in frond of which the orifice plates must be placed should be not higher than $h \leq 1$ mm water column,
- after installation of the orifice plates a thermal testing of the system and checking of correspondence of the actual flow rates to the designed ones is necessary In case of any variations in any direction, one shall correct the diameters of the controlling draining diaphragms

The above mentioned measures after their implementation shall give the following results

- decrease of the electric power consumption for the heat medium transportation,
- decreased heat losses due to overheating of buildings

Implementation of this project will result in reducing energy costs by $148,000 per year Payback period will be 0 3 year

See details of the proposal in Appendix A, ECO #5

ECO #6 Combustion mode control in gas firing units

The works use two boilers of the TO-1 type, four - of the B-25-15G type and one - of GM-50 type manufactured at Russian plants The boilers are in a satisfactory condition though they lack automatic control of air-to-gas ratio No 2 gas trapping unit uses an oil heating tubular oven firing coke-oven gas

High-efficiency gas combustion in the steam boilers and the oven require an optimum ratio of gas and air, periodical monitoring and adjustment

We recommend to utilize at the works a portable combustion analyzer, train a specialist who will take measurements of combustion efficiency every 1-2 days and adjust the combustion mode accordingly

Implementation of this project will allow to reduce energy costs by $9,760 per annum Payback period will be 0 7 year

See details of the proposal in Appendix A, ECO #6

ECO #7 - Conversion of plant boiler-house to uniform type of fuel - coke-oven gas

Currently the boilers of the plant boiler-house use a fuel mixture of the blast-furnace gas and coke-oven gas in the volumetric ratio of 60% of the blast-furnace gas to 40% of the coke-oven gas The heating value of the coke-oven gas is 71 5%, while the heat value of the blast-furnace gas is 28 5% The blast-furnace gas, according to the report records on the maintenance of the boiler units has the calorific value of 1,042 kCal/Nm^3 Classical technologies of the 1950s – 1960s were based on the calorific value of gas equal to 1,240 kcal/Nm^3 The plot for the 1998 calorific value of the blast-furnace gas shows that in average the actual calorific value of the blast—furnace gas is by 20 to 30% lower than the rated one This decreases the efficiency of the boilers by 0 5 to 0 6%, distorts the fuel-and-energy balance of the plant boiler-house

To improve the efficiency of operation of the boilers, the possibility of automating the combustion process, the energy auditors propose to consider a possibility to operate the boilers on coke-oven gas as the basic sort of fuel , while the blast-furnace gas should be used only for the coke batteries Benefits include longer periods between the maintenance of the boilers and lower costs of repair

Implementation of this project will allow to reduce energy costs by $18,500 per annum Payback period will be 0 9 year

See details of the proposal in Appendix A, ECO #7

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 beneficial 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 "MARKOKHIM" is blast-furnace and coke-oven 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
Carbon dioxide CO_2 is the main gas responsible for setting "the green house effect" Saving blast-furnace and coke-oven 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 Appendix A 1 calculations

electricity saving -	25,397,000 kWh
coke-oven gas saving -	15,000,000 m^3
blast-furnace gas saving -	251,105,000 m^3

Electricity
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

Environmental effect of electricity savings can be determined by the formula

$$h = h_n \quad Eps,$$

where

h_n - the specific content of emissions, g/kW h
Eps - electric power saving, kW h

Amounts of pollutants formed during generation of 25,397,000 kWh

1) sulphur dioxide SO_2	h_1 = 9 9 x 25,397,000 = 251,000,000 (g/year)
2) carbon oxide CO	h_2 = 0 5 x 25,397,000 = 12,700,000 (g/year)
3) nitrogen oxides NO_x	h_3 = 2 2 x 25,397,000 = 55,900,000 (g/year)
4) solid particles	h_4 = 4 4 x 25,397,000 = 111,700,000 (g/year)

Coke-oven gas

Calculation of the carbon oxide that forms after combustion of coke-oven gas is made by the formula

$M_{CO} = 0\ 001\ \ B\ \ K_{CO}\ \ Q_r\ \ (1 - q/100)$,

where

B - consumption of gas, m^3/yr

$K_{CO} = 0\ 25$ kg/GJ - the quantity of carbon oxide that is produced per heat unit released after combustion of coke-oven gas

$Q_r = 16\ 5$ MJ/m^3 - the lowest calorific value of the fuel

q = 0 5 % - heat losses resulting from an incomplete gas combustion

$M_{CO} = 0\ 001\ \ 15{,}000{,}000\ \ 0\ 25\ \ 16\ 5\ \ (1 - 0\ 5/100) = 61{,}600$ (kg/yr),

or

$M_{CO} = 61\ 6$ t/yr

Calculation of the nitrogen oxides per time unit (t/yr) shall be made by the formula

$M_{NOx} = 0\ 001\ \ B\ \ K_{NOx}\ \ Q_r\ \ (1 - b)$,

where

$K_{NOx} = 0\ 12$ kg/GJ - a parameter characterizing the amount of the nitrogen oxides forming per 1 GJ of heat, kg/GJ,

b = 0 15 - a coefficient for taking into account the degree of decreasing the level of emissions of nitrogen oxides resulting from implementation of technological measures

$M_{NOx} = 0\ 001\ \ 15{,}000{,}000\ \ 0\ 12\ \ 16\ 5\ \ (1 - 0\ 15) = 25{,}200$ (kg/yr),

or

$M_{NOx} = 25\ 2$ t/yr

Blast-furnace gas

Calculation of the carbon oxide that forms after combustion of blast-furnace gas is made by the formula

$M_{CO} = 0\ 001\ \ B\ \ K_{CO}\ \ Q_r\ \ (1 - q/100)$,

where

B - consumption of blast-furnace gas, m^3/yr

$K_{CO} = 0\ 28$ kg/GJ - the quantity of carbon oxide that is produced per heat unit released after combustion of blast-furnace gas

$Q_r = 3\ 2$ MJ/m^3 - the lowest calorific value of the fuel

q = 0 5 % - heat losses resulting from an incomplete gas combustion

$M_{CO} = 0\ 001\ \ 251{,}105{,}000\ \ 0\ 28\ \ 3\ 2\ \ (1 - 0\ 5/100) = 224{,}000$ (kg/yr),

or

$M_{CO} = 224$ t/yr

Calculation of the nitrogen oxides per time unit (t/yr) shall be done by the formula

$M_{NOx} = 0\ 001\ \ B\ \ K_{NOx}\ \ Q_r\ \ (1 - b)$,

where

$K_{NOx} = 0\ 47$ kg/GJ - a parameter characterizing the amount of nitrogen oxides forming per 1 GJ of heat, kg/GJ,

b = 0 15 - a coefficient for taking into account the degree of decreasing the level of emissions of nitrogen oxides resulting from implementation of technological measures

$M_{NOx} = 0\ 001\ \ 251{,}105{,}000\ \ 0\ 47\ \ 3\ 2\ \ (1 - 0\ 15) = 321{,}000$ (kg/yr),

or

$M_{NOx} = 321$ t/yr

Implementation at the coking works of energy conservation measures will decrease the energy resource consumption, and in its turn lower the quantity of harmful emissions into the atmosphere

TABLE OF POLLUTANT EMISSION REDUCTION

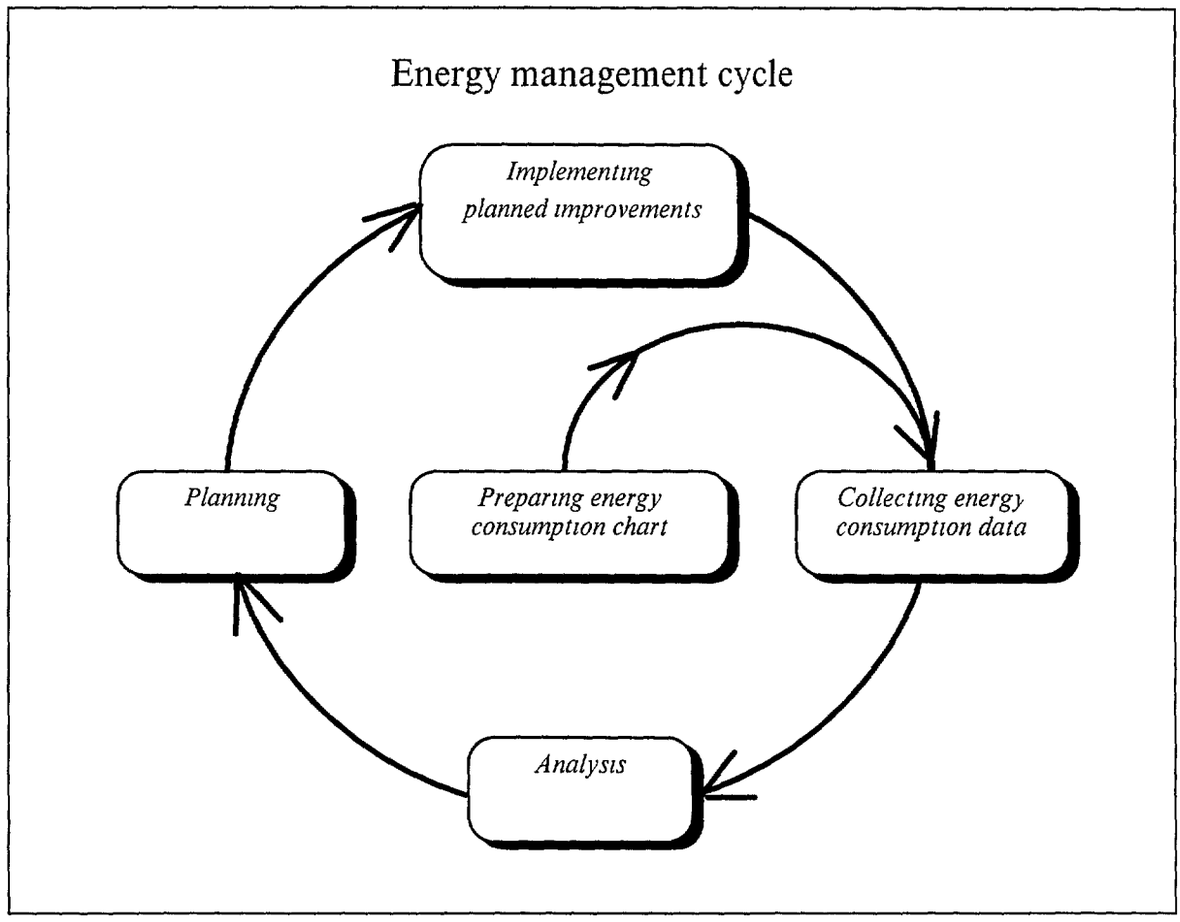
Emissions	Reduction in emissions as result of the energy savings, t/yr			
	Electric power	**Coke-oven gas**	**Blast-furnace gas**	**TOTAL**
Solid particles	111 7	-		111 7
Sulphur dioxide	251 4	-		251 4
Carbon oxide	12 7	61 6	224	298 3
Nitrogen oxides	55 9	25 2	321	402 1
Total emission reduction				1,063 5

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 establishing a separate section of employees to deal only with energy efficiency At a minimum an energy management section should consist of three people technical supervise, an electric engineer and a thermal engineer

The main duties of an energy management section include

- 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

The global experience and practice show that in case of institution of full-time energy management ensures 10% of fuel and energy consumption savings The energy savings are listed below

Annual energy savings

Currently the works use annually on average 98,530,000 kWh of electric power, 1,050,100,000 m^3 of blast furnace gas and 300,000,000 m^3 of coke-oven 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

ECO -# 2 Energy metering system upgrading

ECO description

Energy and fuel consumption monitoring and precise breakdown of this consumption by production lines and units is one of the basic tools of energy management This will provide a realistic depiction of the energy balance of the enterprise, opportunity of energy use assessment and viable possibility of fuel consumption dependent on the equipment characteristics and workloads

Though the existing system of electric power metering permits to acquire a picture of electricity consumption and distribution among production lines, however, it is cumbersome in processing and evaluation of obtained results Thermal energy metering system of the works combines utilization of instrument metering and calculating without the use of measuring devices which precludes provision of realistic thermal energy consumption registration

In order to implement energy management and introduction of cost-accounting within the works production units it is necessary to upgrade the existing energy metering system As one of upgrading options we recommend the ITEK technical instrument set which possesses metrological characteristics and is designed for continuous and periodical (express analysis) 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, Landys and Gyr, Alpha-ABB, etc) with pulse putout 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

The global experience and practice show that in case of institution of full-time energy management ensures 10% of fuel and energy consumption savings Energy savings will amount to

1) Electric power - 98,530,000 x 0 05 = 4,900,000 (kWh)
2) Coke-oven gas - 300,000,000 x 0 05 = 15,000,000 (m^3)
3) Blast-furnace gas - 1,050,100,000 x 0 05 = 52,500,000 (m^3)

Annual cost saving estimate

1 At the price of $0 036 per 1 kWh of electric power the cost savings will be
4,900,000 x 0 036 ~ $176,400
2 At the price of $10 per 1,000 m^3 of coke-oven gas the cost savings will be
15,000 x 10 ~ $150,000
3 At the price of $5 6 per 1,000 m^3 of blast-furnace gas the cost savings will be
52,505 x 5 6 ~ $294,000
Total fuel cost savings will be
176,400 + 150,000 + 294,000 ~ $620,400

Implementation Costs

The cost of energy management institution judging from the experience constitute 50% of estimated savings and are equal to

620,400 x 0,5 = 310,200

Simple payback

Implementation costs - $310,200
Annual cost savings - $620,400
Simple payback period will be
310,200/620,400 ~ 0 5 (year)

ECO # 3 Use of frequency regulated variable speed drive for the fans of dust-free coke pushing system

ECO description

Currently the operation mode of the fans of dust-free coke pushing system is continuous and cyclic Electric motors of DA30-400U-4U1 type are used to drive the fans having the following parameters

- nominal voltage - 6 kV
- nominal current - 58 5 A
- nominal capacity - 500 kW
- efficiency at nominal load - 94%
- power factor at nominal load - 0 87
- nominal rotation speed - 1484 rpm

The load is regulated with the help of the damper (shut-off) and amounts to 400 kW during 15 seconds every 10 minutes The rest of the time the damper stays closed and the drive motor is idling

Typical hourly loads of the drive by electric meter

Time, hours	11 PM	12 PM	1 am	2 am	3 am	4 am	5 am	6 am	7 am	8 am	9 am	10 am
Electric power consumption by meter, kW	120	192	168	144	192	192	124	168	144	168	168	168

In order to reduce electric power consumption it is suggested to regulate the motor speed by frequency with the damper fully opened The source of electric power savings is total absence of power losses while operating with the damper closed With variable speed regulation the fan speed can be reduced to 5-10% of the nominal And the power required by the load from the frequency converter (FC) output will be conditioned only by the losses in the drive mechanism in idling mode i e 5-10% of the nominal

In order to implement variable speed regulation we recommend to utilize frequency converters of the REN series manufactured by the International Consortium "Energosberezhenie" (city of Kharkiv) of the REN-320 type with the following parameters

- nominal capacity - 320 kW
- nominal voltage -3 x 380V, 50 Hz
- nominal efficiency - not less 0 97
- power factor at the nominal load - 0 96

The load test of this FC performed by the manufacturer showed that it is possible to run it for an extended time with overload to 400 kW during 15 seconds every 10 minutes i e in the current work mode

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 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)

PRD is a wide range pressure difference converter The PRD measurement device is designed for operation in automatic monitoring and control systems of technological processes and provides continuous conversion of the measured parameter into a uniform electric output signal It is a fast operating converter and can be utilized for conversion of pulsating pressure differences into a unified electric signal with time constant of up to 2 msec (maximum permissible operational excess pressure is 1 6 MPa and 40 MPa)

Annual energy savings

In 1997 the works used approximately 98,000,000 kWh of electric power, 1,050,100,000 m^3 of blast furnace gas and 300,000,000 m^3 of coke-oven gas
The global experience and practice confirm that quality monitoring of energy ensure 2% of fuel and energy consumption savings Energy savings at the works will amount to
1) Electric power - 98,000,000 x 0 02 = 1,960 (thousand kWh)
2) Blast-furnace gas - 1,050,100,000 x 0 02 = 21,000 ((thousand m^3))
3) Coke-oven gas - 300,000,000 x 0 02 = 6,000 (thousand m^3)

Annual cost saving estimate

1 At the price of $0 033 per 1 kWh of electric power the cost savings will be 1,960,000 x 0 033 ~ $65,000
2 At the price of $5 6 per 1,000 m^3 of blast-furnace gas the cost savings will be 21,000 x 5 6 ~ $118,000
3 At the price of $10 per 1,000 m^3 of coke-oven gas the cost savings will be 6,000 x 10 ~ $60,000

Total fuel cost savings will be
65,000 + 118,000 + 60,000 ~ $243,000

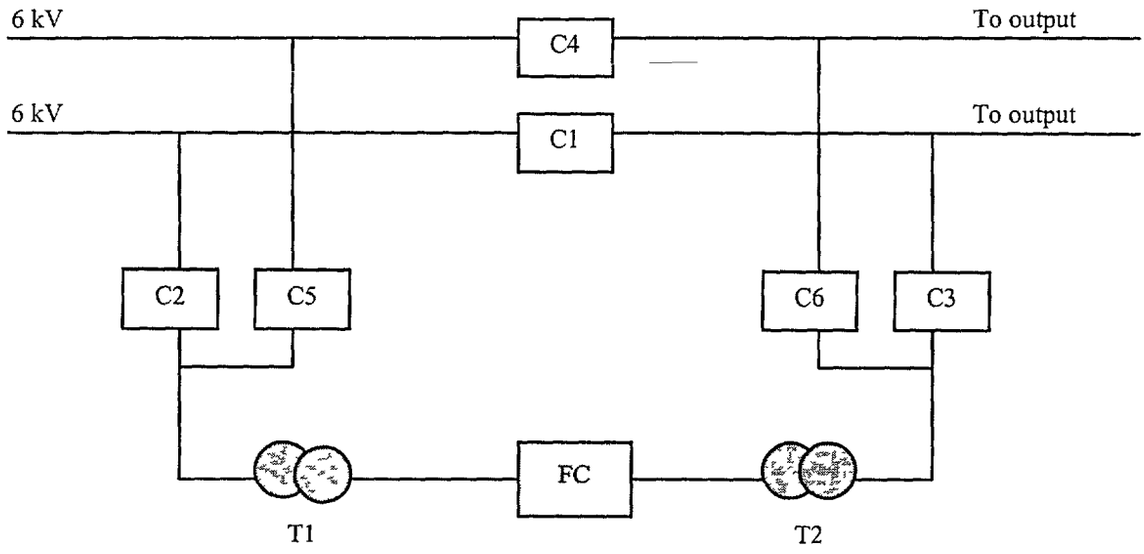
Implementation Costs

Approximate cost of the ITEK automatic metering system is $500,000

Simple payback

Implementation costs - $500,000
Annual cost savings - $243,000
Simple payback period will be
500,000/243,000 ~ 2 (years)

Given that the FC nominal voltage is 380 V it is proposed to employ the following electric circuit permitting to utilize the existing factory-assembled switch gear cell as a by-pass for maintenance and adjustment purposes



C1,C4 - existing switchgear cells
T1 - step-down transformer 6 kV/0 4 kV
T2 - step-up transformer 0 4 kV/6 kV
FC - REN-320 frequency converter
C2, C5, C6, C3 - switchgear cells for connection/disconnection of FC

Capacities of T1 and T2 transformers will be selected in accordance with the FC parameters and will be as follows
for T1 transformer -
$Q1 \geq Pn/(\eta_{FC} \times \cos\varphi_{FC}) = 500/(0\ 97 \times 0\ 96) = 536$ (kVA)
for T1 transformer -
$Q_2 \geq P_n/(\eta_{FC} \times \cos\varphi_{FC}) = 500\ (0\ 94 \times 0\ 87) = 548$ (kVA)

In conformity with the standard range the 630 kVA-type transformers are to be selected Given that the transformers of the similar capacity have $U_k \sim 14\%$ a circuit reactor at the FC input is not needed To perform as C2, C5 and C3, C6 cells the standard switchgear cells are suggested with voltage of 6-10 kV and minimum permissible current of 630A equipped with oil or vacuum switches The entire package of equipment is manufactured in Ukraine

Annual energy savings estimate

Frequency regulation of asynchronous fan drive motor will lead to electric power savings
Average hourly motor load (based on the table) is as follows
P_1= 160kWh
During 1 operation hour power demand is as follows
15 x 6 = 90 sec = 0,025 hour and amounts to

P_2 - 400 x 0 025 = 10 (kWh)
It can be postulated that at reduced revolutions power demand constitutes 10% of the nominal capacity i e 50 kW during 0 975 hour
P_3 = 500 x 0 1 x 0 975 = 49 (kW)
Then an hourly electric power consumption with variable speed drive will be
$P_4 = P_2 + P_3$ = 10 =49 = 59 (kW)
Thus, electric power savings will be
P1 - P4 = 160 - 59 ~ 100 (kW)
Annual energy savings will be
100 x 24 x 365 ~ 876,600 (kWh)

Cost savings estimate

Cost savings due to reduction of electric power consumption at the price of US$0 04 per 1 kWh will be
876,000 x 0 04 ~ 35,000 (US$)

Implementation cost

REN-320 frequency converter - US$35,200
TS-630 transformer of 6kV/0 4kV - 2 at US$12,000 - US$24,000
KM1F-10-630-20 cell at US$4,500 a piece - US$18,000
Installation and commissioning - US$3,800
TOTAL cost - US$81,000

Simple payback

Implementation cost - US$81,000
Annual savings - US$35,000
The simple payback will be
81,000/35,000 = 2 3 (years)

ECO -#4 Steam turbines for co-generation of electric power at the works boiler house

ECO description

During the visit to the works the energy management team have surveyed the following picture The boiler house generates steam with the parameters P = 14 kg/cm^2 and T_{st} = 350^{0}C These parameters are necessary for production processes at the steam ejectors of the coking unity and benzene traps of the gas trapping units The rest of consumers require the steam with the following parameters P = 3-6 kg/cm^2 and T_{st} = 170 - 190^{0}C With this aim the works in cooperation with the "Giprokoks" design institute plans to install reduction and cooling plants (RCP) within the system of the works steam pipeline network This may result in failure to utilize potential energy of superheated steam which can generate up to 5 MW of electric power in wintertime and up to 2 MW in summertime The energy auditors see it expedient to use a steam turbine plant in the works boiler house of 2 MW total capacity This will permit to reduce the volume of purchased power and lower energy costs

Annual energy savings estimate

Electric power generated by in-plant facilities will amount to

2,000 x 24 x 365 = 17,520,000 (kWh)

Annual cost savings estimate

Cost savings by reduction of externally purchased power at the price of $0 04 per 1 kWh will be

17,520,000 x 0 04 ~ $700,000

Implementation costs

Design - $50,000

Equipment (1 turbine)- $400,000

Turnkey installation - $200,000

Overheads and contingencies at 30% - $200,000

Total costs - $850,000

Simple payback

Commissioning costs - $850,000

Annual cost savings - $700,000

Simple payback period will be

850,000/700/000 ~ 1 2 years

ECO -#5 Optimization of the Hot Water Supply System

ECO description

Presently the space heating at the plant is furnished by the heat exchanger unit of the works where 8 pairs of water heaters are installed Each pair consists of one steam-to water heat exchanger and one water-to-water heat exchanger The circulation of heat medium is ensured by three D-320-70 network pumps 90 kW each Make-up water is supplied by KM-55/45 pumps with 11 kW motor drives each During the study of the boiler house and heat exchanger unit the following mode of the hot water supply system was registered

1) ambient temperature $t_a = 2\ 5°C$
2) temperature at the input piping $t_i = 68^0C$
3) temperature at the recovery piping $t_r = 57\ 5^0C$
4) water pressure in the input piping $P_i = 4$ kg/ cm^2
5) water pressure in the recovery piping $P_r = 3\ 2$ kg/ cm^2
6) gauge water supply to the network G = 450 tons per hour
7) steam supply to the heat exchanger unit G_n- = 7 5 tons per hour
8) electric power consumption by the network pump N = 76 kW

At low ambient temperatures of -5 - 10^{0}C two additional network pumps are turned on and thermal medium reaches G = 650 tons per hour

Heat consumption for space heating at the works was

$$Q = G\ \ (i_t - t_r)/\ 1000 = 450\ (68\text{-}75)/1000 = 4\ 73\ \text{(Gcal/hour)}$$

Actual difference between the temperatures was,

$$\Delta i_t = i_t - t_r = 68 - 57\ 5 = 10\ 5\ (^0C),$$

whereas the standard temperatures at $t_a = 2\ 5^0C$ and the operating temperature schedule of hot water networks of 150-70^{0}C should be

$$t_i^s = 78\ 5^0C$$
$$t_r^s = 44\ 8^0C$$

temperature difference will be $\Delta t^s = t_i^s - t_r^s = 78\ 5\text{-}44\ 8 = 33\ 7\ (^0C)$

If we assume that the heat supply corresponds to the demand then the standardized heat use should be as follows

$$Gs = G \times \Delta t^{ac}/\Delta t^s = 450 \times 10\ 5/33\ 7 = 140\ 2\ \text{(tons per hour)}$$

Electric power demand by the network pump will be in this case (according to the pump specifications) = N_s = 45 kW

In order to reduce heat consumption for space heating down to the standardized values and decrease of electric power consumption for network water pumping it is necessary to implement the following measures

- to determine using the installed instruments the actually connected heat load,
- to calculate hydraulic parameters of hot water networks,
- after the hydraulic calculations orifice plates should be installed at each consumption site before each space heating system In this case the entire space heating system will be hydraulically stable,

- it is necessary that the resistance of the internal systems before which the orifice plates must be placed should be not higher than $h \leq 1$ mm water column Otherwise, the internal systems will have the coolant flow rate 1 5 to 2 times higher than the designed one,
- after installation of the orifice plates there is a requirement of thermal testing of the system and checking of conformity of actual flow rates with the designed ones

The above mentioned measures after their implementation will give the following results

- decrease of the electric power consumption for the heat medium transportation,
- decreased heat losses due to overheating of buildings

Annual energy savings estimate

Maximum thermal load for the works space heating is as follows

$$Q_{max} = G_s \times (150\text{-}70)/ 1000 = 140\ 2 \times (150\text{-}70)/1000 = 11\ 2 \text{ (Gcal per hour)},$$

where (150-70) is the difference between the temperatures in the supply and recovery pipelines at the maximum load

The use of heat per 1 degree-day is calculated by the following formula

$$q = Q_{max} \times 24/t_{int} - t_a = 11\ 2 \times 24/18 - (-23) = 6\ 56 \text{ (Gcal/degree-day)},$$

where t_{int} is a calculated internal room temperature

Taking into consideration that the Mariupol region is characterized by n = 3500 degree-days a year the necessary volume of heat will be

$$Q_{year} = q \times n = 6\ 56 \times 3500 \sim 23{,}000 \text{ (Gcal/year)}$$

If taken into account that in case of unoptimised thermal network overheating of building leads to 20% loss of heat then the actual need of heat will be,

$$Q_{year}^{s} = 23{,}000 \times 0\ 8 = 18{,}400 \text{ (Gcal/year)}$$

Actual heat use for space heating in 1997 were

$$Q_{year}^{act} = G_{steam} \times (i_{st} - i_c) = 49{,}170 \times (0\ 73 - 0\ 1) \sim 31{,}000 \text{ (Gcal/year)},$$

where G_{steam} is equal to 49,170 tons of steam according to the works data,
i_{st} is equal to 0 73 Gcal/ton - heat content of 1 ton of superheated steam,
i_c is equal to 0 1 Gcal/ton - heat content of condensate returned from the heat exchanger unit

As the result of optimization of the space heating system the energy savings will be

$$Q_{year}^{act} - Q_{year}^{s} = 31{,}000 - 18{,}400 \sim 12{,}600 \text{ (Gcal/year)}$$

Electric power consumption of the line pump D-320-70 with a motor of N = 90 kW, according to the made measurements, is N_{act} = 76 kW

Electric power consumption during a heating season is

$$E_{act} = N_{act} \times 24 \quad n_{heating} = 76 \times 24 \times 189 = 345{,}000 \text{ (kW)},$$

where

$n_{heating}$ - duration of the heating period

In case of decreasing the flow rate of the line water electric the energy consumption must go down to N_{pr} = 45 kW

Correspondingly, the expected electric power consumption will be

$E_{pr} = N_{pr} \times 24 \times n_{heating} = 45 \times 24 \times 189 = 204{,}000$ (kW)

The expected electric power saving on transporting the heat medium per year will be

$E_{act} - E_{pr} = 345{,}000 - 204{,}000 = 141{,}000$ (kW)

Annual energy cost savings estimate

Cost saving resulting from decreasing the electric power consumption at the price of $0 04 per 1 kWh will be

141,000 x 0 04 = 5,600 ($)

Cost saving resulting from decreasing thermal energy consumption at the price of $11 3 per 1 GCal (according to the data of the works) will be

12,600 x 11 3 = 142,400 ($)

Total saving from implementation of the ECO

5,600 + 142,400 ≅ 148,000 ($)

Implementation Costs

The design costs

- determination of the actual heat loads,
- development of a new thermal lines system,
- hydraulic calculation of the thermal lines

The approximate cost is $15,000

Fulfillment of measures resulting from the study and calculations - $10,000

Thermal and hydraulic tests of thermal networks, adjustment of orifice plates- $5,000

Overhead costs at 30% $9,000

Total costs will be 39,000 ($)

Simple Payback

Commissioning costs - $39,000
Annual cost saving - $148,000
Simple payback period

39,000/148,000 = 0 3 (year)

As the duration of the heating season is 6 months per year, the actual payback since the commissioning will be

6 x 0 3 ~ 1 8 (months)

ECO -#6 Combustion mode control in gas firing units

The works uses two boilers of the TO-1 type, four - of B-25-15G type and one - of GM-50 type manufactured at Russian plants The boilers are in a satisfactory condition though they lack automatic control of air-to-gas ratio No 2 gas trapping unit uses an oil heating oven The JSC "MARKOKHIM" uses two types of fuel blast furnace gas received from the "AzovStal" steel works and coke-oven gas as a product of internal processing

The boilers fire a mixture of gases

- 40% of coke-oven gas,

- 60% of blast furnace gas

Fuel consumption is registered at each boiler

High-efficiency gas combustion in the steam boilers and the oven require an optimum ratio of gas and air, periodical monitoring and adjustment

The "pictures" of the boiler operation modes were taken utilizing the ORSA combustion analyzers The results of the survey showed that the B-25-15 boiler No 1 and No 4 are operated with low efficiency equal to 85 92 - 88 94, actual opportunity of gas saving used for combustion will constitute 2 - 2 5%

The existing combustion control system has three main drawbacks

- air supply for combustion is controlled by the pressure of the input air which entails impossibility of automatic control of correct combustion air-to-fuel ratio at low loads,

- automatic control of excess air in conformity with load is non-existent, i e oxygen supply monitoring is not applied, the existing system relies on adjustment of air supply by the operator in accordance with the operation charts in case of a load change,

- if fuel calorie content change equals 20% during a month the automatic control becomes problematic It is necessary to adjust the combustion process continuously

We recommend to utilize at the works a portable combustion analyzer, train a specialist who will take measurements of combustion efficiency every 1-2 days and adjust the combustion mode accordingly

Annual energy savings estimate

The annual savings should be viewed by the costs of the blast furnace consumption The power manager department has furnished us with the data on blast furnace gas use for the boiler house and oil heating oven for February In order to double-check we have calculated annual costs of fuel using hourly gas consumption (24,200 m^3) multiplied by 7,200 annual boiler operation hours

24 2 x 7,200 ~ 174,300 (m^3/year)

Annual cost savings estimate

At the cost of fuel of US$5 6 per 1000 m^3 the fuel costs are

5 6 x 174,300 ~ 976,000 ($) per year

With conservative estimate of blast furnace gas reduction by approximately 1% the annual savings will amount to $9,760

Implementation costs

Equipment costs

Combustion analyzer - $5,000

Computer - $1,000

Calibration gas set - $500

Shipment - $500

Total equipment costs - $7,000

Simple payback

Commissioning costs - $7,000

Annual cost savings - $9,760

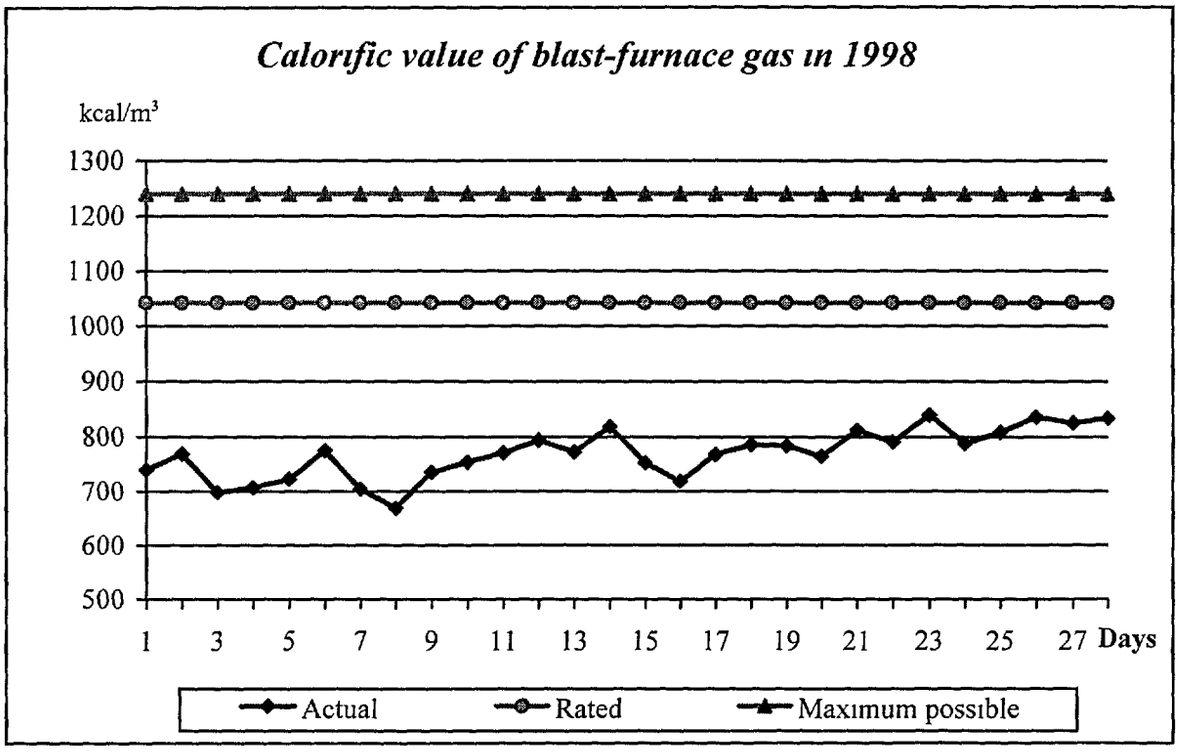
At the price of US$5 6 per 1,000 m^3 of blast furnace gas the simple payback period will be

7,000/9,760 = 0 7 year or 8 4 months

ECO #7 Conversion of plant boiler-house to uniform type of fuel - coke-oven gas

ECO Description

Currently in the boilers of the plant boiler-house as the fuel a mixture of the blast-furnace gas and coke-oven gas are used in the voluminous ratio of 60% of the blast-furnace gas and 40% of the coke-oven gas The heat value of the coke-oven gas is 71 5%, while the heat value of the blast-furnace gas is 28 5% With that there is provided that the blast-furnace gas, according to the report records on the maintenance of the boiler aggregates, has the calorific value of 1,042 kcal/Nm^3 Classical technologies of the 1950s – 1960s were based on the calorific value of gas equal to 1,240 kCal/Nm^3 The plot for the 1998 calorific value of the blast-furnace gas shows that in average the actual calorific value of the blast—furnace gas is by 20 to 30% lower than the rated one



The personnel of the plant cannot foresee the composition of the delivered blast-furnace gas and influence its quality This brings to losing 8 to 10% of the calorific value of the fuel mixture of the gases and, consequently, an increased content of the excess air that amounts to 10%, which decreases the efficiency of the boilers by 0 5 to 0 6%, distorts the fuel-and-energy balance of the plant boiler-house

The misbalance of the thermal energy production concerning the heat value of the fuel and the drinking water consumption is 3 to 15%

To improve the efficiency of operation of the boilers, the possibility of automating the combustion process, the energy auditors propose to consider a possibility to transfer the boilers on coke-oven gas as the basic sort of fuel , while the blast-furnace

gas should be used only for the coke batteries In the result there is possible to prolong the periods between the maintenance of the boilers and to decrease the costs of their repair

Calculation of the annual energy saving

Thermal energy production in 1997 was ≈493,000 Gcal The specific fuel consumption rate per 1 Gcal was 152 9 kg of conventional fuel /Gcal

Improvement of the efficiency by 0 5% provides energy saving in case of the conservative conditions equal to

$$152\ 9 \times 0\ 05 \times 493{,}000 \approx 3{,}770{,}000 \quad \text{(kg of conventional fuel /yr)},$$

which corresponds to the calorific value of the saved blast-furnace gas

$$3{,}770{,}000 \times 7{,}000 / 10^6 \approx 2{,}640 \quad \text{(Gcal)},$$

or in the voluminous terms

$$2{,}640 / 800 \times 10^6 \approx 3{,}300{,}000 \quad (m^3),$$

where 800 is an average actual calorific value of the blast-furnace gas in kcal/Nm^3

Calculation of the annual saving of costs

Cost saving by decreasing the blast-furnace consumption if 1,000 m^3 costs US $5 6 will be equal to

$$3{,}300 \times 5\ 6 \approx \text{US \$18,500}$$

An additional benefit is less maintenance cost

Implementation costs

Designing works	US $2,000
Reconstruction of the burners on the boilers	US $5,000
Pre-start and adjustment works on the "turn-key" basis	US $5,000
Contingency and overhead costs- 30%	US $4,000
TOTAL costs	US $16,000

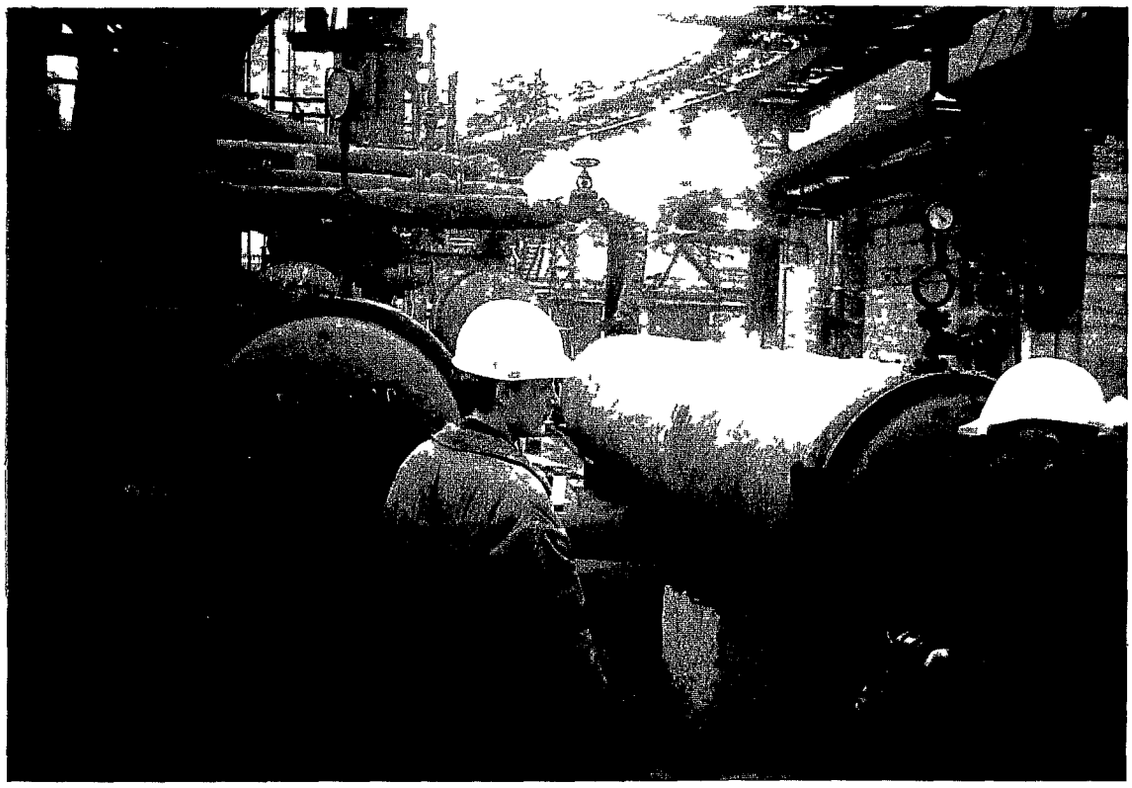
Simple payback

Commissioning costs	- US $16,000
Yearly cost saving	- US $18,500

The simple payback period for the project will be

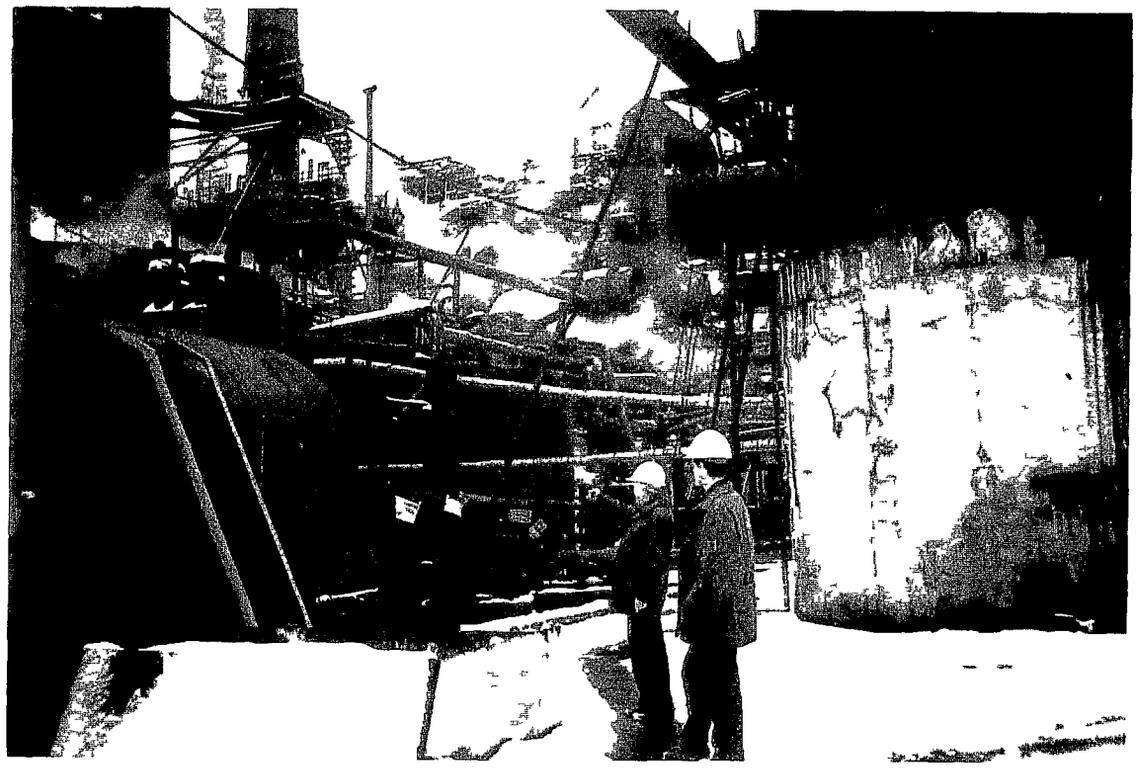
16,000 / 18,500 ≈ 0 9 (year)

APPENDIX B PHOTOGRAPHS OF THE PLANT



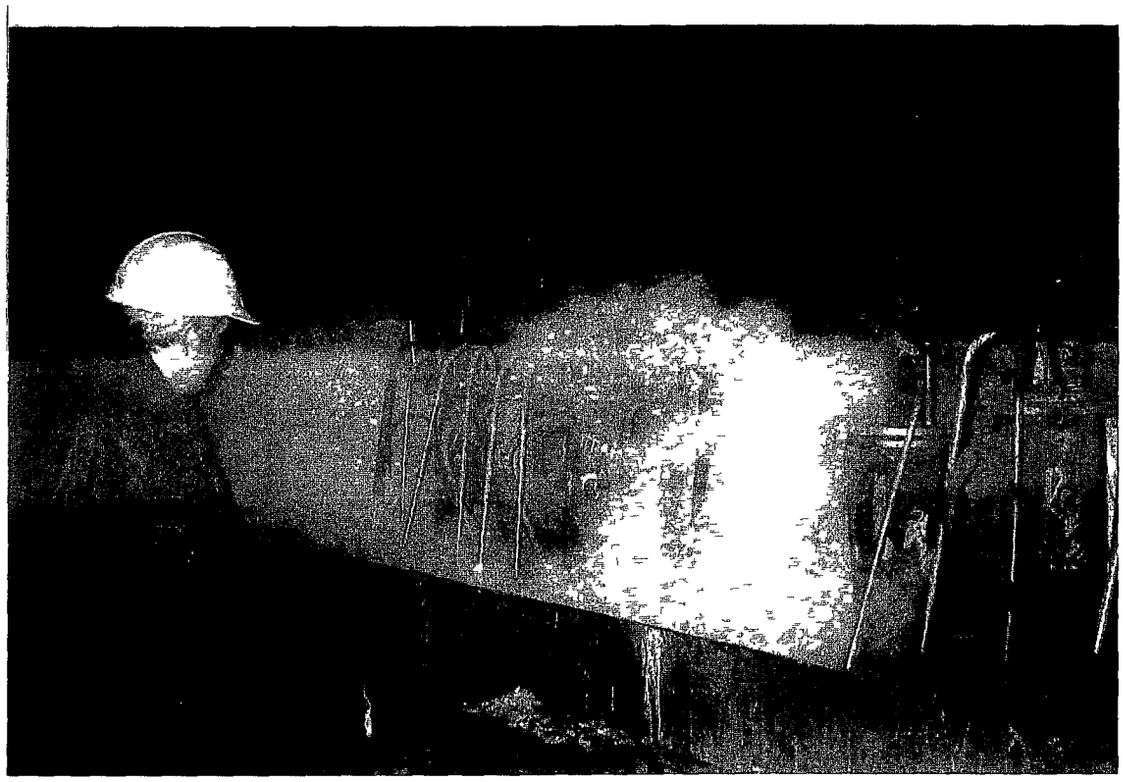
Теплообменники бензольного отделения

Heat exchangers of benzene unit



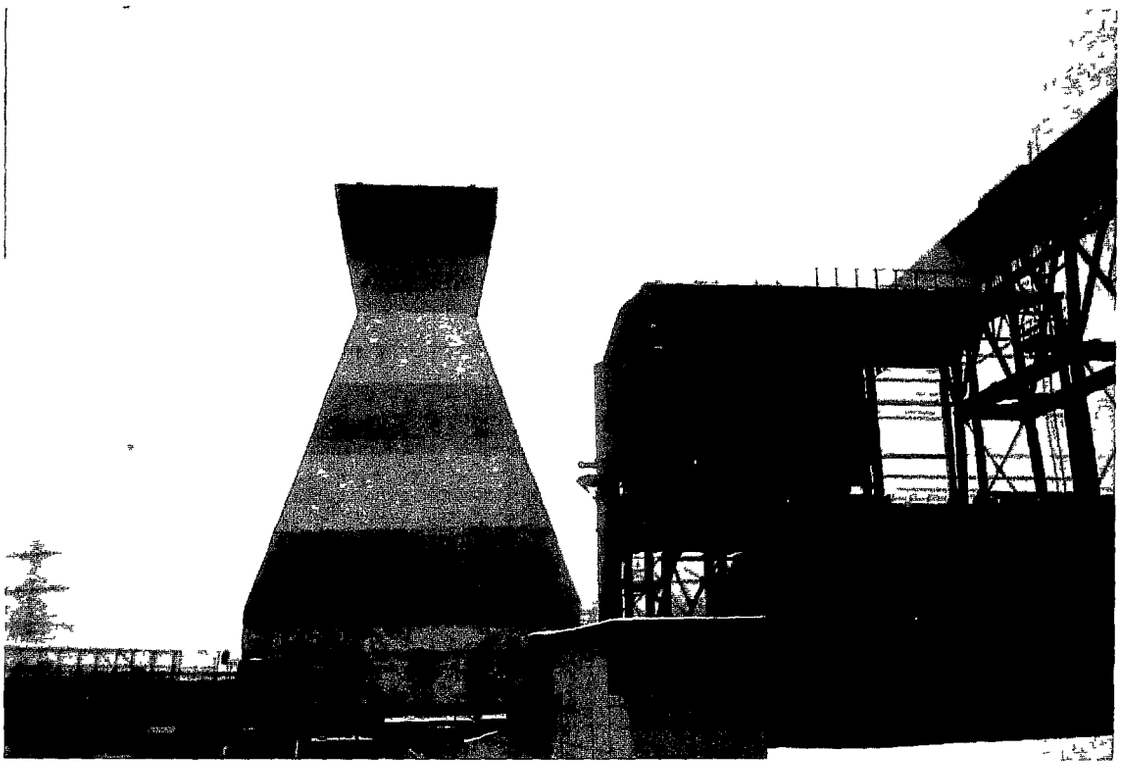
Котельная завода

Plant Boiler-house



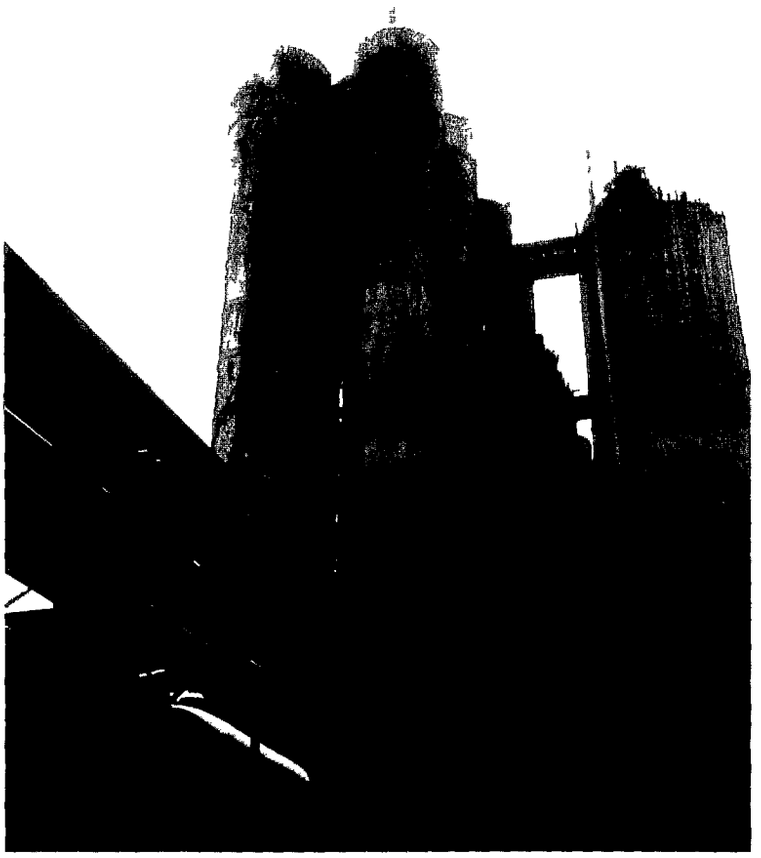
Пробоотборники пара и котловой воды котлов котельной

Steam and boiler water samplers in the Boiler-house



Установка мокрого тушения кокса

Coke quenching plant



Установка сероочистки

Sulfur purification plant

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

56

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)

APPENDIX D ABBREVIATIONS

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