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Industrial Energy Efficiency in Ukraine
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REPORT

ON ENERGY AUDIT

AT THE OPEN JOINT-STOCK COMPANY "INGULETSK ORE CONCENTRATION COMPLEX"

Krivoy Rog, Ukraine

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1. EXECUTIVE SUMMARY

1.1 Introduction

The United States Agency for International Development (USAID) under the Contract #30 has financed energy audits at 24 industrial plants which were selected according to the USAID criteria for implementation of the Industrial Energy Efficiency Project This report describes the findings of the energy audit carried out by the Burns and Roe company at the Open Joint-Stock Company Inguletsk Ore Concentration Complex (OJSC IOCC) in Krivoy Rog, Ukraine

According to Sub-Task #3 of this Contract, 24 industrial plants out of 90 possible candidates were selected for the audit Each plant was considered on the basis of criteria set by the USAID for selecting project participants The selection criteria included long-term economic forecast, financial state of the enterprise, the share of income generated from exports, current output/ rated output ratio, energy saving potential, a possibility for project replication at similar plants, and the accessibility of the plant to serve as a demonstrating facility for others The OJSC IOCC is not the only Ukrainian plant which belongs to the mining and processing sector Most problems pertaining to the plant are typical for Ukrainian industrial enterprises, and their solution can be applied in mining and other industries

The energy audits had the following objectives

- to conduct unofficial training in energy management practices,
- to explain to the plant management the energy management structure,
- to recommend specific steps to improve energy efficiency, including administrative measures, low-cost and no-cost measures,
- to recommend investment opportunities and medium-cost measures aimed at large-scale energy saving

An energy auditors team, comprising two experts, namely (Dmitry Kramarenko - thermal energy and technology energy expert, and Vladimir Mamalyga - electrical engineering expert) conducted energy audit from March 23 to 27

1 2 Administration and energy management

The specific feature of each industrial enterprise is the management's focusing on production issues and its desire to increase production volumes Owing to this, such important issues for the company's operation as energy resources and their cost are often not dealt with adequately

Similar to most Ukrainian industrial enterprises in the past, energy expenses of this plant were substantially subsidized, making energy conservation far-from-priority issue in the plant's activity

In the last few years, energy expenses increased dramatically due to the growing energy prices Currently, energy cost makes up 40% of the price of plant's products

Most Ukrainian industrial enterprises have an expert or a group of experts - energy engineers Typically, these experts are responsible for reliable energy supply to the plant rather than

improving its energy efficiency Due to growing energy prices and the uncertainties in the supply of all types of fuel, energy management is becoming a forefront activity Each enterprise should properly consider introduction of the position of energy manager or, in case with huge industrial facilities, even energy management groups

Such services should regularly monitor all processes and, in particular, estimate monthly energy consumption volumes The data on monthly energy consumption should then be presented graphically and compared with relevant indices in preceding months or years in order to detect changes in energy consumption volumes If such changes have really occurred, the energy management group should identify their cause and make a decision on whether some measures should be implemented in this regard For instance, if monthly figures show an increase in energy consumption, the cause should be detected with further elimination of the problem

In addition to this, the energy management group should systematically study all processes to identify energy conservation opportunities The group experts should assure the implementation of energy efficiency proposals at the plant, beginning from the recommendations listed in this report The energy conservation group should consider all changes proposed to the plant to check their energy efficiency

An energy management group at the plant of the IOCC size should consist of several persons Preferably, such group should include thermal (steam and gas supply and steam and gas operated, and hot water supply systems, heating and heat-operated equipment, etc) and power engineers (transformers, motors, etc) The group leader should report directly to the top management of the plant

Many enterprises assign to their energy management groups such tasks as "to reduce total annual energy consumption by 5%" Of course, the planned percentage may change, but such approach, when a task is set, can be serve as a criterion to assess the work of the group itself The above percentage of energy saving could be much higher at Ukrainian industrial enterprises, where energy conservation reserves are substantial Incentive schemes for specialists in charge of efficient utilization of energy resources should be implemented at plants

1 3 Major Findings

- As expected, the energy auditors team has revealed a number of opportunities to improve energy efficiency under current energy prices Earlier, when energy prices were 20-30 times lower than now, energy efficiency measures were irrelevant Currently, improvement of energy efficiency can be profitable, but is difficult to realize because of high discount rates for bank loans and economic obstacles related to barter settlements and inter-enterprise arrears

- the OJSC IOCC is considered quite successful according to Ukrainian standards for enterprises of such scale, however it has to use barter when selling its products

- Being a large consumer of energy resources, the concentration complex has a number of problems related to efficient utilization of energy resources

  - low efficiency of gas equipment in the boiler house due to the lack of up-to-date automatic systems and inadequate insulation of the boilers,

  - low efficiency of electrical equipment due to the lack of up-to-date automatic control systems,

  - energy efficiency of the plant is also decreasing because rated capacities do not correspond to the actual production output

1.4 Recommendations

The recommendations set forth in this report will help improve energy efficiency, decrease costs for energy resources, enhance the quality of products while reducing their cost, and to assure the competitiveness of the enterprise The complex has several energy conservation opportunities (ECOs) with different pay-back periods
(Table 1 1 List of the Energy Conservation Opportunities (ECOs))

The implementation of the proposed ECOs with a very short payback period (ECO-06, ECO-07, ECO-08, ECO-09, ECO-10) will reduce power consumption by ***3,581,000*** kW•h/year and natural gas consumption by ***3,569,000*** m^3 a year The cost of ECOs with a very short payback period is $***123,000***, the saving is expected to be $***423,700***, average payback period is ***0 29*** year

The implementation of the proposed ECOs with a short and medium payback period (ECO-01, ECO-2, ECO-03, ECO-05, ECO-11, ECO-12) will reduce power consumption by ***84,014,000*** kW•h /year, and gas consumption by ***5,643,000*** m^3/year The cost of ECOs with a short and medium pay-back period is $***4,044,400***, and the saving is expected to be $***4,246,400***, average payback period is ***0 95*** year

The enterprise also presents energy conservation opportunities with pay-back periods of more than 2 years (ECO-04)

The assessment and implementation of the above-listed ECOs and search for other ECOs would require a more detailed energy audit of the plant, elaboration of the development plan of the enterprise, and selection of the energy conservation strategy

List of the Energy Conservation Opportunities

Table 1 1

# of ECO	ECO	Power savings (ths kW•h)	Natural gas savings (ths m^3)	Annual savings (ths $/ year)	Cost of proposed measures (ths $)	Simple payback period (year)	Clause # of this report
1	Institution of Energy Management	53,301	2,102	2,570	2,140	0 83	7 1
2	Modernization of the pulp pumping plant PPP–1	14,016	0	631	760	1 20	7 2
3	Modernization of the pulp pumping plant PPP–2	14,016	0	631	712	1 13	7 2
4	Up-grading of the electric drive system for the plant of circulating water supply	7,000	0	315	732	2 32	7 3 1
5	Introduction of the automated control system at the plant of circulating water supply	2,681	0	121	100	0 83	7 3 2
6	Up-grading of the water supply system to the concentration plants	2,681	0	121	60	0 5	7 4
7	Replacement of pump for water supply to ball mills	131	0	5,9	1 7	0 29	7 5
8	Adjustment of combustion process in boilers of the boiler plant	0	3,500	290	60	0 2	7 6 1
9	Thermal insulation of the end sides of boilers' economizers at the boiler plant	0	22 5	1 9	0 3	0 16	7 6 2
10	Thermal insulation of boilers' screens at the boiler house	0	58 8	4 9	1 0	0 2	7 6 3
11	Additional thermal insulation of the external enclosure of boilers	0	40 6	3 4	2 4	0 7	7 6 4
12	Utilization of effluent gas heat at the boiler house	0	3,500	290	330	1 14	7 6 5
	TOTAL	**93,826**	**9,223 9**	**4,985 1**	**4,899 4**	**0 98**	

2 GENERAL INFORMATION

Name – Open Joint-Stock Company "Inguletsk Ore Concentration Complex" (IOCC), Krivoy Rog

General Director – Alexander P Stankov
Chief Energy Engineer – Nikolay S Orel

Tel – (0564) 22-83-30, 22-83-31
Fax – (0564) 22-11-92

Legal Address

"Inguletsk Ore Concentration Complex",
Dniepropetrovsk oblast, 324064, Krivoy Rog

2 1 Enterprise history

The first stage of the Inguletsk Ore Concentration Complex was put into operation in 1964

For the whole time of the complex operation continuous activities have been carried out to up-grade and modernize the production facilities In 1997 the first stage of the underground conveying system was put into operation The complex has begun production and marketing of the sand

2 2 Production output

The enterprise is engaged in open-cast mining of magnesite and ferruginous quartzite, processes it and produces the following

- iron ore concentrate,
- construction crushed stone,
- sand,
- heat

The rated capacity of the processing complex of the enterprise was designed for production of 15 million tons of concentrate per year

2 3 *Number of personnel*

At present about 10,000 employees work for the Inguletsk Ore Concentration Complex (IOCC)

2 4 *Similar Enterprises in Ukraine*

There are dozens of enterprises in Ukraine, producing iron ore raw materials The most similar, in terms of the technological level and types of production, are the Northern Concentration Complex (Krivoy Rog), Poltava Concentration Complex (Komsomolsk), Southern Concentration Complex (Krivoy Rog), NovoKrivorozhsky Concentration Complex (Krivoy Rog)

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3 CURRENT STATUS OF THE ENTERPRISE

3 1 Export opportunities

At present, the major part of iron ore concentrate is marketed at the domestic market of Ukraine, while some ore concentrate is also exported to the Eastern Europe

3.2. Structure of the enterprise

The enterprise consists of

- open cut,
- department of railway transport,
- department of automobile transport,
- crushing-and-concentration complex,
- boiler house,
- auxiliary departments, providing for the operation of principal workshops

3 3 Consumers of the enterprise's products

Main consumers of the iron ore raw material in Ukraine are steel works of Krivoy Rog, Dniepropetrovsk Dnieprodzerzhinsk and Enakiev

The products are also exported to East European countries

3 4 Importance of the sector to the national economy

Since the Open Joint-Stock Company "Inguletsk Ore Concentration Complex" is one of the largest producers of raw materials (iron ore) for the ferrous metallurgy in Ukraine and other CIS countries, and its products are competitive, this enterprise has good prospects and is of importance for the Ukrainian economy

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4. FINANCIAL STATUS OF THE ENTERPRISE

4.1. Currency versus barter

Marketing of the most part of the enterprise's products (70%) is carried out through barter transactions

4 2 Viability of the enterprise

During all history of its operation (including last years) the complex was among those few enterprises of mining sector, which have been profitable

At present, the level of profitability has reached *30%*

5 ENERGY CONSUMPTION

5 1. Power

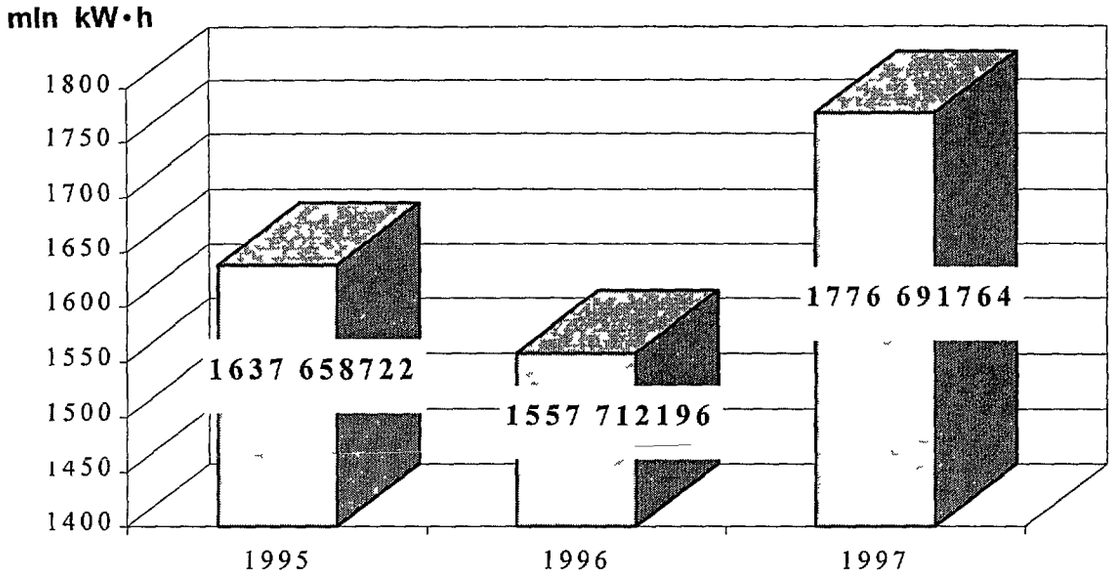

Figure 5 1 *Energy consumption by the complex in 1995 – 1997*

Energy consumption by major units of the enterprise

Table 5 1 *Energy consumption by major departments of the enterprise*

#	Department	Units	January 1998	August 1997
1	Concentration plant # 1	kW h	51,439,800	53,095,900
2	Concentration plant # 2	kW h	49,143,000	52,536,550
3	Crushing plant	kW h	6,839,450	6,000,610
4	Open cut	kW h	5,742,600	4,881,350
5	Burden preparation works (PPW)	kW h	880,950	924,400
6	Pulp facilities and process water supply plant	kW h	33,328,780	31,350,530
7	Power department	kW h	3,660,300	2,633,110
8	Department of railway transport	kW h	1,553,780	1,884,400
9	Other consumers	kW h	1,015,030	999,850
	Total	kW h	153,603,690	154,306,700

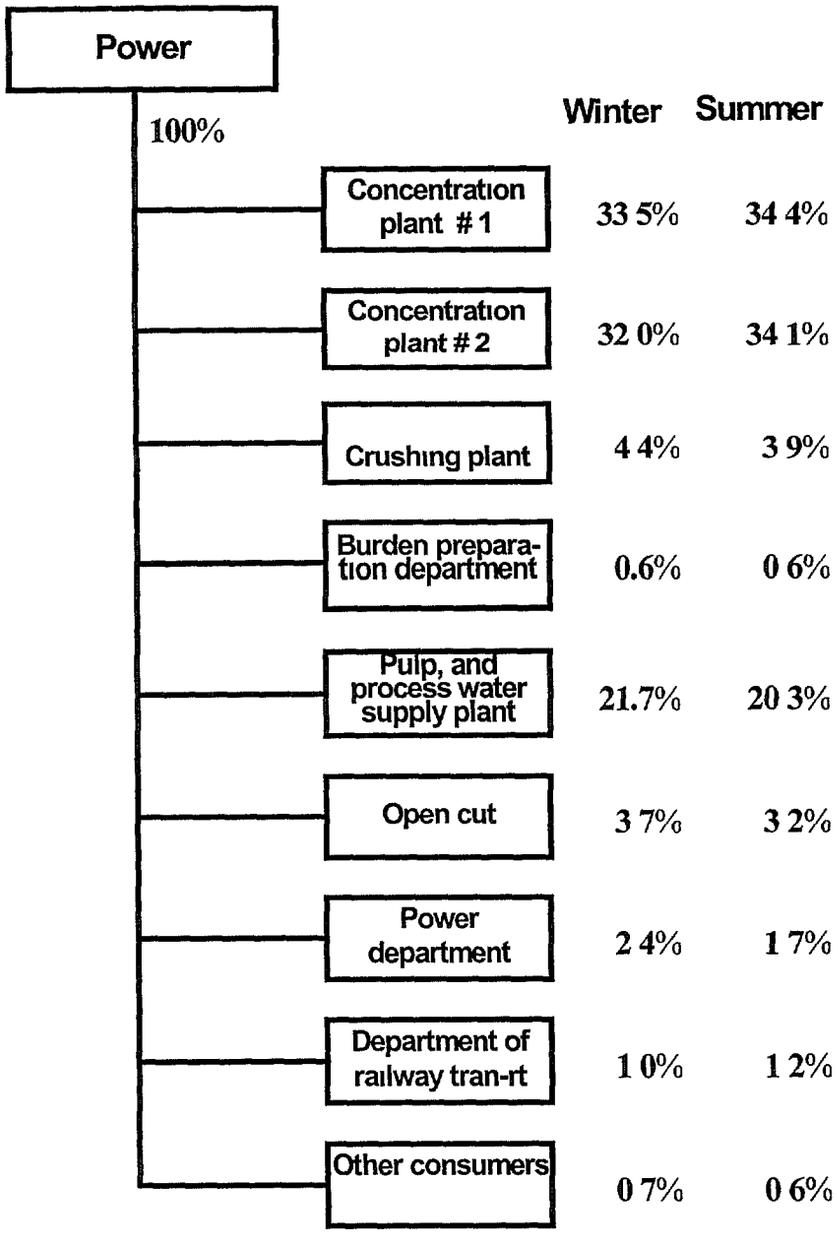

Figure 5 2 **Balance of power consumption by the enterprise units**

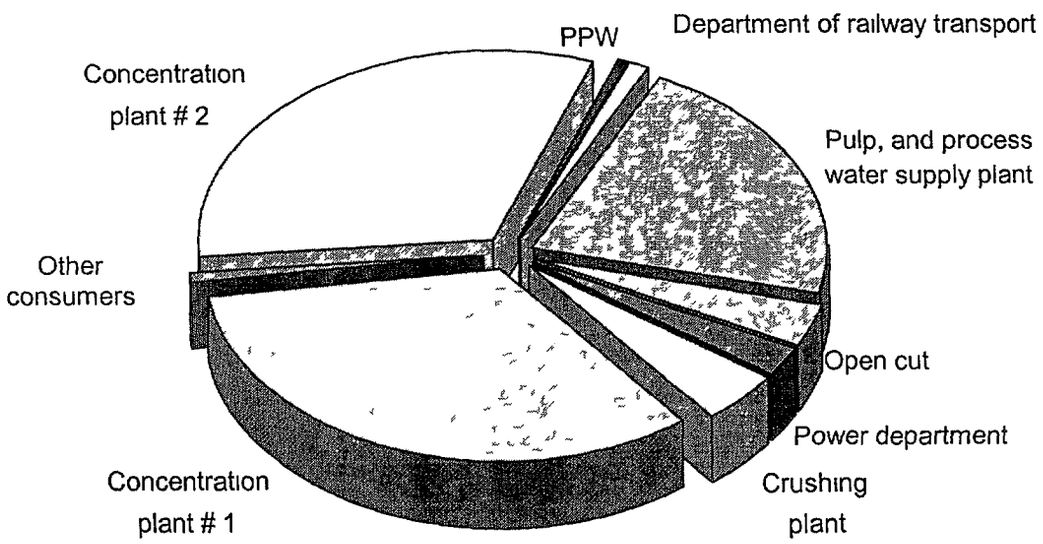

Figure 5 3 *Power consumption by the enterprise units*

Table 5 2 *Power consumption in 1997*

	Power consumption kW h
Month	**1997**
January	151,846,901
February	136,317,489
March	158,145,682
April	146,681,989
May	146,055,001
June	145,001,940
July	149,419,237
August	154,933,590
September	149,623,280
October	145,429,842
November	148,600,077
December	144,636,736
Total	**1,776,691,764**

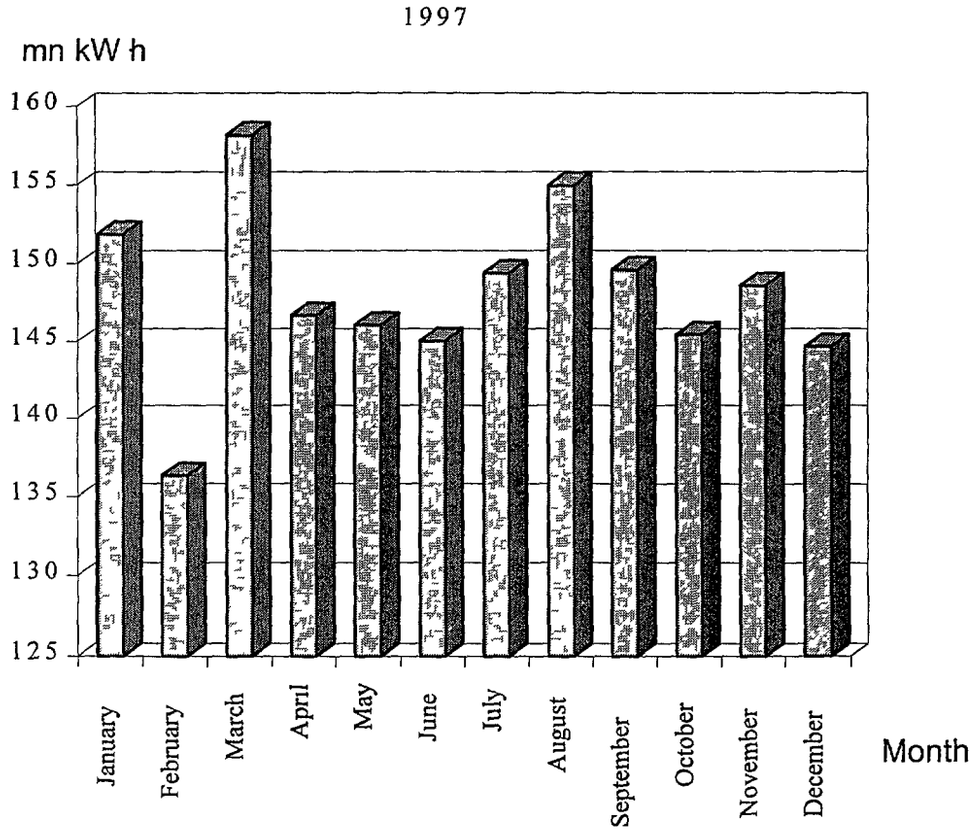

Figure 5 4 *Power consumption by the enterprise in 1997*

5 2 *Natural gas*

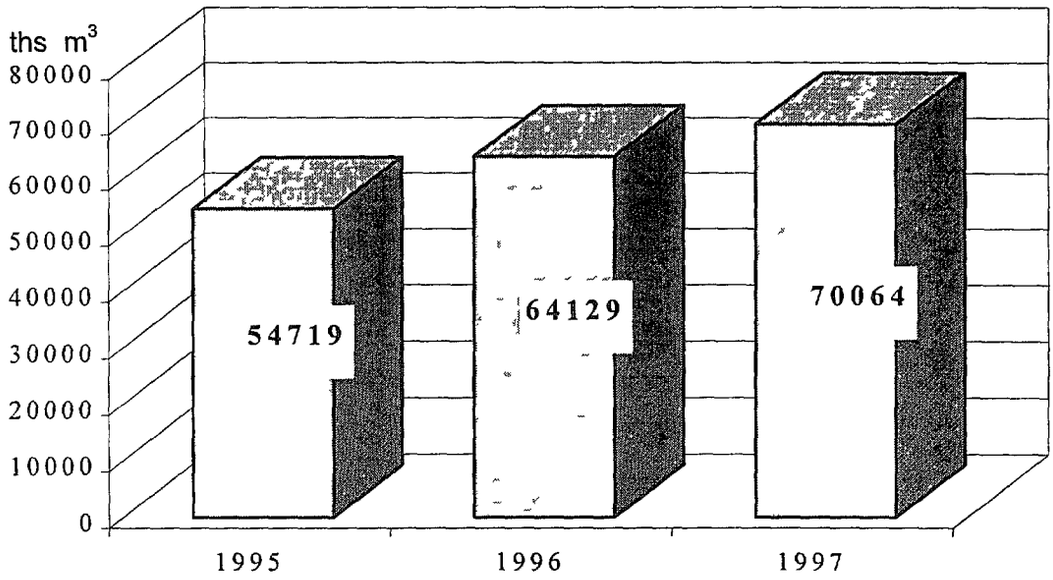

Figure 5 5 *Natural gas consumption in 1995 – 1997*

Table 5 3 *Natural gas consumption by the enterprise units*

#	Department	Units	January 1998	August 1997
1	Boiler house	ths m^3	9,921	2,193
2	Bricks production plant	ths m^3	36	40
3	Zinc melting furnaces	ths m^3	5	5
4	Canteen	ths m^3	5	5
	Total	ths m^3	9,967	2,243

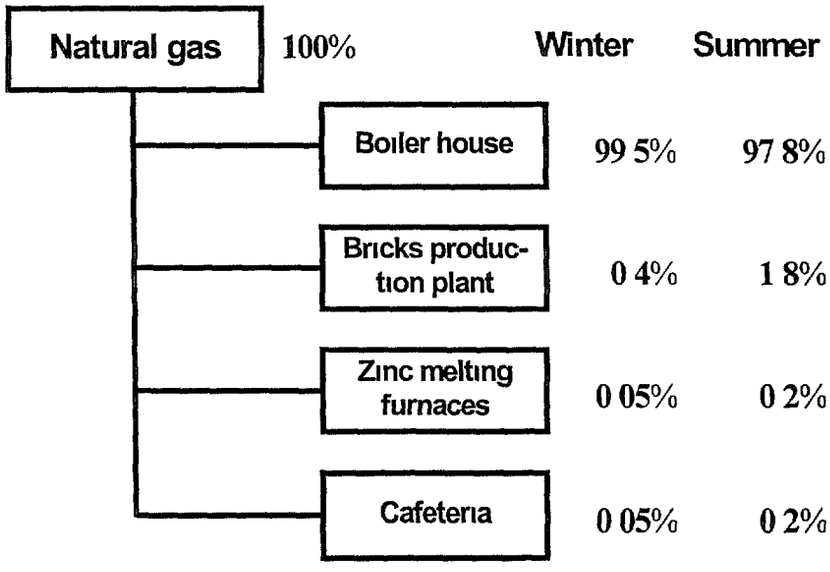

Figure 5 6 *Balance of natural gas consumption by the enterprise units*

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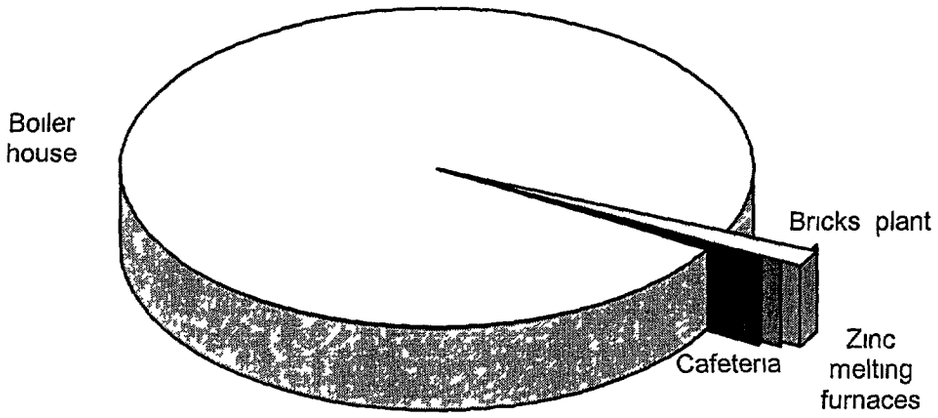

Figure 5 7 ***Natural gas consumption by the enterprise units***

Table 5 4 ***Natural gas consumption in 1997***

	Natural gas consumption, ths m^3
Month	**1997**
January	12,679
February	10,844
March	9,127
April	6,538
May	2,792
June	2,262
July	2,001
August	2,243
September	2,178
October	4,332
November	6,484
December	8,584
Total	**70,064**

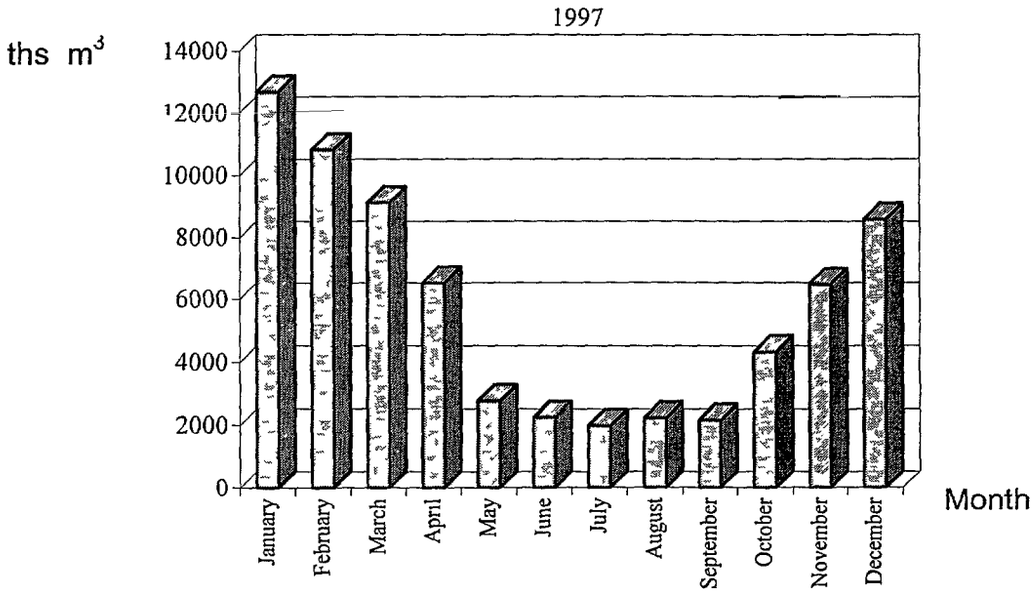

Figure 5 8 ***Natural gas consumption in 1997***

Production of heat by the boiler house and consumption of steam and hot water

Table 5 5 ***Heat consumption (steam, hot water)***

#	Consumers	Units	January 1998	August 1997
1	Own needs of the enterprise	GCal	54,495	9,981
2	District residents	GCal	26,272	3,898
3	Other enterprises	GCal	5,226	1,268
	Total	GCal	85,993	15,147

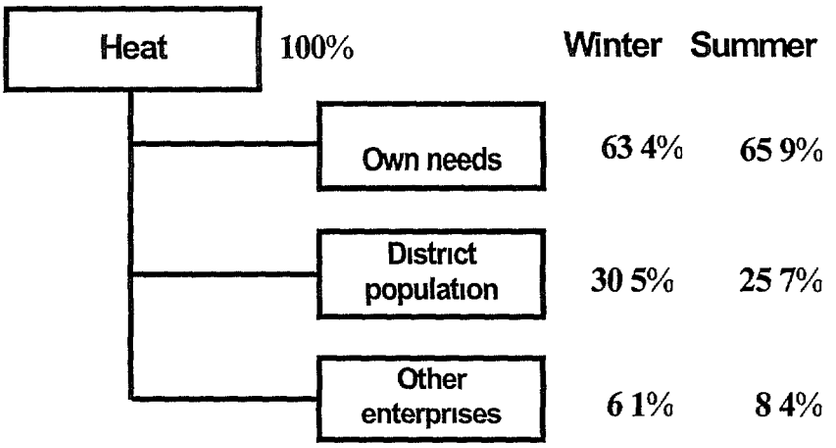

Figure 5 9 ***Balance of heat consumption (steam, hot water)***

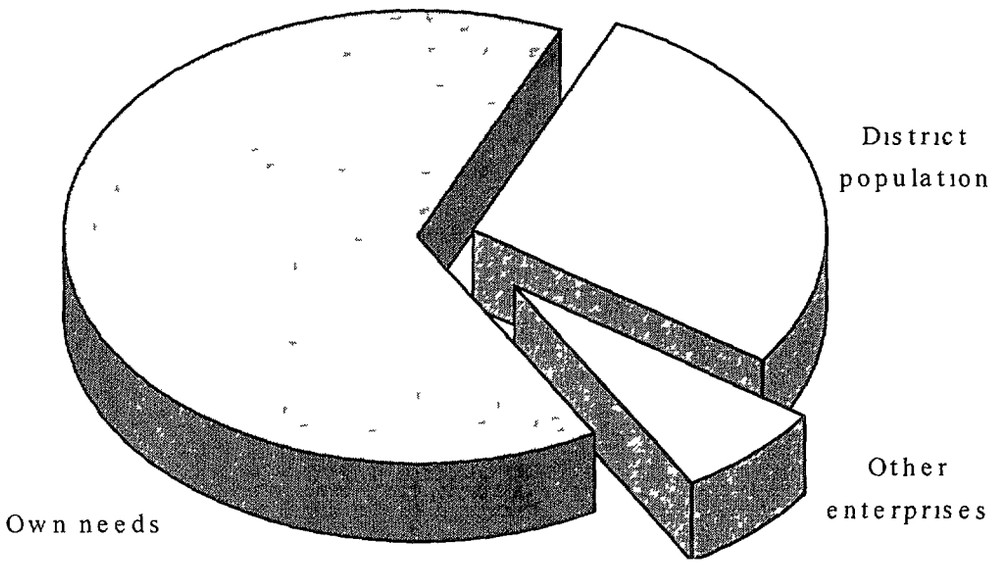

Figure 5 10 ***Steam and hot water consumption***

6 PREVIOUS ACTIVITY IN THE FIELD OF ENERGY CONSERVATION

Inguletsk Ore Concentration Complex is one of the few mining enterprises in Ukraine, that during some years have carried out some activity, related to the energy conservation Thus, railway transport replaced quarry dump trucks and an underground conveying system was commissioned last year An automated system of monitoring and control of automobile transport was installed in an open cut According to the concentration complex order the institutes "Mechanobrchermet" and Krivbassruda" worked out a complete set of energy saving measures However, economic aspect of these measures requires more thorough elaboration, the fact, that seemingly explains why these measures were not implemented

It is also important to note that up to now no energy audits have been carried out at the enterprise The above increases the importance of the energy audit, performed at the Inguletsk Ore Concentration Complex, which results are shown in this report

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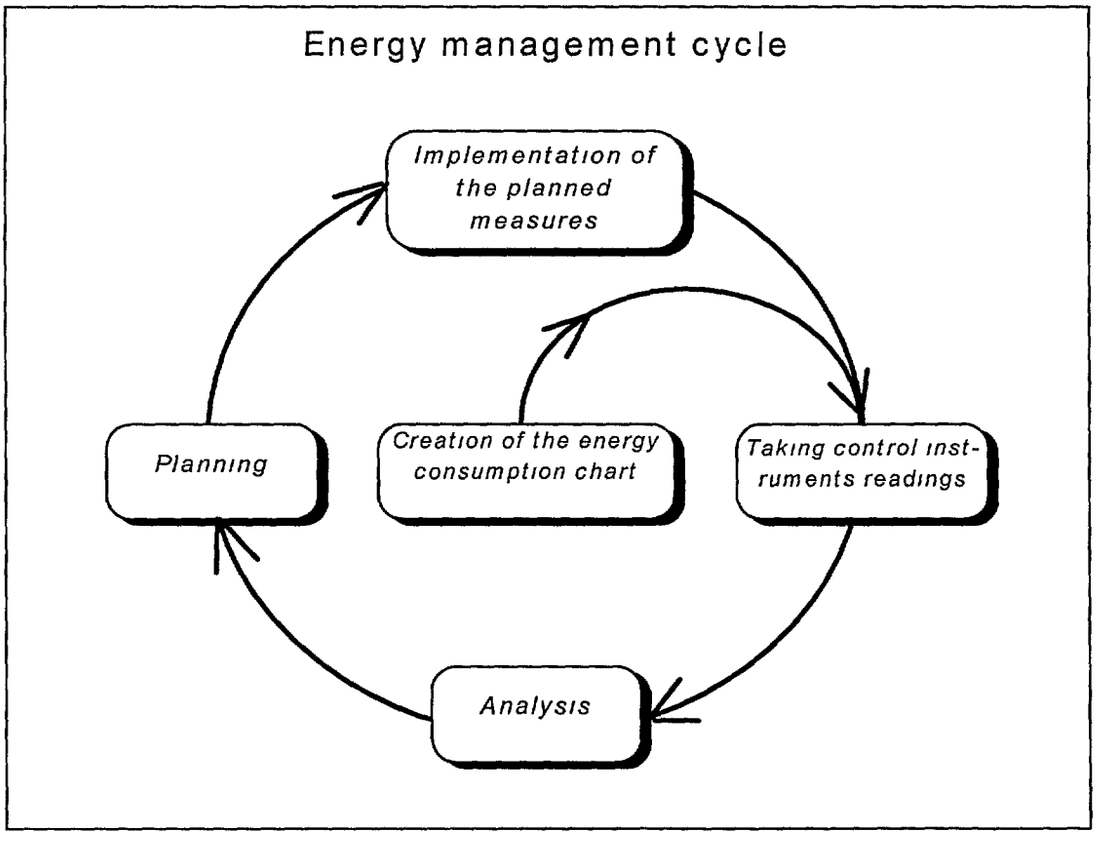
7 ENERGY AUDIT

7 1 Institution of energy management

Description of the ECO

Energy Management is the main mechanism of reducing energy consumption and increasing energy efficiency in the industrial enterprises Energy management is a system of management, based upon the serial measurements and tests, thus, providing such type of the enterprise operation, when the exact needed amount of energy is consumed for the production purposes Energy management is an instrument for the enterprise control, which ensures continuous study, therefore providing the knowledge of distribution and consumption of energy both for the production and for heating and other non-production purposes



Picture 7 1 **Energy Management Cycle**

Introduction of the energy management would make it possible to obtain more detailed picture of energy consumption, which would provide a basis to compare consumption levels with those at the other enterprises for the purpose of thorough evaluation of the energy saving projects, planned for the introduction at this enterprise

Energy Management begins from the appointment of a corresponding employee (energy manager), who would bear responsibility for the introduction of energy management at the enterprise Following are the main duties of the energy manager

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- Preparing facility's energy consumption chart (probably in collaboration with an outside consultant - energy auditor),
- Collecting fuel and energy consumption data, using measuring instrumentation,
- Preparing a plan for installation additional meters and measuring equipment,
- Collecting data on raw materials, energy consumption and production output,
- Carrying out basic calculations, related to the improvement of energy efficiency, both for overall plant and for individual production lines,
- Implementing new technologies on existing and new energy systems to improve energy efficiency of operation,
- Keeping himself informed on trends in the current energy policy and accompanying issues, (e g , new tax legislation, existing restrictions for energy consumption levels, subsidies, environmental aspects etc)

It is proposed to introduce an energy management system at the enterprise in full volume Implementation of this proposal will provide an opportunity to reduce energy consumption by *3%*

To introduce energy management system the enterprise should elaborate and install a power metering system with interpretation of the power meters readings from all transformer sub-stations in a time range The existing commercial system of metering monitors only overall power consumption, while all internal consumers are checked sporadically

It is necessary to elaborate a metering system for all kind of energy, employing up-to-date computer devices, which will provide opportunities to assess the energy consumption dynamics in the process of production and to prepare recommendations concerning energy saving

Calculation of the annual energy saving

According to the 1997 records, the enterprise consumed for a year some ***1776692*** ths kW•h of power and ***70064*** ths m^3 of fuel (natural gas) The world experience and practice confirm that after introduction of the energy management the energy consumption is usually reduced by *3%* The energy saving would make up

1) Power – $1,776,692 \times 0\ 03 = 53,301$ ths kW•h
2) Natural Gas – $70,064 \times 0\ 03 = 2,102$ ths m^3

Calculation of annual savings of energy costs

1 At the price of $45 for ***1,000 kW•h*** of power the savings will be

$$53,301 \times 45 = \$2,400,000$$

2 At the price of $83 for ***1,000*** m^3 of gas the savings will be

$$2,102 \times 83 = \$170,000$$

The total savings of energy expenses will make up

$$2,400,000 + 170,000 = \$2,570,000$$

Costs of setting-up the energy management department

Energy management department wages fund and incentive fund to stimulate production departments to save energy	*$100,000*
Introduction of the energy metering system at the plant (designing, mounting, adjustment)	*$2,000,000*
Purchase of necessary energy audit equipment	*$40,000*
Total costs	*$21,400,000*

Simple payback period

$21,400,000/$2,570,000 = 0 83 year

7.2 Modernization of the pulp pumping plants PPP-1 and PPP-2

Proposal

To install at the pulp pumping plants of the Inguletsk Ore Concentration Complex frequency converters to control pumps operation

Study results

At present two pulp pumping plants are operating at the complex PPP-1 (10 pumps) and PPP-2 (6 pumps) Capacity of pump driving motors is 3200 kW at each pulp pumping plant

Annual Energy Saving

Installation of frequency converters to control pumps operation would reduce the consumed power by 50%

The annual power saving for PPP-1 and PPP-2 would be

3,200 kW *0 5* *8,760* hour/year = *14,016,000* kW h/year

Saving of annual costs

At the price of $45 for one thousand kW•h of power the savings of annual expenses for each pulp pumping plant would make up

14,016 ths kW•h/year *$45*/thousand kW•h = *$631,000*/year

Implementaion cost

The following equipment shall be purchased to implement this energy conservation opportunity

1) For PPP-1

- frequency converter

  3,200 kW × *$200*/kW = *$640,000*

- high voltage switches to disconnect motors from frequency converters after the pumps start-up, and their connection to the 6 kV line

  10 pieces × *$10,000* = *$100,000*

- cables and wires

  10 pieces × *$2,000* = *$20,000*

Total for PPP-1 *$760,000*

2) For PPP-2

- frequency converter

  3,200 kW × *$200*/kW = *$640,000*

- high voltage switches

  6 pieces × *$10,000* = *$60,000*

- cables and wires

  6 pieces × *$2,000* = *$12,000*

Total for PPP-2 *$712,000*

Simple payback period

Payback periods for two pulp pumping plants would make up

- For PPP-1

  $760,000/*$631,000*/year = *1 20* year

- For PPP-2

  $712,000/*$631,000*/year = *1 13* year

Conclusion Given comparatively short payback periods it is recommended to implement these measures at any interest rate on loans in Ukraine

7 3 *Upgrading of circulating water supply plant.*

7 3 1 Upgrading of the electric drive system for the plant of circulating water supply

Proposal

To install frequency converter for the purpose of controlling pumps of circulating water supply plant

Study results

At present, the circulating water supply plant is equipped with two types of pumps with driving synchronized motors, ***1000 and 1600 kW*** each There are 16 pumps operating at the enterprise

Power saving

Installation of a variable speed drive would provide a possibility to reduce the consumed power by 800 kW The annual saving of power, consumed by the system of circulating water supply, resulted from installation of the frequency converters will make up

800 kW × 8,760 hours/year = 7,000,000 kW • h/year

Saving of annual costs

At power price of $45 for a thousand kW • h the savings of annual expenses would make up

7,000 ths kW • h/year *$45*/thousand kW • h = ***$315,000***/year

Implementation cost

Since there are two types of motors operating at the plant (1000 and 1600 kW) it is necessary to install two types of frequency converters

The cost of frequency converter is equal to $200 for 1 kW of the motor power

The following equipment shall be purchased to implement this energy conservation opportunity

- frequency converter to control 1000 kW motors (at the price of $200,000)
- frequency converter to control 1600 kW motors (at the price of $320,000)
- high voltage switches to disconnect motors from frequency converters after the pumps start-up, and their connection to the 6 kV line

  16 pieces × ***$10,000 = $160,000***

- cables and wires

  16 pieces × ***$2,000 = $32,000***

Total ***$732,000***

23

Simple payback period

Payback period for this ECO is

$732,000/$315,000/year = 2 32 year

Conclusion Due to the quite long payback period, implementation of this opportunity may be recommended on condition that a loan is available for a lower interest rate than the present rate of Ukrainian state loan bonds

7 3 2 Introduction of the automated control system at the circulating water supply plant

Proposal

Install controlled valves and an automated control system to controlr operation of circulating water supply to the concentration plants

Study results

The circulating water supply plant is connected to the concentration plants with five pipe-lines, running from the common header The pumps discharge into the common header At present all pipe-lines have manually controlled gate valves, and manometers, reading pressure in these pipe-lines From time to time maintenance personnel manually adjust pressure in the pipe-lines, running from the plant of circulating water supply

Annual energy savings

Automation of operation of the circulating water supply plant would save *3–5%* of the power, used for water pumping, i e

$$0\ 03 \times (2 \times 1{,}600\ \text{kW} + 7 \times 1{,}000\ \text{kW}) \times 8{,}760\ \text{hours/year} = 2{,}681{,}000\ \text{kW/hour/year}$$

Annual saving of costs

At the power price of *$45* for *1,000* kW h the saving of expenses would make up

$$2{,}681{,}000\ \text{kW/hour/year} \quad \$45\ /\text{ths kW h} = \$121{,}000/\text{year}$$

Implementation cost

Cost of automatic equipment

- conrolled valves (*5* pieces) *$10,000* × *5* pc = *$50,000*
- automation equipment *$50,000*

Total amount, required to implement this energy conservation opportunity *$100,000*

Simple payback period

This ECO's payback period is

$$\$100{,}000 / \$121{,}000/year = 0\ 83\ year$$

Conclusion Given the short payback period this energy conservation opportunity is one of the most prospective for implementation at the enterprise

7.4. Up-grading of the system of water supply to the concentration plants

Proposal

To create closed system of the process water supply to the concentration plants # 1 and # 2

Study results

At present, the system of process water supply is of open type That is why, due to accidental switching on and off the sections of concentration plants the present energy expenses by 3 - 5% exceed the necessary amount To eliminate such losses it is necessary to lay and put into operation up to 200 m of pipes

Annual saving of energy

Creation of the closed system of process water supply at the concentration plants would save at least 3% of the power annually consumed for water pumping

$$0\ 03 \times (2 \times 1600\ \text{kW} + 7 \times 1{,}000\ \text{kW}) \times 8{,}760\ \text{hour/year} =$$
$$= 2{,}681{,}000\ \text{kW} \cdot \text{hour/year}$$

Annual saving of costs

At the price of *$45* for *1,000* kW h of power the annual saving would be

$$2{,}681{,}000\ \text{kW} \cdot \text{h/year} \quad \$45/\text{ths kW h} = \$121{,}000/\text{year}$$

Cost of putting into operation

Cost of a pipe	*$200* for *1* meter
Total cost of pipes	*$200*/m × *200* m = *$40,000*
Cost of designing and study work	*$20,000*

Total cost of this ECO implementation ***$60,000***

Simple payback period

The payback period of this ECO would make up

$60,000 / 121,000/year = 0 5 year

Conclusion Given the short payback period this energy conservation opportunity is one of the most prospective for implementation at the enterprise

7.5. Replacement of the pump for water supply to ball mills with more efficient ones

Proposal

To replace the pump ***8GR–8*** by three more efficient pumps of ***AR-100 150 170DN*** type

Study results

At present, water to the ball mills is supplied by ***8GR–8*** pumps There are also back-up units to ensure reliability of water supply ***8GR–8*** pumps are driven by ***125*** kW or ***132*** kW motors The study results show that the motors are loaded for ***40–60%*** of their rated power That is why it is necessary to replace the existing motor (pump-motor assembly) by that of less power Since ***8GR–8*** pump and its motor are subject to replacement (due to their wearing out), it is recommended to consider expediency of their replacement with three pumps of ***AR-100 150 170DN*** type and one frequency converter

Annual saving of energy

Replacement of ***8ÃĐ–8*** pump by three more efficient pumps of ***AĐ-100 150 170AI*** type (with the motors power of ***20*** kW) the power saving would make up ***25%*** Thus, the annual power saving would be

0 25 (*3* pieces *20* kW) *8760* hours/year = *131,000* kW • h/year

Annual saving of costs

At the power price of ***$45*** for ***1,000*** kW h the saving would make up

131,000 kW/year *$45*/ths kW h = *$5,900*/year

Implementation cost

The cost of ***8GR–8*** pump is ***$20,000***, but taking into consideration their lower reliability and shorter service life (***2–3*** times), compared to AR-***100 150 170DN*** pumps, their actual cost will be higher and make up some ***$40,000***

The cost of a system, consisting of three ***AR-100 150 170DN*** pumps with motors and one frequency converter will be

- pumps with motors (***3 pieces***) ***$20,900***
- frequency converter ***$20,800***

Total ***$41,700***

Difference in cost of two options ***$41,700 – $40,000 =$1,700***

Simple payback period

The payback period of this ECO is

$1,700/$5,900/year = ***0 29 year***

Conclusion Given the short payback period it is recommended to implement this energy conservation opportunity for all pumps, at the time of their planned replacement

7 6 Modernization of the boiler house to enhance efficiency of its operation

The following parameters have been determined during tests

- composition of gas and air mixtures (***O_2***, ***CO***, ***CO_2***, ***NO_x***, excess air) – by gas analyzer ***ENERAC - 2000***, produced by the ***Energy Efficiency Systems, Inc*** (USA),
- surface temperatures - by the ***Heat Spy DHS-24X,*** infrared temperature detector/indicator, produced by the ***Wahl Instruments, Inc*** (USA)

All measurements were carried out at operating boilers

The following has been measured

1) composition of effluent gas (#1,2,4 boilers),
2) composition of effluent gas (hot-water boiler),
3) external surfaces temperature of boilers

Measurements have been carried out at the following ambient conditions

- barometric pressure – ***100–101 kPa***
- ambient temperature – ***14–19 °C***

7 6 1 Adjustment of combustion process in boilers

Proposal

Install systems to adjust combustion process upon actual air flows and to control automatically the fuel-air ratio according to the boilers load

Study results

There are three boilers of ***DKVR-10/13*** type, one boiler of ***DKVR-20/13*** type and one boiler of ***KVGM-100*** type at the boiler house

The system of combustion process control, used at these boilers, is out-dated, though it is widely used in the CIS countries As a result exhaust gases have ***50 . 80%*** of excess air

Main drawbacks of the existing system of combustion process control are the following

- Use of the values of forced air pressure instead of actual values of air flow Therefore, it is not possible to carry out quality control of air flow, and the fuel-air ratio during the combustion process,
- Lack of automatic control of excess air supply according to the load, i e no control of oxygen supply Existing system is based on manual control of air supply, according to the mode schemes, when the load is changed In fact it is not performed and the boiler operates at excessive supply of air,
- Lack of automatic correction of excess air at boilers outlets

We propose to solve all three problems For this purpose a piezometric ring shall be installed at the forced-draft fan of each boiler Piezometric ring will be an element of the air forcing system Auxiliary equipment shall include two differential pressure transducers, gas (air) analyzer, controller with microprocessor, and a drive with frequency control This system will provide possibility to adjust combustion process upon actual air flows and to control automatically the relationship fuel-air according to the boiler load

Upon implementation of this ECO the boiler may operate at the following values of excess air *5%* after the boiler, and *15%* before induced-draft fan Fuel-air ratio will be controlled automatically according to the load This will result in ***5-10%*** of fuel (natural gas) saving

Annual saving of energy

Annual consumption of natural gas by the boiler house is ***70,000,000*** m^3 *5%* of annual saving of natural gas will correspond to ***3,500,000*** m^3/year

Annual saving of costs

At the natural gas price of ***$83*** for ***1,000*** m^3 the annual saving will be

3,500,000 m^3/year x ***$83***/ths m^3= ***$290,000*** a year

Implementation cost

Cost of equipment

Differential transducer, *10* pieces	*$15,000*
Microprocessor based controller, *5* pieces	*$7,500*
Gas analyzer, *5* pieces	*$20,000*
Frequency controlled drive, *5* pieces	*$7,500*
Shipping and transportation	*$10,000*
TOTAL cost of equipment	*$60,000*

Cost of installation and putting into operation

Materials and labor to be provided by the enterprise Their cost will be low

Registration and certification in the State Committee for Supervision	*$2,000*
Technical inspection and acceptance	*$2,000*
Total cost for registration and acceptance	*$4,000*
Total cost for putting into operation	*$60,000*

Simple payback period

Cost for putting into operation	*$60,000*
Annual saving of expenses	*$290,000*

At the price of *$83* for *1000* m^3 of natural gas the simple payback period will make up

$60,000 / $290,000 = 0 2 year

Conclusion Due to the short payback period it is recommended to implement this ECO

7 6 2 Heat insulation of the end sides of boilers' economizers

Proposal

To install thermal insulation at the end sides of boilers' economizers to reduce heat losses

Study results

Average temperature of the end sides of ***DKVR-10/13*** boilers' economizers is 90°C (while the rated temperature is 40°C) Installation of thermal insulation will reduce heat losses, therefore the boilers operation will be more efficient

Annual saving of energy

Heat losses at the end sides of economizer (one boiler) at the temperature 90°C (heat transfer factor α=*6 7* kCal/m²h°C), total area of non-insulated sections of pipes *15* m², average ambient temperature *15* °C make up

$$15 \quad 6\ 7 \quad (90-15) = 7{,}500 \text{ kCal/h}$$

Heat losses at one boiler, after installation of thermal insulation and lowering temperature of the end sides of economizer down to *40*°C (heat transfer factor α=*2 0* kCal/m²h°C), at the area of thermal insulation *10* m² will make up

$$10 \quad 2\ 0 \quad (40-15) = 500 \text{ kCal/h}$$

Reduction of heat losses from the economizer of one boiler, after installation of thermal insulation, will be *7,500* kCal/h – *500* kCal/h = *7,000* kCal/h

Annual saving of heat, taking into consideration shutdown of one boiler for summer period, (factor *2,5*) will be

$$7{,}000 \quad 24 \quad 365 \quad 2{,}5 = 153{,}300{,}000 \text{ kCal/year}$$

Annual saving of natural gas at the lowest heat value of natural gas Q^d_i=*8000* kCal/m³ of gas and boiler combustion efficiency of *85*%, will be

$$153{,}300{,}000/(8{,}000 \times 0\ 85) = 22{,}500 \text{ m}^3\text{/year}$$

Annual saving of costs

At the cost of natural gas *$83* for *1,000* m³ the expenses saving would make up

$$22{,}500 \text{ m}^3\text{/year} \times \$83\text{/ths m}^3 = \$1{,}900 \text{ /year}$$

Implementation cost

Cost of heat insulation (including designing and installation) for three boilers

$$30 \text{ m}^2 \quad \$10\text{/m}^2 = \$300$$

Simple payback period

Cost of putting into operation	*$300*
Annual saving of expenses	*$1,900*

At the price of *$83* for 1,000 m³ of natural gas the simple payback period would be

$$\$300 \,/\, \$1{,}900 = 0\ 16 \text{ year}$$

Conclusion Due to the short payback period and its low-cost it is recommended to implement this ECO

7 6 3 Thermal insulation of boilers screens

Proposal

To install thermal insulation at the front and back screens (collectors, drums, pipes) of the boilers to reduce heat losses

Study results

Average temperature of the collectors, drums, pipes at the front and back screens of ***DKVR-10/13*** and ***DKVR-20/13*** boilers is 160°C (while the rated temperature is 40°C) Installation of thermal insulation will reduce heat losses, therefore the boilers operation will be more efficient

Annual saving of energy

Heat losses at the front and back screens of one boiler at the average surface temperature 160°C (heat transfer factor α=*5 0* kCal/m²h°Ñ), total area of non-insulated sections *20* m², average ambient temperature *15* °Ñ make up

20 5 0 (160 – 15) = 14,500 kCal/h

Heat losses at one boiler, after installation of thermal insulation and lowering temperature of the front and back screens down to *40*°Ñ (heat transfer factor α=*2 4* kCal/m²h°Ñ), at the area of thermal insulation *25* i² will make up

25 2 4 (40 – 15) = 1,500 kCal/h

Reduction of heat losses from the screens of one boiler, after installation of thermal insulation, will be *14,500* kCal/h – *1,500* kCal/h = *13,000* kCal/h

Annual saving of heat, taking into consideration shutdown of one boiler for summer period, (factor *3,5*) will be

13,000 24 365 3,5 = 400,000,000 kCal/year

Annual saving of natural gas at the lowest heat value of natural gas Q^d_l=*8,000* kCal/m³ of gas and boiler combustion efficiency of *85*% will be

400,000,000 /(8,000 x 0 85) =58,800 m³/year

Annual saving of expenses

At the price of natural gas *$83* for *1,000* m³ the expenses saving would make up

58,800 m³/year x *$83*/ths m³= *$4,900* /year

Cost of putting into operation

Cost of heat insulation (including designing and installation) for four boilers

$$100\ \text{m}^2 \quad \$10/\text{m}^2 = \$1000$$

Simple payback period

Cost of putting into operation *$1000*

Annual saving of expenses *$4,900*

At the price of *$83* for 1,000 m^3 of natural gas the simple payback period would be

$$\$1000 / \$4,900 = 0\ 2\ \text{year}$$

Conclusion Due to the short payback period it is recommended to implement this ECO

7 6 4 Additional thermal insulation of the external enclosure of boilers

Proposal

To install additional thermal insulation at the external enclosure of boilers to reduce heat losses

Study results

Average temperature at the external enclosure of ***DKVR-10/13*** and ***DKVR-20/13*** boilers is 65°C (while the rated temperature is 40°C) Installation of additional thermal insulation will reduce heat losses, therefore the boilers operation will be more efficient

Annual saving of energy

Heat losses at one boiler at the temperature of external enclosure 65°C (heat transfer factor α=*2 5* kCal/m^2h°C), total area of *120* m^2, average ambient temperature *15* °C make up

$$120\ \ 2\ 5\ \ (65 - 15) = 15{,}000\ \text{kCal/h}$$

Heat losses at one boiler, after installation of additional thermal insulation and lowering temperature of external enclosure down to *40*°C (heat transfer factor α=*2 0* kCal/m^2h°C) will make up

$$120\ \ 2\ 0\ \ (40 - 15) = 6{,}000\ \text{kCal/h}$$

Reduction of heat losses at one boiler, after installation of additional thermal insulation, will be *15,000* kCal/h – *6,000* kCal/h = *9,000* kCal/h

Annual saving of heat, taking into consideration shutdown of one boiler for summer period, (factor *3,5*) will be

$$9{,}000\ \ 24\ \ 365\ \ 3{,}5 = 275{,}940{,}000\ \text{kCal/year}$$

Annual saving of natural gas at the lowest heat value of natural gas Q^b_i=*8,000* kCal/m^3 of gas and boiler combustion efficiency of *85%* will be

275,940,000 /(8,000 x 0 85)=40,600 m^3/year

Annual saving of expenses

At the price of natural gas *$83* for *1,000* m^3 the expenses saving would make up

40,600 m^3/year x *$83*/ths m^3= *$3,400* /year

Implementation cost

Cost of heat insulation (including designing and installation) for four boilers

480 m^2 *$5*/m^2 = *$2,400*

Simple payback period

Cost of putting into operation *$2,400*

Annual saving of expenses *$3,400*

At the price of *$83* for 1,000 m^3 of natural gas the simple payback period would be

$2,400 / $3,400 = 0 7 year

Conclusion Due to the short payback period it is recommended to implement this ECO as soon as possible

7 6 5 Utilization of the boilers effluent gas heat

Proposal

Install "effluent gas - air" heat exchangers (plate or contact type) at the boilers to utilize effluent gas heat and to heat primary air, supplied for the combustion process

Study results

Temperature of effluent gas after economizers of ***DKVR-10/13, DKVR-20/13 and KVGM-100*** boilers is in the range of 110 - 175^{0}C (at the same there is no pre-heating of the air, supplied for the combustion process) Utilization of effluent gas heat for primary air heating will increase the operation efficiency of existing boilers

Annual saving of energy

33

Heating of primary air, supplied for combustion process, by 60 - 70°C will result in more 400 kCal/m^3 of gas, therefore the gas saving (at the lowest heat value of natural gas Q^d_l=*8,000* kCal/m^3 of gas) will be *400/8,000=5%*

Annual consumption of natural gas by the boiler house is *70,000,000* m^3
5% of annual natural gas saving will correspond to *3,500,000* m^3 of gas

Annual saving of costs

At the price of natural gas *$83* for *1,000* m^3 the cost saving would make up

3,500,000 m^3/year x *$83*/ths m^3= *$290,000* /year

Cost of putting into operation

Heat exchanger (air heater), *5* pieces	*$250,000*
Shipping and transportation	*$15,000*
Installation and putting into operation	*$50,000*
Technical inspection and acceptance	*$5,000*
Total cost for putting into operation	*$330,000*

Simple payback period

Cost of putting into operation	*$330,000*
Annual saving of expenses	*$290,000*

At the price of *$83* for 1,000 m^3 of natural gas the simple payback period would be

$330,000 / $290,000 = 1,14 year

Conclusion The payback period of this ECO is not long, therefore it is recommended to consider possibility of its implementation

8 ENVIRONMENTAL IMPACT OF RECOMMENDATIONS

Implementation of energy conservation opportunities results in reduction of harmful exhausts into the atmosphere, due to decrease in fuel and power consumption

According to the Ministry of Energy of Ukraine in 1996 an average quantity of harmful exhausts for each ***1000 kW•h*** of the generated power was

CO – *0 5 kg,*

NO_x – *2 2 kg,*

SO_2 – *9 9 kg,*

ASH – *4 4 kg*

Combustion of ***1000*** m^3 of natural gas entails emission of

CO (***Carbon monoxide***) – ***0 28 kg,***

NO_x (***Oxides of nitrogen***) – ***1 22 kg,***

Implementation of the proposed energy conservation opportunities would reduce the power consumption by ***93826*** thousand kW•h/year, that is equal to the following reduction of harmful exhausts into the atmosphere

CO 93,826 thousand kW•h/year × ***0 5*** kg/thousand kW•h = 45,913 kg/year

NO_o 93,826 thousand kW•h/year × ***2 2*** kg/thousand kW•h = 206,417 kg/year

SO_2 93,826 thousand kW•h/year × ***9 9*** kg/thousand kW•h = 928,877 kg/year

ASH 93,826 thousand kW•h/year × ***4 4*** kg/thousand kW•h = 412,834 kg/year

Implementation of the proposed energy conservation opportunities would reduce the natural gas consumption by ***9,223 9*** thousand m^3/year, that is equal to the following reduction of harmful exhausts into the atmosphere

CO ***9,223 9***thousand m^3/year × ***0 28*** kg/thousand m^3 = ***2,583*** kg/year

NO_o ***9,223 9*** thousand m^3/year × ***1 22*** kg/thousand m^3= ***11,253*** kg/year

The overall reduction of harmful emission would be

CO ***49,496*** kg/year

NO_o ***217,670*** kg/year

SO_2 ***928,877*** kg/year

ASH ***412,834*** kg/year

APPENDIX A

LIST OF ENERGY CONSERVATION OPPORTUNITIES

Table A 1

List of Energy Conservation Opportunities

# of ECO	ECO	Power savings (ths kW•h)	Natural gas savings (ths m^3)	Annual savings (ths $/ year)	Cost of proposed measures (ths $)	Simple payback period (year)	Clause # of this report
1	Energy Management Introduction	53,301	2,102	2,570	2,140	0 83	7 1
2	Modernization of the pulp pumping plant PPP–1	14,016	0	631	760	1 20	7 2
3	Modernization of the pulp pumping plant PPP–2	14,016	0	631	712	1 13	7 2
4	Up-grading of the electric drive system for the plant of circulating water supply	7,000	0	315	732	2 32	7 3 1
5	Introduction of the automated control system at the plant of circulating water supply	2,681	0	121	100	0 83	7 3 2
6	Up-grading of the water supply system in the concentration plants	2,681	0	121	60	0 5	7 4
7	Replacement of the pump for water supply in ball mills by more efficient one	131	0	5,9	1 7	0 29	7 5
8	Adjustment of combustion process in boilers of the boiler plant	0	3500	290	60	0 2	7 6 1
9	Thermal insulation of the end sides of boilers' economizers at the boiler plant	0	22 5	1 9	0 3	0 16	7 6 2
10	Thermal insulation of boilers' screens at the boiler house	0	58 8	4 9	1 0	0 2	7 6 3
11	Additional thermal insulation of the external enclosure of boilers	0	40 6	3 49	2 4	0 7	7 6 4
12	Utilization of the effluent gas heat at the boiler house	0	3,500	290	330	1 14	7 6 5
	TOTAL	**93,826**	**9,205 7**	**4,983 6**	**4,899 4**	**0 98**	

APPENDIX B

RESULTS OF MEASUREMENTS AND COLLECTED DATA

Following are the results of measurements, carried out at the boiler house boilers

1 Composition of gas mixtures

Boiler #4

DKVR 20/13
SERIAL # 11003246
ENERAC MODEL 2000
COMBUSTION TEST RECORD
FOR BURNS & ROE
TIME 08 05 17
DATE 03/24/97
FUEL NATURAL GAS 21870 BTU/LB

COMBUSTION EFFICIENCY	83 2	%
AMBIENT TEMPERATURE	16	°C
STACK TEMPERATURE	132	°C
OXYGEN	08 5	%
CARBON MONOXIDE	0	PPM
CARBON DIOXIDE	07 2	%
COMBUSTIBLE GASES	0 00	%
STACK DRAFT (INCHES H20)	– 3 7	
EXCESS AIR	61	%
OXIDES of NITROGEN	85	PPM
SULFUR DIOXIDE	0	PPM
CARBON MONOXIDE ALARM	1990	PPM

MODE PPM OXY_REF = 3%

Boiler #4

DKVR 20/13
SERIAL # 11003246
ENERAC MODEL 2000
COMBUSTION TEST RECORD
FOR BURNS & ROE
TIME 08 23 14
DATE 03/24/97
FUEL NATURAL GAS 21870 BTU/LB

COMBUSTION EFFICIENCY	83 4	%
AMBIENT TEMPERATURE	16	°C
STACK TEMPERATURE	131	°C
OXYGEN	07 5	%
CARBON MONOXIDE	0	PPM
CARBON DIOXIDE	07 7	%
COMBUSTIBLE GASES	0 00	%
STACK DRAFT (INCHES H20)	– 3 0	
EXCESS AIR	51	%
OXIDES of NITROGEN	79	PPM
SULFUR DIOXIDE	0	PPM
CARBON MONOXIDE ALARM	1990	PPM

MODE PPM OXY_REF = 3%

Boiler #2

DKVR 10/13
SERIAL # 11003246
ENERAC MODEL 2000
COMBUSTION TEST RECORD
FOR BURNS & ROE
TIME 08 32 48
DATE 03/24/97
FUEL NATURAL GAS 21870 BTU/LB

COMBUSTION EFFICIENCY	79 6	%
AMBIENT TEMPERATURE	16	°C
STACK TEMPERATURE	173	°C
OXYGEN	10 0	%
CARBON MONOXIDE	0	PPM
CARBON DIOXIDE	06 3	%
COMBUSTIBLE GASES	0 00	%
STACK DRAFT (INCHES H20)	– 4 0	
EXCESS AIR	82	%
OXIDES of NITROGEN	72	PPM
SULFUR DIOXIDE	0	PPM
CARBON MONOXIDE ALARM	1990	PPM

MODE PPM OXY_REF = 3%

Boiler #1

DKVR 10/13
SERIAL # 11003246
ENERAC MODEL 2000
COMBUSTION TEST RECORD
FOR BURNS & ROE
TIME 08 41 07
DATE 03/24/97
FUEL NATURAL GAS 21870 BTU/LB

COMBUSTION EFFICIENCY	82 9	%
AMBIENT TEMPERATURE	16	°C
STACK TEMPERATURE	142	°C
OXYGEN	07 9	%
CARBON MONOXIDE	9	PPM
CARBON DIOXIDE	07 5	%
COMBUSTIBLE GASES	0 00	%
STACK DRAFT (INCHES H20)	– 5 4	
EXCESS AIR	54	%
OXIDES of NITROGEN	48	PPM
SULFUR DIOXIDE	0	PPM
CARBON MONOXIDE ALARM	1990	PPM

MODE PPM OXY_REF = 3%

Boiler #1
DKVR 10/13
SERIAL # 11003246
ENERAC MODEL 2000
COMBUSTION TEST RECORD
FOR BURNS & ROE
TIME 08 49 34
DATE 03/24/97
FUEL NATURAL GAS 21870 BTU/LB

COMBUSTION EFFICIENCY	82 0	%
AMBIENT TEMPERATURE	16	°C
STACK TEMPERATURE	147	°C
OXYGEN	9 7	%
CARBON MONOXIDE	0	PPM
CARBON DIOXIDE	06 5	%
COMBUSTIBLE GASES	0 00	%
STACK DRAFT (INCHES H20)	– 5 3	
EXCESS AIR	76	%
OXIDES of NITROGEN	74	PPM
SULFUR DIOXIDE	0	PPM
CARBON MONOXIDE ALARM	1990	PPM

MODE PPM OXY_REF = 3%

Hot water boiler
DKVR 100
SERIAL # 11003246
ENERAC MODEL 2000
COMBUSTION TEST RECORD
FOR BURNS & ROE
TIME 08 41 07
DATE 03/24/97
FUEL NATURAL GAS 21870 BTU/LB

COMBUSTION EFFICIENCY	77 0	%
AMBIENT TEMPERATURE	14	°C
STACK TEMPERATURE	112	°C
OXYGEN	16 0	%
CARBON MONOXIDE	33	PPM
CARBON DIOXIDE	02 9	%
COMBUSTIBLE GASES	0 00	%
STACK DRAFT (INCHES H20)	– 0 7	
EXCESS AIR	290	%
OXIDES of NITROGEN	44	PPM
SULFUR DIOXIDE	0	PPM
CARBON MONOXIDE ALARM	1990	PPM

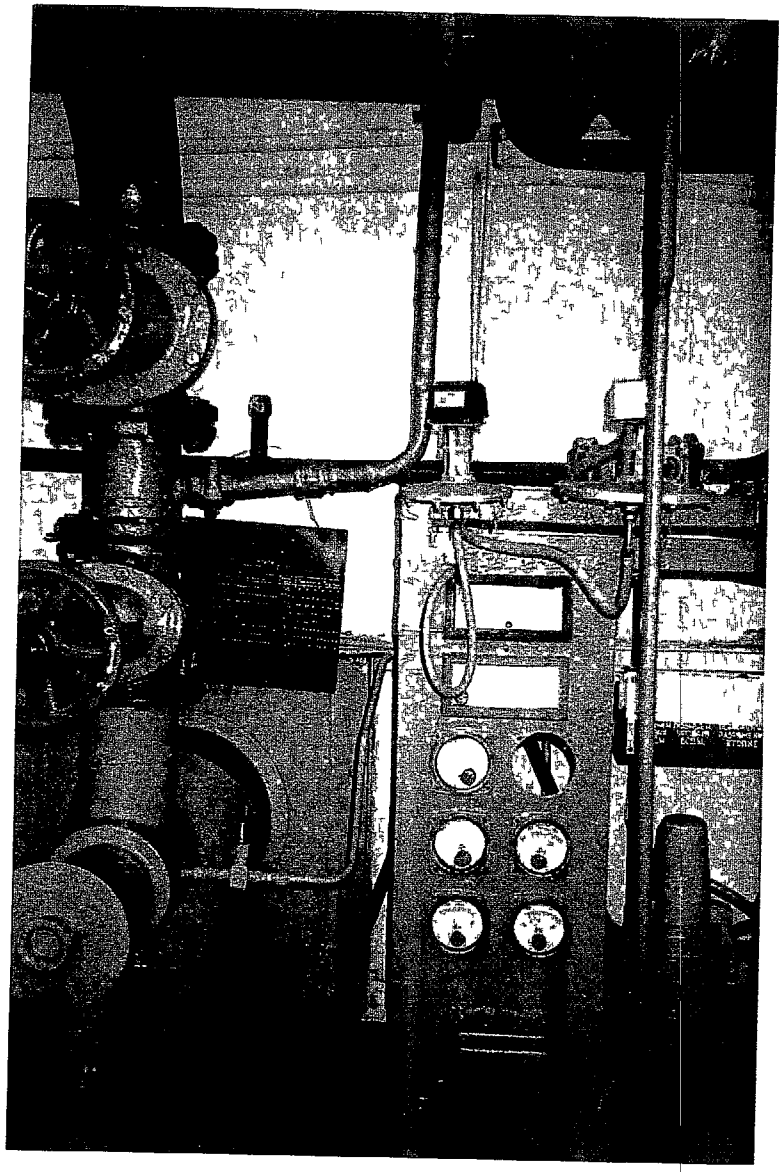
MODE PPM OXY_REF = 3%

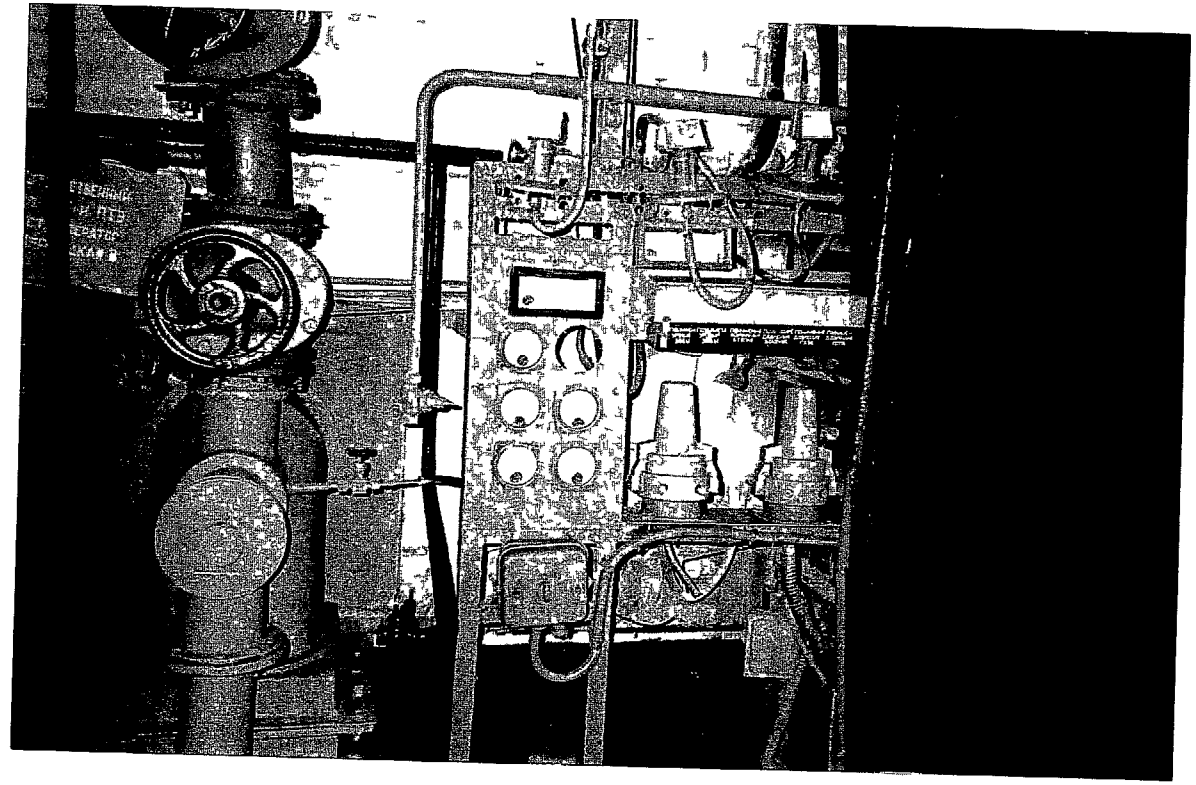
2 Surface temperatures

Surface	Temperature, °C		
	Boiler #1 DKVR-10/13	Boiler #2 DKVR-10/13	Boiler #4 DKVR-20/13
Front enclosure	50–80	85	87
Right side enclosure	70	65	40–45
Left side enclosure	60	55	40–45
Back enclosure	50	55	80–90
Economizer sides	80–100	80–100	–
Front screen	154	157	150
Back screen	163	150	162

APPENDIX C

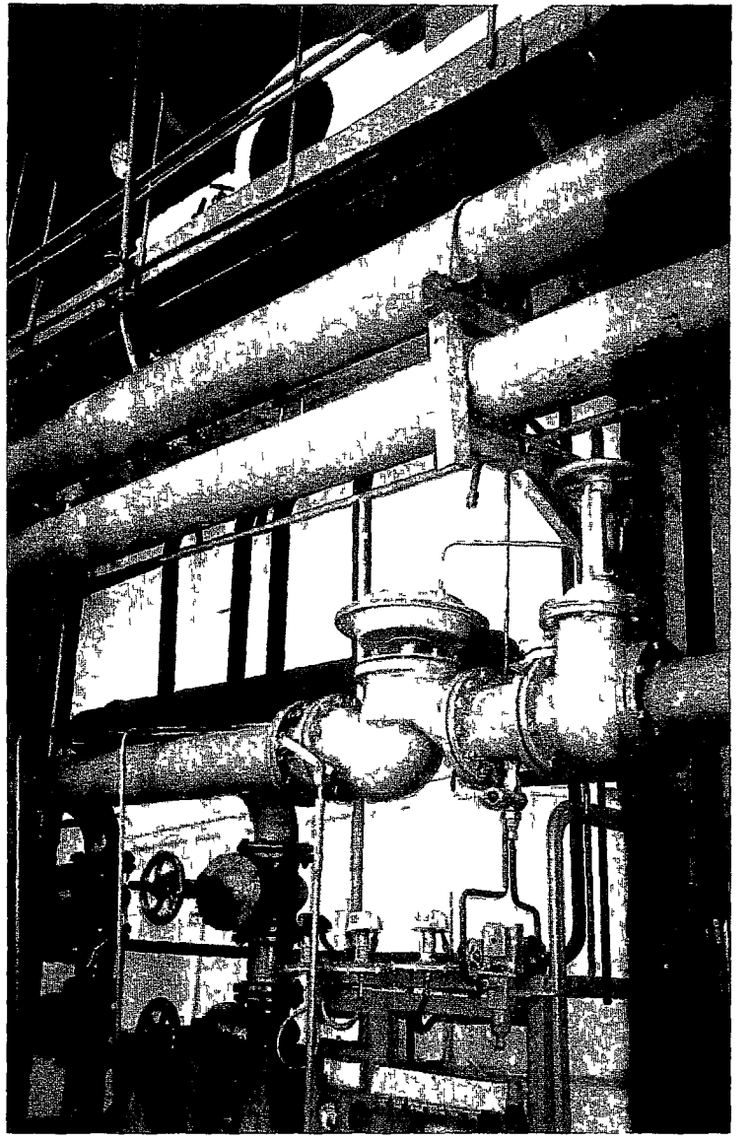
PLANT PHOTOGRAPHS





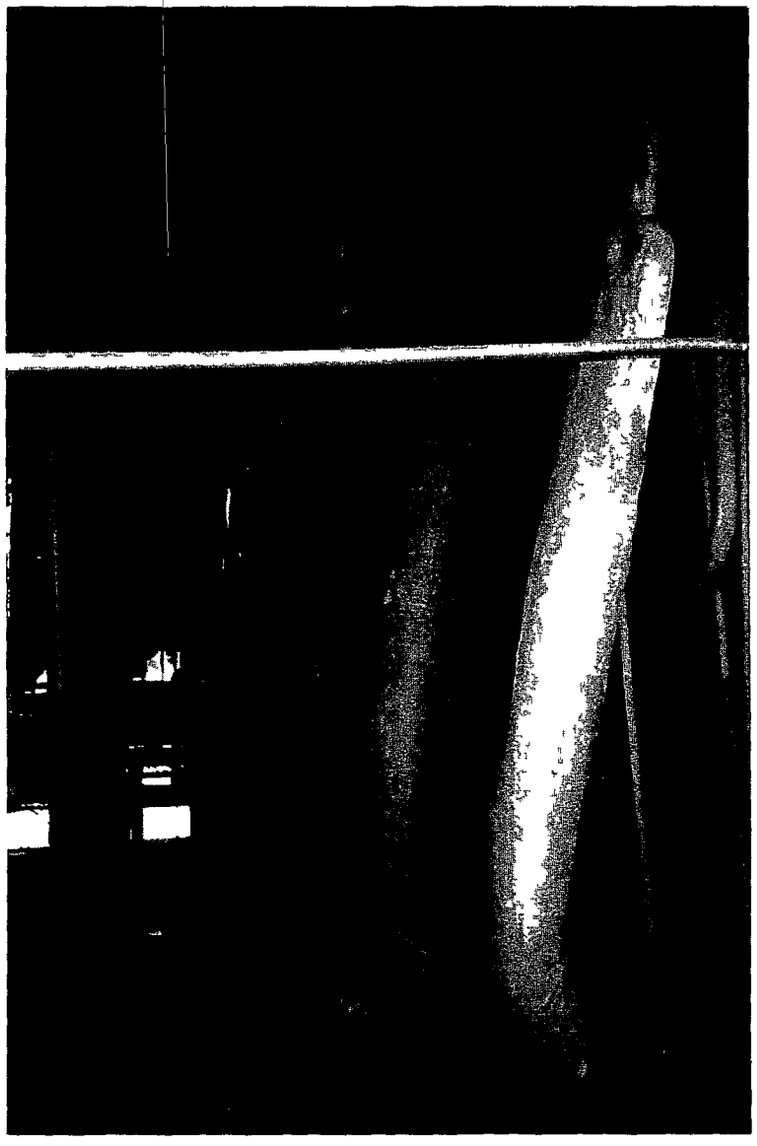
Панели приборов контроля параметров котлов ***ДКВР 10/13***

Panels of the instruments for controlling parameters of ***DKVR 10/13*** Boilers



Система регулирования подачи газа на котел ***ДКВР 10/13***

System controlling gas supply to ***DKVR 10/13*** Boiler



Теплоизоляция паропроводов в котельной

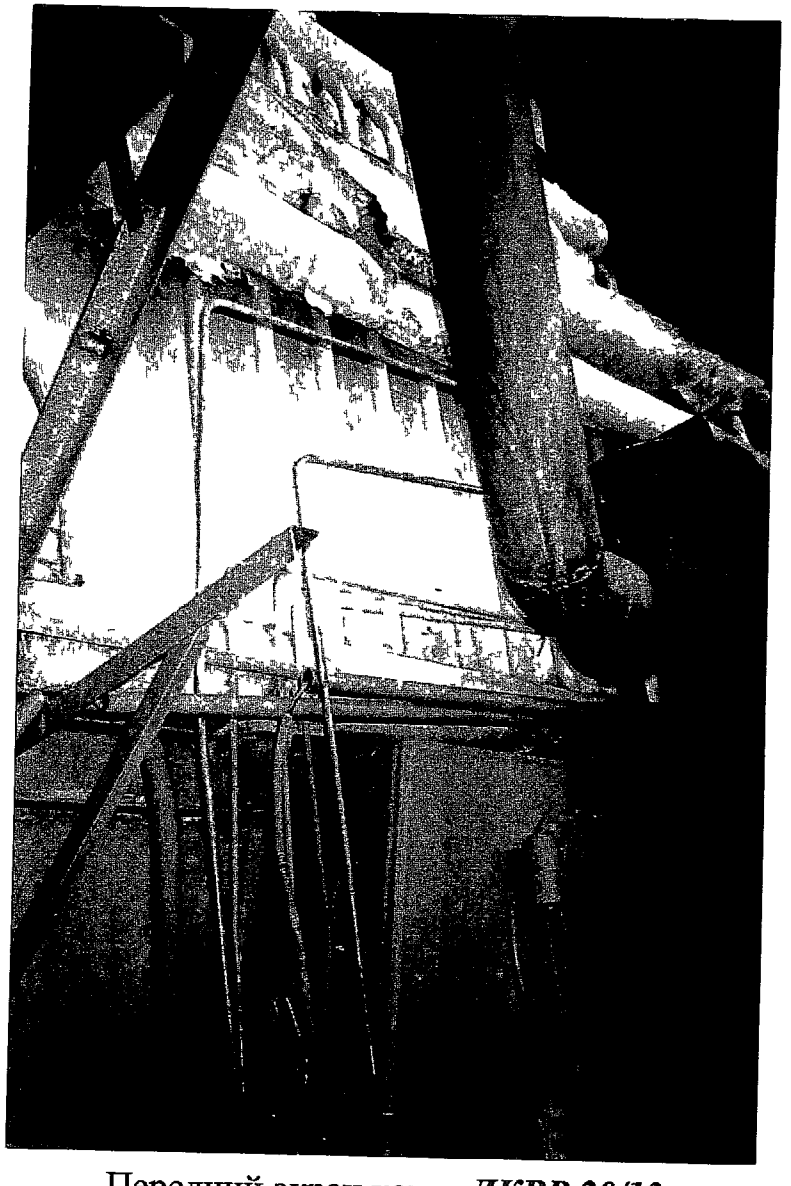
Thermal insulation of the stream lines in the boiler house

Торцевые стороны экономайзеров котлов ***ДКВР 10/13***

Side views of economizers of ***DKVR 10/13*** Boilers

Теплоизоляция торцов экономайзера котла ***ДКВР 20/13***

Thermal insulation of the side ends of economizers for ***DKVR 20/13*** Boiler



Передний экран котла ***ДКВР 20/13***

The front screen of ***DKVR 20/13*** Boiler

APPENDIX D

UNITS OF MEASUREMENT

CURRENCY

1 UAH Hrivnya, National currency of Ukraine
1 UAH = US $0 493 (as of December 1997)

UNITS OF MEASUREMENTS RELATION

HEAT

1 Cal = 4,187 J
1 kCal = 4,187 kJ = 3,968 Btu
1 GCal = 4,187 10^3 MJ = 4,187 GJ
1 Âtu = 1055 J = 1,055 kJ = 1,055 10^{-3} MJ

POWER

1 W = 3,6 10^3 J = 3,6 kJ
1 kW = 3,6 10^3 J = 3,6 MJ = 860 kCal
1 MW = 3,6 10^3 MJ = 0,86 GCal
1 kCal = 1,163 10^{-3} kW
1 GCal = 1163 kW = 1,163 MW =3 95 MBtu
1 kW = 1,36 hp
1 kW = 1,34 hp

PRESSURE

1 kgf/cm^2 = 1 atm
1 atm = 101,325 kPa = 0,1 MPa
1 b = 10^5 Pa = 100 kPa = 0,1 MPa

LENGTH UNITS

1 mm = 0,0394 in = 0,00328 ft
1 cm = 0,3937 in = 0,0328 ft
1 m = 39,37 in = 3,281 ft

WEIGHT UNITS

1 g = 2,2046 10^{-3} lb
1 kg = 2,2046 lb
1 t = 1000 kg = 2,2046 10^3 lb

SQUARE MEASURE

1 cm^2 = 0,155 in^2 = 1,076 10^{-3} ft^2
1 m^2 = 1,55 10^3 in^2= 10,76 ft^2

VOLUME MEASURE

1 m^3 = 35,31 ft^3 = 1000 l
1 l = 35,31 10^{-3} ft^3
1 l = 0,264 gal (US)

CALORIFIC VALUE

1 kJ/kg = 0,43 Btu/lb
1 kJ/m^3 = 26,84 10^{-3} Btu/ft^3
1 MJ/m^3 = 26,84 Btu/ft^3
1 kCal/m^3 = 4,187 kJ/m^3 = 0,112 Âtu/ft^3

TEMPERATURE

°Ñ = 0,56 (°F – 32)

APPENDIX E

LIST OF ABBREVIATIONS

ABBREVIATIONS

ECO	–	Energy Conservation Opportunity,
UAH	–	Hrivnya,
Q-ty	–	quantity,
mo	–	month,
OJSC	–	open joint-stock company,
Ru	–	rouble,
CIS	–	Commonwealth of Independent States,
tab	–	table,
etc	–	et cetera,
i e	–	that is,
Tel	–	telephone,
ths	–	thousand,
ESC	–	energy service company,
USAID	–	US Agency for International Development,

UNITS OF MEASUREMENT

Btu	–	British Thermal Unit,
W	–	watt,
GJ	–	gigajoule,
GCal	–	gigacalorie,
g	–	gram,
kVA	–	kilovolt-ampere
kW	–	kilowatt,
kW/h	–	kilowatt/hour,
kV	–	kilovolt ,
kg	–	kilogram,
kgf	–	kilogram-force,
kg s f	–	kilogram of standard fuel (kilogram of coal equivalent),
kCal	–	kilocalorie,
Lm	–	lumen,
MJ	–	megajoule,
MW	–	megawatt,
m	–	meter,
m^2	–	square meter,
m^3	–	cubic meter,
mm	–	millimeter,
cm^2	–	square centimeter,
°C	–	Celsius degree,
t	–	metric ton,
°F	–	Farenheit degree,
h	–	hour,