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Industrial Energy Efficiency - Ukraine
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REPORT
ON ENERGY AUDIT
AT *KHARKIV PISTON PLANT*,
City of KHARKIV, UKRAINE

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INDUSTRIAL ENERGY EFFICIENCY AUDIT REPORT

PISTON PLANT, KHARKIV

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1 EXECUTIVE SUMMARY

1 1 Introduction

This energy audit has been conducted under a program sponsored by the US Agency for International Development This project, also referred to as Delivery Order #30, consisted of performing twenty four audits throughout Ukraine The purpose of the project is to develop Ukrainian energy service company (ESCO) capabilities To accomplish this task, Burns and Roe Enterprises, Inc (the primary contractor) hired Ukrainian engineers These engineers were trained in U S techniques of conducting energy audits and in ESCO concepts The industrial energy audits were conducted to facilitate the ESCO training

Since these enterprises are very large, a one week visit is not sufficient to adequately audit the entire facility The site visit was restricted to one week due to 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 one week 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 engaging the engineers trained under this project to continue this work This will result in a complete understanding of energy usage within the plant, as well as a complete listing of all potential energy improvement projects

This report describes findings of the energy audit performed dy Burns and Roe Enterprises, Inc at the closed-type joint stock company "Avtramat" Currently the plant specialises in production of engine pistons for tractors, agricultural machinery, cars and trucks, special equipment and spares for cars

Production output in 1996 was 43,143,000 hrivnas Energy costs were 7 9% of total production cost

Output of the JSC "Avtramat" makes up 95% of total national production Presently the "Avtramat" comprises eleven workshops two foundries, four machine and five auxiliary shops

Number of personnel is 1 883

The objectives of the energy efficiency audits were to

- Conduct informal training in energy management practices
- Create an institutional awareness of energy management
- Recommend specific steps for improved energy efficiency
- Recommend medium cost and capital investments actions, reflecting large energy conservation opportunities

The project team, consisting of one U S expert and three Ukrainian ESCO members,

performed the energy efficiency audit during November 24 through28, 1997 In accordance with the purposes of the project, the audit team prepared the following report

1 2 Principal Findings

The Kharkiv piston plant is an energy intensive enterprise Energy consumption over ten months of 1997 was as follows

- electric power -13,720,000 kWh
- natural gas - 3,068,000 cubic meters
- district heat - 8,500 Gcal

The Piston Plant is reasonably successful by Ukrainian standards but still has to rely on the bartering system for its supply of gas and electric power

The energy inefficiency is exacerbated via oversizing and overbuilding of all heat and electric supply systems Electric distribution is oversized by 350%

One of the energy audit participants, Mr Tarnovsky, saw possibilities for some private development beyond the AID program in the area of heat distribution system

The most important factor in developing private sector ESCO is an availability of long term (2-3 years) financing Ukrainian banks demand exorbitant interest rates for a loan of 6 months duration This makes developing private sector ESCO in Ukraine almost impossible

The present project schedule makes the monitoring phase impossible for ECOs that require heating season for their implementation

1 3 Recommendations

Below is the list of energy conservation opportunities at the plant These measures are recommended to be implemented in the shortest period The plant management is recommended to consider implementation of other ECOs as soon as financially possible

In order 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 implement an energy saving activity

For example, ECO #1 "Institution of energy management" will set up systematic energy conservation activities by establishing an energy management section responsible for the control and analysis of the energy consumption at the plant and development of recommendations for renovation and improvement of any energy saving systems

Generally the energy management section should consist as a minimum of three persons technical supervisor, electrical and thermal engineers The supervisor should be a part of the

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plant management and report directly to the plant general manager It is essential as energy consumption and energy costs acquire a special importance and a plant manager should be aware of energy conservation potential

The best part of the proposed measures have direct applications with minor adjustments at other industrial plants i e they can serve as a standardized solution for a standard problem

If implemented the measures proposed by the auditors will reduce energy consumption annually

- of electric power by 5,648,000 kWh (35%)
- of natural gas by 546,000 m3 (15%)
- of thermal energy by 935 GCal (11%),

and will result additionally in reduction of pollutant emissions

1 Solid particles by 24 8 tons/year

2 Sulfur dioxide 55 tons/year

3 Carbon oxide by 7 5 tons/year

4 Nitrogen oxide by 14 tons/year

Plant energy efficiency can be improved, costs reduced and enhance competitiveness of the enterprise preserved based on recommendations listed in the following Table No 1

Capital investments of $1,845,760 into the improvement of energy efficiency (ECO#1 through ECO#9) will result in annual savings of $813,590 later

Energy conservation opportunity (ECO) list

ECO #	Description	Electricity, 1,000 kWh ч	Natural gas, 1,000 m^3	Thermal energy, GCal	Annual savings, $	Project cost, $	Payback, years
1	**Institution of Energy Management** This ECO will ensure energy use management and reduce energy costs by 10%	1,600	371	935	32,000	20,000	0 6
2	**Monitoring and Recording of Power Consumption** Metring and monitoring system will reduce power consumption by 5%	800			33,600	20,000	0 6
3	**Monitoring and Recording of Compressed Air Consumption** Registration and analysis system will reduce eliminate compressed air waste	1,440			60,500	33,000	0 6
4	**Monitoring and Recording of Natural Gas Consumption** This ECO will reduce natural gas use		74		6,100	3,900	0 6

5	**Overhaul of the Plant Hot Water System** This ECO will save 40% of natural gas and 80% of electricity used for hot water supply	108	81		11,040	11,000	1
6	**Thermal Insulation of the Hot Water Tanks** This ECO will reduce heat waste		19 8		1,640	1,560	1
7	**Controlling Insulation Heat Losses** Identification and elimination of heat losses will reduce energy use			85	3,230	1,300	0 4
8	**Overhaul of the Plant's Boiler House** This ECO will reduce thermal energy costs for plant heating				230,000	155,000	0 7
9	**Installation of Back Pressure Steam Turbine and Overhaul of Process Ovens** This ECO will significantly reduce elerctricity consumption	1,700			441,000	1,600,000	3 6
	TOTAL	5,648	545 8	935	813,590	1,845,760	2 3

2 FACILITY BACKGROUND

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2 1 History of the Plant

Avtramat Joint Stock Company was created 04/08/93 out of collective enterprise after it's reorganization Piston Plant, which was originally the main enterprise of *Kharkivtractorozapchast* corporation, was founded in June 1930 The following Table represents the Plant's capacity before the World War II

	Units	**1936**	**1940**
Number of Employees	persons	359	557
Gross Production	thousand rubles	4710	10955

During the war the plant moved to the city of Omsk in 1941, and in 1943, after Kharkiv's liberation, the new enterprise was started in the old buildings

Currently the facility consists of

- 11 production workshops
- 2 foundries casting motor pistons for tractors, farm machinery, autotrucks and cars, as well as compressor and turbine wheels
- 4 machine workshops producing pistons for tractors, farm truck, autotruck and car motors

  - Toolmaker's Shop
  - Shipping Department
  - Machine Tool Department
  - Mechanical-Repair Department
  - Maintenance Department

- Construction and Repair Department
- Packaging Department

For the time being Kharkiv Piston Plant owns large working area and production facilities All of the main workshops are characterized by low-efficiency energy usage The main energy consumers are the foundries, with electrical ovens, heat-treatment furnaces and plasma jet remelting units These foundries operate 24 hours a day, 5 days a week The equipment has different age, but is outdated, although kept in a good working condition

2 2 Types of Products

Avtramat Plant produces engine pistons for tractors, farm machinery, trucks and cars, optional equipment and spare parts for motorcars

COMMERCIAL OUTPUT FOR 1996 AT CURRENT PRICES

№	Product	Units	Total Production
1	Truck Spare Parts	UAH 1000	6,564
2	Tractor Spare Parts	UAH 1000	23,327
3	Half-Finished Articles	UAH 1000	2,306
4	Optional Equipment	UAH 1000	157
5	Special Technological Equipment	UAH 1000	233
6	Motocars Spare Parts	UAH 1000	9,610
7	Misc Product	UAH 1000	946
	Total Commercial Output	**UAH 1000**	**43,143**

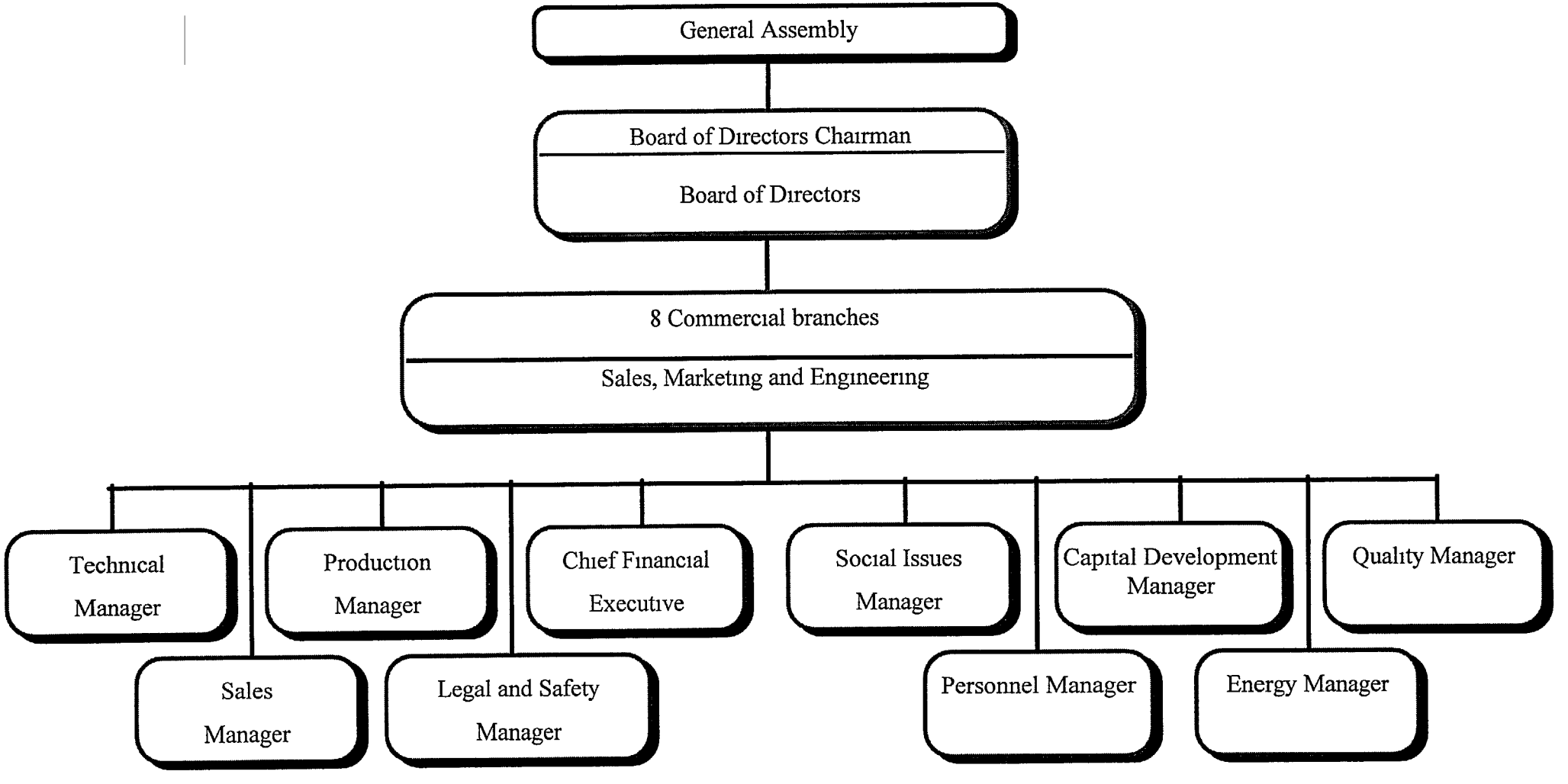
2 3 Number of Employees

The facility uses continuous casting technology, therefore foundries operate 24 hours a day Machine workshops and auxiliary shops run 8 hours daily

The plant has 1883 employees, including

Engineering Staff	468
Production Workers	386
Auxiliary Workers	1029

Organizational Management Structure of JSC AVTRAMAT



2 4 Number of Similar Enterprises in the Ukraine

Currently Ukraine has on its territory three enterprises manufacturing engine pistons for tractors and motorcars These are

1 Kharkiv Piston Plant
2 Kyiv "I Lepse" Plant
3 Konotop Piston Plant

2 5 Significance of Sector to Economy

Kharkiv Piston Plant's product has large demand in the country's market, as well as in the export market and in the former CIS The facility produces 95% of the pistons manufactured in the country The demand for pistons is caused by low quality of fuel used in the former CIS countries, which reduces considerably engine pistons' service life

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3 CURRENT STATUS OF PRODUCTION

3 1 Total Capacity of the Plant

GROSS TURN-OUT 1995-97 ANALYSIS

#	Year	Units	Commercial Output at 1997 prices
1	1995	UAH 1000	28,081
2	1996	UAH 1000	43,143
3	1997 (9 months)	UAH 1000	32,890

It is possible that in 1997 the facility will be able to maintain its 1996 level of production

3 2 Recent Production 1997 vs 1995 & 1996

1995-1997 PRODUCTIVITY ANALYSIS

#	Year	Units	Productivity per worker
1	1995	UAH 1000	14,7
2	1996	UAH 1000	18,8
3	1997 (9 months)	UAH 1000	17,6

Obviously, there is a tendency for increase in productivity

3 3 Current Trend

Current economic situation is characterized by setback in production and low purchasing power of the internal market Therefore, the facility has created *Impex* offspring, which is dealing with sales activities and expanding to exportl markets, such as former CIS countries, Bulgaria, Czech Republic, China, Mongolia, as well as one-time supplies to Western European countries

3 4 Exports Vs Domestic Consumption

Currently 70% of the output is exported to NIS countries Among the plant's permanent customers are

in Ukraine	Kharkiv tractor engine plant "Serp & Molot"
in Belarus	Borisov Machine Plant
	Minsk Engine Plant
in Russia	Rybinsk Engine Plant

In recent years the pistons were also exported to Eastern Europe, Latin America and China Currently the percentage of exports to Western countries is insignificant

4 FINANCIAL STATUS OF THE PLANT

4 1 Currency Vs Barter

Every transaction with NIS countries is paid in hard currency via bank accounts of the contract participants Transactions inside the country are performed as barter operations, when the plant's product is exchanged for a different product or services This is due to the country's unstable economic situation Barter operations constitute 60% of total sales in the internal market This practice started several years ago, and although every effort is made by the Ukrainian Government to improve the situation, there haven't been any positive changes The following table represents hard currency to barter operations ratio in the last three years

HARD CURRENCY TO BARTER OPERATIONS RATIO IN 1995-1997

#	Operation	Units	1995	1996	1997 (9 months)
1	Total Sales	UAH 1000	20,045	40,350	32,770
	Barter Operations	UAH 1000	13,500	28,080	17,030
3	Percentage of Barter	%	67	70	52

4 2 Viability of Facility

Currently the facility doesn't operate at full output due to the country's economic situation, production crisis, general industrial decline which is particular severe in equipment manufacturing, disruption of old relationships with suppliers and customers, and customers' lack of hard currency For instance, in 1996 the plant operated at 31% capacity

However, the Plant's rating is 99 68 points (according to Altman method based on current position and solvency), which is high enough and corresponds to the first class This means that the enterprise is generally considered to be solvent and capable of paying Accounts payable equal accounts receivable

Percentage of fuel costs in cost of production is 7 9%

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5 ANNUAL ENERGY CONSUMPTION AND COSTS

5 1 Annual Energy Consumption, 1996 - 1997

ELECTRIC CONSUMPTION

Months	1996 kWh	1997 (10 months) kWh
January	1,418,380	1,501,917
February	1,347,750	1,666,489
March	1,751,1620	1,598,407
April	1,724,291	1,515,047
May	1,370,033	1,101,700
June	1,127,533	1,130,475
July	1,265,935	1,176,304
August	1,205,455	1,208,239
September	1,210,008	1,361,054
October	1,338,999	1,460,529
November	1,106,556	
December	1,487,853	
TOTAL	16,353,955	13,720,161

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GAS CONSUMPTION

Months	1996 1,000 m^3	1997 (10 months) 1,000 m^3
January	314	422
February	316	333
March	365	314
April	360	385
May	282	240
June	250	200
July	237	262
August	276	250
September	297	290
October	307	372
November	280	
December	425	
TOTAL	3,709	3,068

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CONSUMPTION OF HEAT FROM OUTSIDE SUPPLIERS

Months	1996 Gcal	1997 (10 months) Gcal
January	2,286	2,006 69
February	1,935	1,495 873
March	1,904	1,023
April	451	642 01
May	-	-
June	-	-
July	-	-
August	-	-
September	-	-
October	-	123 218
November	400	
December	1,301	
TOTAL	8,277	5,290 791

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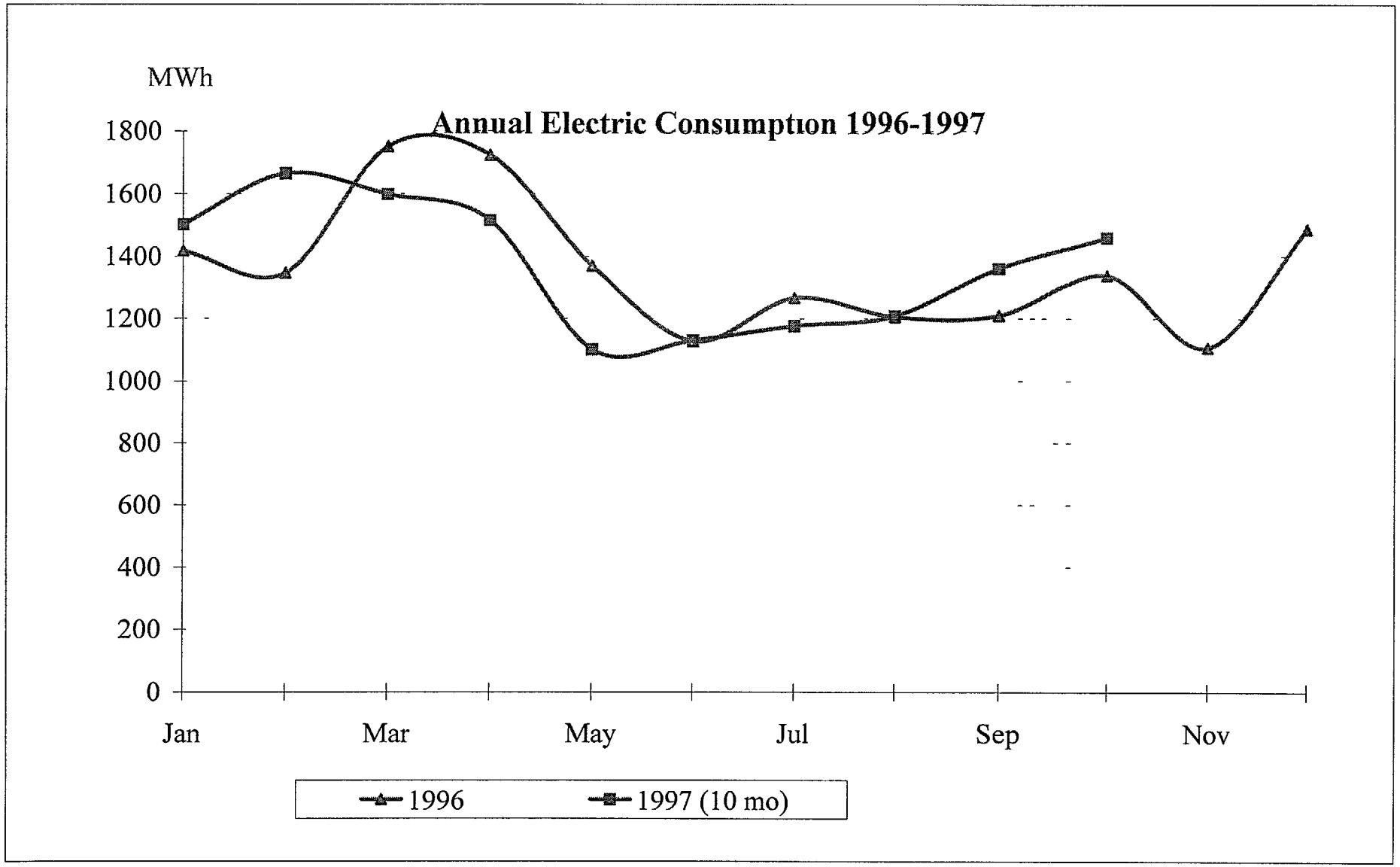
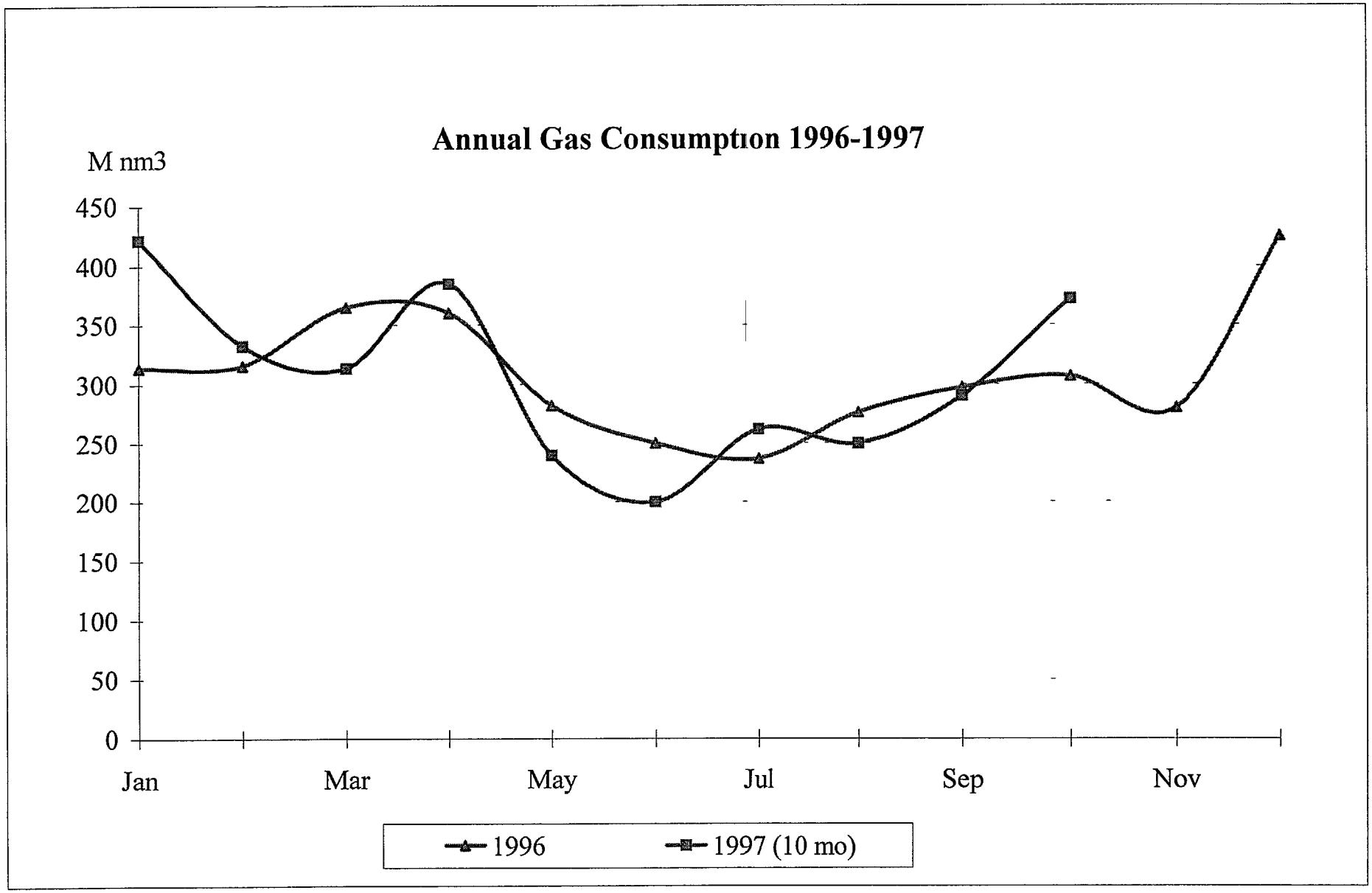

MWh
Annual Electric Consumption 1996-1997
1800
1600
1400
1200
1000
800
600
400
200
0
Jan
Mar
May
Jul
Sep
Nov
1996
1997 (10 mo)


Annual Gas Consumption 1996-1997
M nm3
450
400
350
300
250
200
150
100
50
0
Jan
Mar
May
Jul
Sep
Nov
1996
1997 (10 mo)

5 2 Current Energy and Fuel Prices

Electricity

The facility pays for electricity according to the tariff based on stated capacity and actual consumption

1 Stated capacity
2 Actual electric consumption according to kW meters

Contract for electricity supply with Pravex company is based on following costs

- 1 kWh of stated power $3 5
- 1 kWh of consumed power $0 03

Stated capacity 5,000 kW
Payments for stated capacity 5 000 * 3 5 = $17,500

Average monthly electric consumption	1,440,000 kWh
Payments for consumed power	1,440,000 * 0 03 = $43,200
Total payments	17,500 + 43,200 = $60,700
Actual cost per kWh	60,700 / 11,440,000 = $0 042

Fuel

The only fuel used in the facility is natural gas

Cost for 1000 $м^3$ is $83

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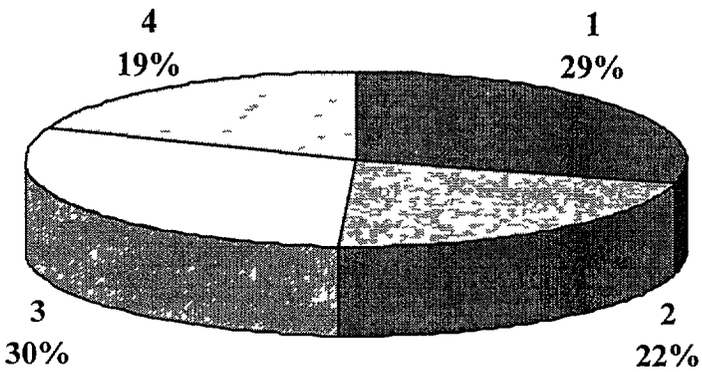
5 3 Energy Use Profile

Average electricity consumption per hour is 2,800 kW

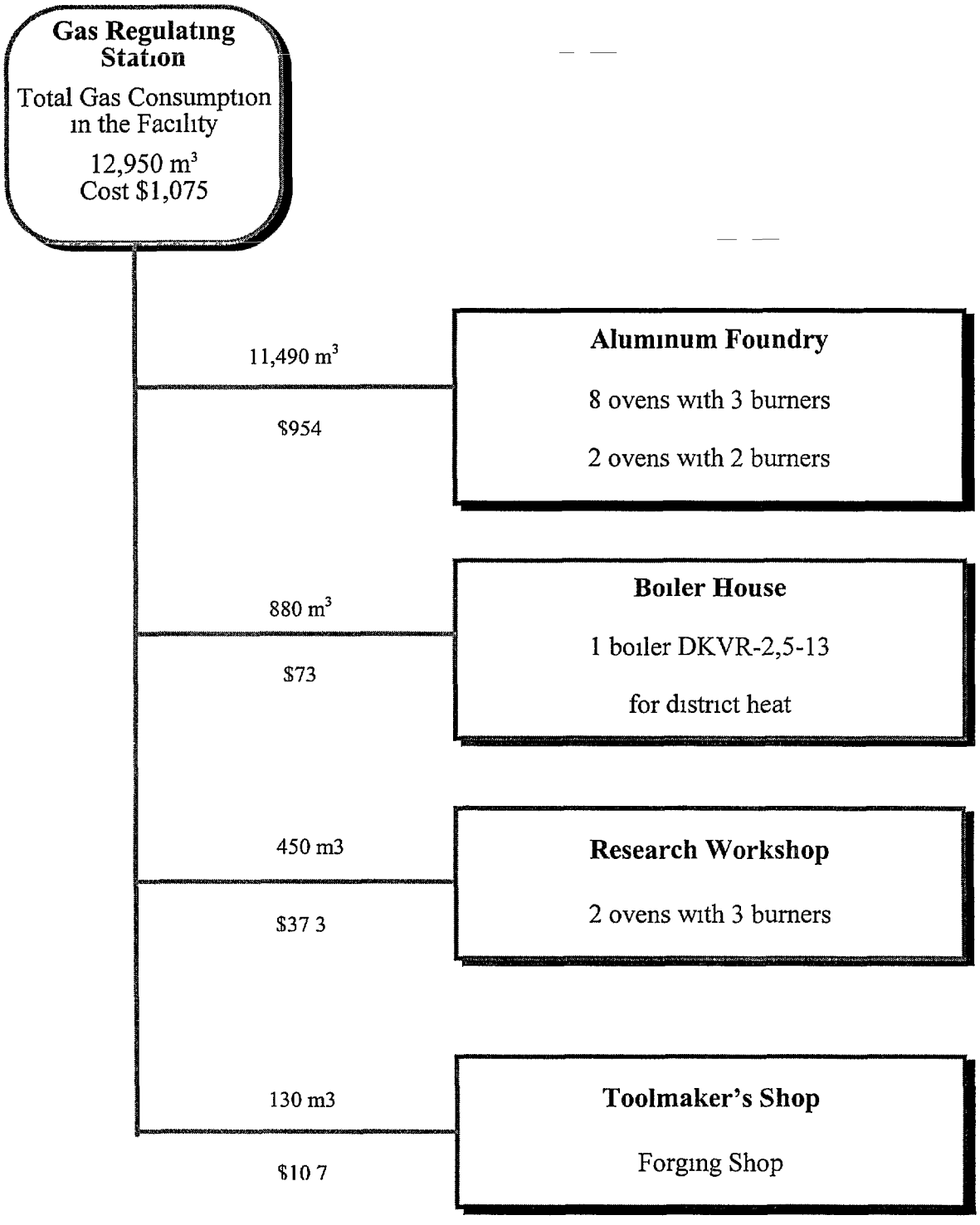
Hourly Distribution of Power Consumption



#	Consumers	%	Load, kW	Cost, $
1	Electric Heater Ovens	29 3	820 4	34 4
2	Compressor Station	21 5	602	25 3
3	Production Workshops	30	840	35 3
4	Misc consumers	19 2	537 6	22 6
	TOTAL	100	2,800	117 6

Gas Consumption Distribution in the Facility

28 Nov 1997



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6 PREVIOUS ENERGY IMPROVEMENTS

In 1997 the plant undertook the following energy and fuel saving measures

1 Technological redesign of piston production line, implementation of computer controlled equipment and reduction in the number of piston treatment operations made redundant 10 process machines with 150 kW installed capacity This will result in electricity savings of 258,000 kWh per year

At current price of $0 042 per kWh annual savings will be

0 042 * 258,000 = $10,830

2 Increasing insulation of electric (in VAZ pistons workshop) and melting furnaces (in foundries) will result in annual electricity savings of 49,000 kWh

At current price of $0 042 per kWh annual savings will be

0 042 * 49,000 = $2,060

3 Implementing calibrated air jets and pneumatic air valves (in machine workshops 1 & 3) for improving air-blast cleaning technology and operation control based on actual load will result in annual electricity savings of 187,000 kWh

At current price of $0 042 per kWh annual savings will be

0 042 * 187,000 = $7,850

4 Control of heat distribution to different users will result in annual heat savings of 215 Gcal

At current price of $26 5 per Gcal annual savings will be

26 5 * 215 = $5,700

5 Acid wash of district heat system (in machine workshop 1) will result in annual heat savings of 210 Gcal

At current price of $26 5 per Gcal annual savings will be

26 5 * 210 = $5,560

6 Insulation of workshop gates will result in annual heat savings of 38 Gcal

At current price of $26 5 per Gcal annual savings will be

26 5 * 38 = $1,000

7 Insulation of hot water headers in the workshops will result in annual heat savings of 181 Gcal

At current price of $26 5 per Gcal annual savings will be

26 5 * 181 = $4,800

Total annual energy cost savings

10,830 + 2,60 + 7,850 + 5,700 + 5,560 + 1,000 + 4,800 = $37,800

The plant has been regularly implementing (and is planning) all sorts of energy saving improvements in order to reduce production costs Some of the proposed projects haven't been implemented due to lack

of technical decisions that could fulfill all the requirements On the other hand, some of the technical projects seemed to be too complicated and expensive to implement, with no payback

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7 ENERGY AUDIT

As the result of the energy audit at the JSC "Avtramat" 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 5,648,000 kWh (35%)

2 Natural gas by 545,800 m^3 (15%)

3 Thermal energy by 935 GCal (11%)

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 Energy management is a management system based on standard measurements and checks providing for such operation of the plant that ensures only absolutely necessary consumption of energy for production purposes

In order to implement continuous supervision and analysis of energy use we recommend to institute energy management system and provide necessary measuring equipment

Implementation of this project will reduce fuel and energy costs by 32,000 $/year Payback period will be 0 6 year

See details of this proposal in Appendix A1, ECO #1

ECO #2 - Monitoring and Recording of Power Consumption

Electrical system of the facility comprises 110 kV open-air electrical distribution substation with 2 transformers 16,000 kVA with 110/6 kV voltage, 4 distribution substations with 6 kV voltage and 14 transformer substations with 6/0 4 kV voltage Total designed capacity is 17,880 kVA

There are electric meters installed on 6 kV side of in and out feeders at 110 kV distribution substation Distribution points and transformer substations are not provided with metering equipment Consequently, there's no data on power consumption by specific users

According to both published data and practical experience, implementation of record keeping and control of energy consumption will result in 5% savings To this goal we recommend installation of 50 electrical consumption meters and a computerized record keeping system

Implementation of this ECO will decrease annual electric consumption by 800,000 kWh, annual cost savings will come to $33,600, simple payback is 0 6 year

See Appendix A 2 ECO #2 for more details on this proposal

ECO #3 - Monitoring and Recording of Compressed Air Consumption

Currently the facility uses for technological processes compressed air produced by a centralized compressor rated at 100 m^3/min and 6 Bar, installed in the central compressor station The audit check of the workshops indicated considerable leaks of compressed air on stand-by equipment located in the idle workshops We assume that as much as 50% of compressed air is being lost The lack of production and consumption accounting results in negligent attitude towards compressed air usage

This results in increased compressor load and increased electrical consumption

We propose installing 14 meters of compressed air in the compressor station and main workshops This will allow to register and analyze compressed air consumption, and, consequently, eliminate losses in due course Assuming conservatively that implementation of this ECO will result in 30% savings of electricity used by the compressor, annual energy savings will come to 1,440,000 kWh Annual cost savings will be $60,500 Payback is 0 6 year

See Appendix A 3, ECO #3 for more details on this proposal

ECO #4 - Monitoring and Recording of Natural Gas Consumption

Current natural gas consumption at the facility is about 3,700,000 m^3 per year Total gas consumption is recorded via the gas meter installed at the plant's gas regulating station Only the boiler house and the two ovens at the aluminum foundry are provided with the meters Therefore the inefficiency of gas consumption due to faulty technological equipment is further increased by losses occurring due to operational staff's lack of actual consumption information and, consequently, lack of responsibility for excessive consumption According to expert evaluation supported by world-wide practice, fuel accounting and control will result as a minimum in 10% cost savings

We recommend to install additional gas meters on essential technological equipment Assuming conservatively that gas consumption record keeping will save 2% of total gas consumption, annual energy savings will come to 74,000 m^3 At annual cost savings of $6,100, payback is 0 64 year

See Appendix A 4, ECO#4 for more details on this proposal

ECO #5 - Overhaul of the Plant Hot Water System

Currently the plant uses the following system of hot water supply

1) Steam boiler DKVR-2,5-13 produces steam with 0 7 Bar pressure and 115°C temperature,
2) The steam is then sent to 2 storage tanks with 37 m^3 and 26 5 m^3 capacity,
3) Direct steam is bubbled into the cold water to heat it,

When water temperature reaches 60-65°C, it is pumped to the end users according to a

timetable

DKVR-2 5 boilers are about 30 years old

We recommend to change the configuration of the hot water supply system, as well as the equipment We recommend the following

1) Use as a heat source 200-250 kW capacity boiler with 95-70°C water temperature and at least 90% efficiency,
2) Use adequately sized plate-type heat exchanger,
3) Cold water will be heated in the heat exchanger to 60°C and sent to the hot water storage tanks,
4) Hot water to the end users will be supplied from the storage tanks via the existing pipeline system and according to the current timetables

This system will save 40% of natural gas and 80% of electricity Payback period is 1 year

See Appendix A 5, ECO#5 for more details on this proposal

ECO #6 - Thermal Insulation of the Hot Water Tanks

The plant's boiler room has two hot water storage tanks Both tanks are not insulated The outside surface temperature is 60°C to 70°C We estimate that more then 10% of heat is lost via uninsulated tank walls

We propose to insulate the tanks with foamed polyurethane insulation followed by coating with aluminum paint This will reduce heat losses by 90-95 % Implementation of this ECO will result in annual gas savings of 19,800 m^3, annual cost savings will be $1,640 Payback is 0 95 year

See Appendix A 6, ECO#6 for more details on this proposal

ECO #7 - Controlling Insulation Heat Losses

During the audit the audit team performed surface temperature measurements of the equipment and heat systems using non-contact thermometer ("heat spy") This was done to locate and evaluate heat losses due to poor insulation The results indicated that considerable losses occur in the heat distribution system, district heat systems, in technological processes, etc

A non-contact thermometer is necessary for implementation of facility-wide energy management program This, according to expert evaluation, saves up to 10% of the energy used In our opinion, timely detection and correction of heat losses due to poor insulation will result in an annual energy savings of 85Gcal Annual cost savings will be $3,230 Payback period will be 0 4 year

See Appendix A 7, ECO#7 for more details on this proposal

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ECO #8 - Overhaul of the Plant's Boiler House

Currently the facility purchases the heat energy for district heat purposes from the Kharkivoblenergo (a specialized utility) The heat energy is supplied via an external pipeline system

We recommend to retrofit the boiler house to enable the facility to have its own heat source that could cover all its heating needs Old equipment should be dismounted and replaced with modern water boilers (type VK-21 or VK-31) with efficiency of 90% or better Implementation of this project will allow $230,000 reduction in annual energy costs The expected payback is 0 67 year

See Appendix A 8, ECO#8 for more details on this proposal

ECO#9 - Installation of Back Pressure Steam Turbine and Overhaul of Process Ovens

During the visit the audit team observed operation of 10 aluminum casting furnaces On most furnaces visible flame tips were reaching the fume-collecting hood Outside surface temperature of the metal hood was as high as 360°C, despite air inflows from the outside Expert estimate of furnace efficiency is not more than 25%

There's no doubt that this aluminum casting process needs to be improved Plant's management wishes to improve technology by using a complex casting unit consisting of two ovens A gas oven will be used for melting aluminum and an electric oven for chemical composition conditioning This will allow production of aluminum alloy of desired composition

We recommend to equip the gas oven of the proposed system with a firebrick envelope and smoke fumes evaporation cooling unit Such arrangement will recover 60-65% of heat produced and provide the facility with 15,000 Gcal of free heat energy annually

Converting only 10% of this heat into an electric energy will produce up to 1,700,000 kWh We estimate the annual cost savings to be $441,400 and payback to be 3 6 years

See Appendix A 9, ECO#9 for more details on this proposal

8 ENVIRONMENTAL IMPACT OF RECOMMENDATIONS

The proposed project contains energy conservation measures aimed at saving fuel and electric power The main fuel used at Kharkiv Piston Plant is natural gas The harmful substance that forms in a significant quantity during combustion of natural gas burning are nitrogen oxides (NO_x) The nitrogen oxides are harmful to the human health and can cause severe respiratory problems

Since combustion of natural gas results in the least emissions of the carbon dioxide CO_2 (that is the gas primarily responsible for setting "the green house effect"), saving natural gas will contribute to weakening of "the green house effect" This happens because less coal will be burnt if natural gas is available for combustion

Carbon monoxide (CO) is another harmful substance that forms after an incomplete combustion of natural gas Reduction in natural gas combustion will contribute to reduction in carbon monoxide emissions

Annual natural gas savings on implementation of energy saving measures at Kharkiv Piston Plant will be as shown in Appendix A 8 calculations

electricity saving -	5,648,000 kW h
natural gas saving -	545,800 m^3

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

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

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

$$h = h_n \quad Eps,$$

where

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

Amounts of pollutants formed during generation of 5,648,000 kWh

1) sulfur dioxide SO_2 h_1 = 9 9 x 5,648,000 = 55,000,000 (g/year)

2) carbon oxide CO h_2 = 0 5 x 5,648,000 = 2,800,000 (g/year)

3) nitrogen oxides NO_x h_3 = 2 2 x 5,648,000 = 12,400,000 (g/year)

4) solid particles h_4 = 4 4 x 5,648,000 = 24,800,000 (g/year)

Calculation of the carbon dioxide that forms at burning natural gas is made by the formula

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

where

B - consumption of natural gas, m^3/yr

K_{CO} = 0 25 kg/GJ - the quantity of carbon dioxide that is produced per heat unit releasing at burning of natural gas

$Q_r = 35 MJ/m^3$ - the lowest calorific value of natural gas

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

$M_{CO} = 0\ 001\ \ 545{,}800\ \ 0\ 25\ \ 35\ \ (1 - 0\ 5/100) = 4{,}700$ (kg/yr),

or $M_{CO} = 4\ 7$ 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 1 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 some technical measures

$M_{NOx} = 0\ 001\ \ 545{,}800\ \ 0\ 1\ \ 35\ \ (1 - 0\ 15) = 1{,}600$ (kg/yr),

or $M_{NOx} = 1\ 6$ t/yr

Implementing at the Piston Plant conservation measures allows to decrease the energy consumption, and that in its turn, to decrease the quantity of harmful emissions into the atmosphere The data showing decreasing emissions of contaminating substances are given in the following table

Emissions	Reduction in emissions as a result of the energy savings, t/yr		
	Electric power	**Natural gas**	**TOTAL**
Solid particles	24 8	-	24 8
Sulphur dioxide	55	-	55
Carbon oxide	2 8	4 7	7 5
Nitrogen oxide	12 4	1 6	14

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Appendix A. ENERGY CONSERVATION OPPORTUNITIES (ECO'S)

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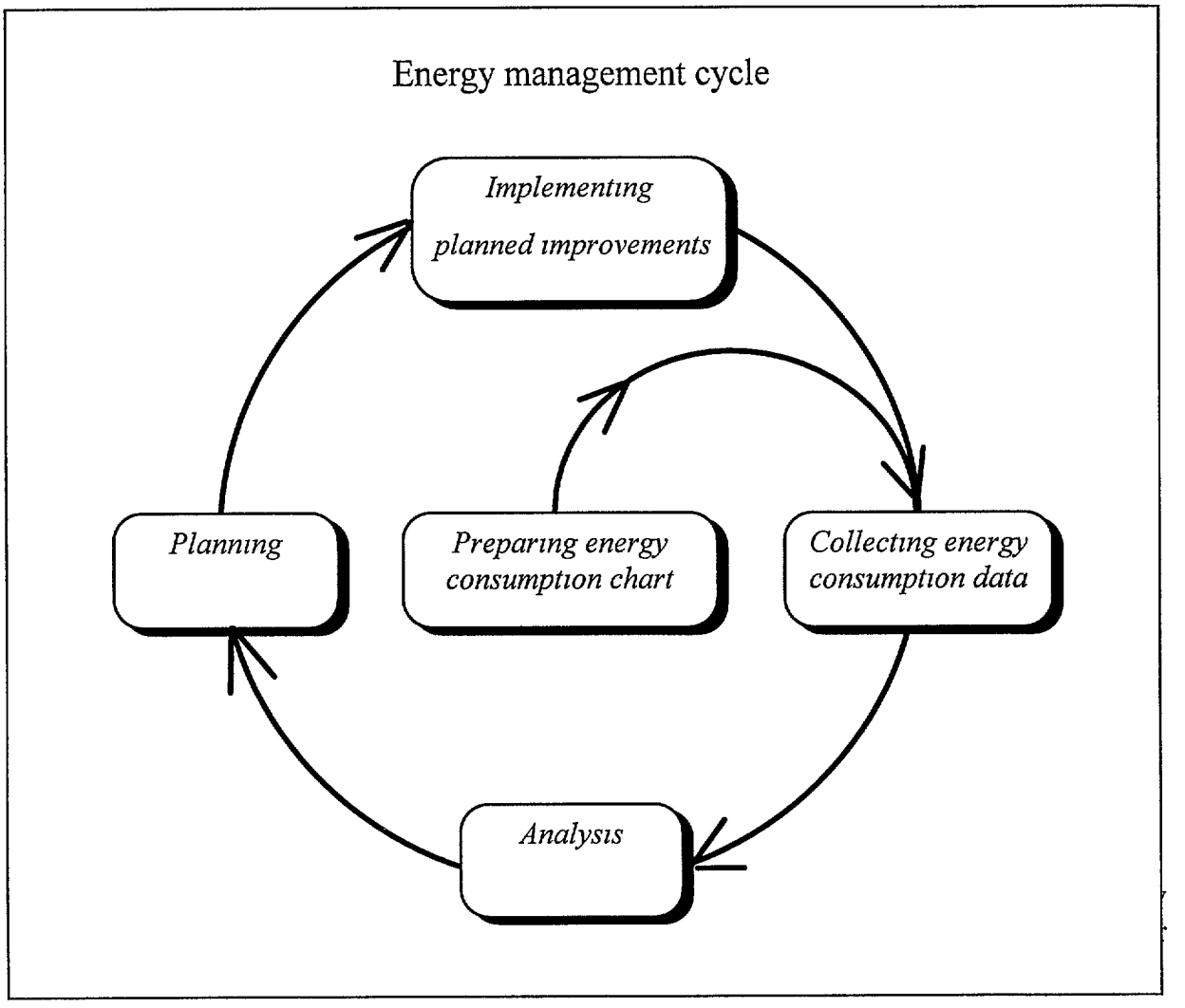
A 1 ECO # 1 Institution of energy management

Description of Opportunity

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



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

Annual energy savings

Currently the works use annually on average 16,000,000 kWh of electric power and 3,710,000 m^3 of natural 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

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The global experience and practice show that in case of institution of full-time energy management ensures from 3 to 10% of fuel and energy consumption savings Energy savings will amount to

1) Electric power - 16,000,000 x 0 1 = 1,600,000 (kWh)

2) Natural gas - 3,710,000 x 0 1 = 371,000 (m^3)

Annual cost saving estimate

1 At the price of $0 04 per 1 kWh of electric power the cost savings will be

1,600,000 x 0 04 ~ $64,000

2 At the price of $26 5 per 1 GCal of thermal energy the cost savings will be

85 26 5 = 33,760

3 At the price of $83 per 1,000 m^3 of natural gas the cost savings will be

371 x 83 ~ $30,790

Total energy cost savings will be

64,000 + 30,790 + 21,000 ~ $89,400

Implementation Costs

According to the world practice, expenses on implementing energy management constitute 50% of estimated energy savings, i e

89,400 x 0 05 ~ $44,700

Simple payback

Implementation costs - $44,700

Annual cost savings - $89,400

Simple payback period will be

44,700/89,400 ~ 0 5 (year)

A 2 ECO #2 - Monitoring and Recording of Power Consumption

Description of Opportunity

Electrical system of the facility comprises 110 kV open-air electrical distribution plant with 2 transformers 16,000 kVA each with 110/6 kV voltage, 4 distribution substations with 6 kV voltage and 14 transformer substations with 6/0 4 kV voltage Total designed capacity is 17,880 kVA

There are electric meters installed on 6 kV side of in and out feeders at 110 kV distribution plant Distribution points and transformer substations are not provided with metering equipment Consequently, there's no data on electricity consumption by specific users Therefore, it's impossible to evaluate production costs or build correct planning strategy Equally, the employees don't realize benefits from energy saving It will be impossible neither to plan energy conservation measures nor evaluate results of already implemented changes before metering system and consumption record keeping system are introduced

According to both published data and practical experience, energy consumption record keeping and control system will decrease losses and result in 5% savings To this goal we recommend to install 50 electrical consumption meters with computerized record keeping system

Annual Energy Savings

Average annual energy consumption is 16,000,000 kWh 5% decrease in electricity consumption will result in savings of

16,000,000 / 0 05 = 800,000 kWh

Annual Cost Savings

At current electricity cost of $0 04 per kWh annual savings will be

800,000 x 0 042 = $33,600

Implementation Costs

50 three-phase electric meters with built-in sensors at $87	4350$
114 metering transformers at $12	1370$
Cables	3500$
PC with printer	650$
Subcontracting enterprise services	5500$
Overhead costs @ 30%	4600$
TOTAL COSTS	**$20,000**

Simple Payback

Implementation costs	$20,000
Cost savings	$33,600

Simple payback will be
20,000 / 33,600 = 0,6 year

A 3 ECO #3 - Monitoring and Recording of Compressed Air Consumption

Description of Opportunity

Currently the facility uses for technological processes compressed air produced by a centralized compressor rated at 100 m^3/hr and 6 Bar The compressor is installed in the central compressor station The audit check of the workshops indicated considerable compressed air leaks on stand-by equipment in idle workshops These leaks are due mostly to sealing locknuts and don't cost much to fix

Neither management nor operating staff have been able to estimate the need for compressed air in a particular workshop, as well as compressed air losses Basing on the visual check, we would assume that as much as 50% of compressed air is being lost The lack of compressed air production and consumption accounting results in negligent attitude towards its usage At current situation it's impossible to evaluate the cost of compressed air in production cost at every particular workshop It's also hard to encourage conservation of compressed air

All of the above results in an increased compressor load and increased electrical consumption

We recommend installing 14 compressed air meters in the compressor station and main workshops This will allow to register and analyze compressed air consumption, and, consequently, eliminate losses in due course, which will result in electricity savings on compressor motor

Annual Energy Savings

At a most conservative estimate, implementation of this ECO will result in 30% savings of electricity used by compressor Electricity consumption by the compressor station constitutes not less then 30% of total electricity consumption on the facility, which averages in annual 16,000,000 kWh

Proposed electric consumption for compressed air production

16,000,000 × 0 30 = 4,800,000 kWh

Annual electricity savings will be

4,800,000 × 0 3 = 1,440,000 kWh

Annual Electricity Cost Savings

At current price of $0 042 per kWh, annual cost savings will be

1,440,000 × 0 042 = $60,500

Implementation costs

12 gas meters @ $1,700	$20,400
2 gas meters @ $2,500	$5,000
Overhead expenses @ 30%	$7,600
TOTAL COSTS	**$33,000**

Simple Payback

Implementation costs	$33,000
Annual cost savings	$60,500

Simple Payback is

33,000 / 60,500 = 0,6 year

A 4 ECO #4 - Monitoring and Recording of Natural Gas Consumption

Description of Opportunity

Current natural gas consumption at the facility is about 3,700,000 m^3 per year Total gas consumption is recorded via the gas meter installed at the plant gas regulating station Only the boiler house and the two ovens at the aluminum foundry are provided with meters Therefore the inefficiency of gas consumption due to faulty technological equipment is further increased due to operational staff's lack of actual consumption information and, consequently, lack of responsibility for excessive consumption Gas usage accounting should constitute one of the component parts of enterprises' energy management program According to expert evaluation supported by world-wide practice, energy accounting and control will result as a minimum in 10% cost savings

We propose to install additional gas meters on essential technological equipment, which will allow to in future to implement the energy management program at full extent In this case we will build our efficiency calculations on pessimistic assumption of 2-3% gas savings

Annual Energy Savings

Assuming conservatively that gas consumption record keeping system will allow 2% savings, at current annual consumption of 3,700,000 annual gas savings come to

3,700,000 × 0 02 = 74,000 m^3

Annual Cost Savings

At current gas price of $0 083 per 1 m^3, annual cost savings will be

74,000 × 0 083 = $6,100

Implementation Costs

3 gas meters @ $1,000	$3,000
Overhead expenses @ 30%	$900
TOTAL COSTS	**$3,900**

Simple Payback

Implementation Cost	$3,900
Annual cost savings	$6,100

Simple payback will be
3900 / 6100 = 0,6 year

A 5 ECO #5 - Overhaul of the Plant Hot Water System

Description of Opportunity

Currently the plant uses the following system of hot water supply

1) Steam boiler DKVR-2,5-13 produces steam with P_{steam} = 0 7 Bar pressure and $t°_{steam}$ = 115°C temperature,
2) The steam is then sent to 2 storage tanks with V_1 = 37 m^3 and V_2 = 26 5 m^3 capacity,
3) Direct steam is bubbled into cold water to heat it,

When water temperature has reaches $t°_{hot\ water}$ = 60-65°C, it is pumped to the end users according to a timetable

DKVR-2,5-13 boiler operates 24 hours a day and produces 250-300 kg of steam using 35-40 m^3 of gas per hour Technology also includes a draft van, which, according measurements taken, consumes N = 18 kW or 129,600 kWh annually

DKVR-2 5 boilers are about 30 years old Cut out sections of an idle boiler indicate that there is a 4 to 8 mm layer of crust on pipes internal diameter This results in 50% efficiency of the boiler, as there's no condensate in existing hot water system Chemical water treatment with two Na-cation filters cannot provide appropriate quality of the steam boiler makeup water

As a result, the facility has considerable natural gas and electricity losses

We recommend to change the configuration of hot water supply system, as well as the equipment We recommend the following

1) Use as a heat source is 200-250 kW capacity boiler with 95-70°C water temperature and at least 90% efficiency,
2) Use adequately sized plate-type heat exchanger Circulator and burner fan motors consume not more than 3 kW,
3) Cold water will be heated in the heat exchanger to 60°C and sent to the hot water storage tanks,
4) Hot water to the end users will be supplied from the storage tanks via the existing pipeline system and according to the current timetables

This system will save 40% of natural gas and 80% of electricity

Annual Energy Savings

Hot water consumption on the facility according to measurements is $G_{hot\ water}$ = 80 tons per day year round In winter hot water supply period ($n_{heating}$ = 150 days) average cold water temperature is $t°_{cold\ water}^{heating}$ = 10°C, hot water temperature is $t°_{hot\ water}^{heating}$ = 60°C In summer hot water supply period ($n_{non\ heating}$ = 150 days) average cold water temperature is $t°_{cold\ water}^{non\ heating}$ 20°C, hot water temperature is $t°_{hot\ water}^{non\ heating}$ 45°C

Calculation for the annual amount of heat used for hot water supply will be

$Q_{hot\ water} = [G_{hot\ water} \times (t°_{hot\ water}{}^{heating} - t°_{hcold\ water}{}^{heating}) \times n_{heating} + G_{hot\ water} \times (t°_{hot\ water}{}^{non\ heating} - t°_{hcold\ water}{}^{non\text{-}heating}) \times n_{non\ heating}] / 1{,}000$ Gcal

$Q_{hot\ water} = [\ 80 \times (\ 60\text{-}10\ ) \times 150 + 80 \times (\ 45 - 20\ ) \times 150\ ] / 1{,}000 = 900$ Gcal

Measurements have shown that it takes $G_{gas}{}^{daily}$ 880 m^3 of gas to produce daily needed amount of hot water with $Q_{daily} = 4$ Gcal heat content Therefore, actual gas consumption is

$b_{actual} = G_{gas}{}^{daily} / Q_{daily} = 880 / 4 = 220\ m^3/Gcal$

Proposed equipment will consume $b_{proposed} = 130\ m^3/Gcal$

Gas savings on producing 1Gcal of heat in hot water will be

$b_{actual} - b_{proposed} = 220 - 130 = 90\ m^3/Gcal$

Annual gas savings at $Q_{hot\ water} = 900$ Gcal

$90 \times 900 = 81{,}000\ m^3$

DKVR-2 5 boiler's draft fan annual electricity consumption E_{actual} is

$18 \times 24 \times 300 = 129{,}600$ kW

where

N = 18 kW - draft fan hourly electric consumption,

$O_{hrs} = 24 \times 300$ hr - operation hours per year

Circulator and burner fan motors in the proposed system consume not more than $N_{proposed} = 3$ kW, so, annual electric consumption is

$E_{proposed} = N_{proposed} \times O_{hrs} = 3 \times 24 \times 300 = 21{,}600$ kW

Annual electricity savings

$E_{actual} - E_{proposed} = 129{,}600 - 21{,}600 = 108{,}000$ kW

Annual Cost Savings

At current natural gas price of \$0 083 per 1 m^3, annual gas cost savings will be
$81{,}000 \times 0\ 083 = \$6{,}720$

At current electricity price of \$0 042 per 1 kWh, annual electricity cost savings will be
$108{,}000 \times 0\ 042 = \$4{,}500$

Total cost savings on this ECO

6,720 + 4,500 = $11,220

Implementation Costs

Equipment costs boiler and water heater	$6,000
Design works	$1,000
Installation costs	$2,000
Overhead expenses @ 30%	$2,000
TOTAL COSTS	**$11,000**

Simple Payback

Annual savings	$11,220
Implementation costs	$11,000

Simple payback is

11,000 / 11,220 = 1 year

A 6 ECO #6 - Thermal Insulation of the Hot Water Tanks

Description of Opportunity

Two hot water storage tanks installed in the plant's boiler room are $V_1 = 37\ m^3$ and $V_2 = 26\ 5\ m^3$ capacity Overall outside surface of the tanks is $F = 130\ m^3$ Both tanks are not insulated Outside surface temperature is 60°C to 70°C Heat losses due to insufficient walls insulation are more then 10%

We propose to insulate the tanks with foamed polyurethane insulation followed by coating with aluminum paint This will reduce heat losses by 90-95 %

Annual Energy Savings

Overall uninsulated surface is $F = 130\ m^2$

Heat losses to the environment are calculated as

$Q_{losses} = K \times F \times \Delta t \times 10^6$ (Gcal/hr))

where

$K = 3{,}2\ Ccal/m^2 \times h \times °C$ - heat flow

$F = 130\ m^2$ - heat-transfer area

$\Delta t = (t°_{surface} - t°_{ambient})$ - temperature interval

$t°_{surface}$ - tank outside surface temperature

$t°_{ambient}$ - ambient temperature

Summer and winter temperatures are different, therefore heat losses during heating and non-heating seasons are calculated separately

Heat losses during heating season, if $t°_{surface}^{heating} = 60°C$, $t°_{ambient}^{heating} = 20°C$, heating days $n_{heating} = 150$, is

$$Q_{losses}^{heating} = K \times F \times (t°_{surface}^{heating} - t°_{ambient}^{heating}) \times 24 \times n_{heating} \times 10^6 =$$
$$= 3{,}2 \times 130 \times (60\text{-}20) \times 24 \times 150 \times 10^6 = 60\ Gcal$$

Heat losses during non-heating season, if $t°_{surface}^{non_heating} = 50°C$, $t°_{ambient}^{non\ heating} = 30°C$, heating days $n_{non\ heating} = 150$, is

$$Q_{losses}^{non\ heating} = K \times F \times (t°_{surface}^{non_heating} - t°_{ambient}^{non\ heating}) \times 24 \times n_{non\ heating} \times 10^6 =$$
$$= 3{,}2 \times 130 \times (50\text{-}30) \times 24 \times 150 \times 10^6 = 30\ Gcal$$

Total annual losses are

$Q_{losses} = Q_{losses}^{heating} + Q_{losses}^{non\ heating} = 60 + 30 = 90$ Gcal

Specific gas consumption for the boiler house is b = 220 m^3/ Gcal

Annual gas savings will be

$Q_{losses} \times b = 90 \times 220 = 19{,}800\ m^3$

Annual Cost Savings

At current natural gas price of $0 083 per 1 m^3, annual gas cost savings will be

$S_r \times 0\ 083 = 19{,}800 \times 0{,}083 = \$1{,}640$

Implementation Costs

Costs of insulating 130 m^3 tank surface at $10 per 1 m^2 of deposition insulation

$130 \times 10 = \$1{,}300$

Overhead expenses @ 20%	$260
Total	$1,560

Simple Payback

Annual savings	$1,640
Implementation costs	$1,560

Simple payback

1,560 / 1,640 = 0 95 year

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A 7 ECO #7 - Controlling Insulation Heat Losses

Description of Opportunity

During the audit the audit team performed surface temperature measurements of the equipment and heat systems using non-contact thermometer ("heat spy") This was done to locate and evaluate heat losses due to poor insulation The heat spy's function us based on objects' infrared radiation measuring and converting at 0°C - 1000°C temperature range The results indicated that considerable losses occur

- in heat distribution system due to insufficient pipeline and stop valves,
- in district heat systems due to hydraulic and, consequently, thermal unbalance of heating equipment,
- in technological processes due to faulty insulation of technology ovens and other equipment

A non-contact thermometer is necessary for implementation of facility-wide energy management program This, according to expert evaluation, saves up to 10% of the energy used In our opinion, timely detection and correction of heat losses due to poor insulation will allow to reduce fuel consumption

Annual Energy Savings

Assuming conservatively that proposed equipment will allow to locate just 10% of heat losses, fixing the imperfections found will result in 0 5 - 1% gas savings Basing on annual gas consumption for district heat needs at 8,500 Gcal (according to the plant's data), annual gas savings may come to

8,500 × 0 01 = 85 Gcal

Annual Cost Savings

At current price of $38 per 1 Gcal, annual cost savings will be

85 × 38 = $3,230

Implementation Costs

non-contact remote-sensing thermometer (heat spy)	$1,000
Overhead expenses @ 30%	$300
TOTAL COSTS	**$1,300**

Simple Payback

Annual cost savings	$3,230
Implementation costs	$1,300

Simple payback is 1,300 / 3,230 = 0 4 year

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A 8 ECO #8 - Overhaul of the Plant's Boiler House

Description of Opportunity

Currently the facility purchases the heat energy for district heat purposes from the Kharkivoblenergo (a specialized utility) The heat energy is supplied via an external pipeline system This has following drawbacks

- high heat cost - at UAH 72 ($38) per 1 Gcal
- additional costs of reducing heat networks working parameters using mixing pump This is due to different external pipeline working parameters and safety parameters of internal heating system

  External pipeline parameters are

  - supply pipe pressure is P_{supply} = 11 5 kg/cm^2
  - return pipe pressure is P_{return} = 5 5 kg/cm^2
  - temperature chart is 150 - 70°C

  Durability and safety parameters of internal heating system equipment are

  - supply pipe pressure is P_{supply} = 6 kg/cm^2
  - return pipe pressure is P_{return} = 3 kg/cm^2
  - temperature chart is 95 - 70°C

  60% out of N = 50 kW consumed by the mixing pump is used to reduce the temperature chart and 40% to support hydraulic mode

- limited possibility of controlling quality and quantity of heat received, as external pipeline system uses qualitative criteria, (and not quantitative, as in the West), for heat provision control This results in necessity of having operational staff at the plant's boiler house that produces hot water 24 hours a day

Considering the aforementioned, we recommend to retrofit the boiler house to enable the facility to have its own heat source that could cover all its heating needs Retrofitting will require dismounting of existing steam boilers DKVR - 2,5 - 13 that are worn out and are unserviceable for technical reasons, and installing modern water boilers (type VK-21 or VK-31) with efficiency of 90% or better

The following calculations will help determine the boiler house's thermal performance and equipment configuration

According to the plant's data, maximum annual energy consumption for district heat purposes is Q_{annual} = 8,500 Gcal per n_{annual} = 3,500 degree-days Heat consumption per 1 degree-day is

$q = Q_{annual} / n_{annual}$ = 8,500 / 3,500 = 2 43 Gcal/degree-day

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Maximum amount of degree-days per coldest day with designed minimum temperature is

t_{min} = -23°C
n_{max} = 18 - (-23) = 41

Maximum hourly heat output for new boilers should be not less than

$Q_{hr} = q \times n_{max} / 24 = 2{,}43 \times 41 / 24 = 4\ 2$ Gcal/hr

Installation of two boilers with N = 2 MW capacity and one boiler with N = 1 25 MW capacity will allow required output

Overall capacity of proposed equipment is N = 5 25 MW, heat output is Q = 4 5 Gcal/hr Such equipment configuration will allow to select the most efficient operation mode of the boiler house

Annual Cost Savings

Annual heat costs at annual consumption of Q_{annual} = 8,500 Gcal and current tariff at UAH 72 ($38) per 1 Gcal are

38 × 8,500 = $324,000

Annual costs of gas needed to produce the same annual amount of heat, i e Q_{annual} = 8,500 Gcal, with an autonomous boiler house at current gas price at $0 083 per 1 m^3 and specific fuel consumption at b = 133 m^3/Gcal and with η = 90% boiler efficiency will be

$Q_{annual} \times b \times 0\ 083 = 8500 \times 133 \times 0\ 083$ = $94,000

Annual heat cost savings will come to

324,000 - 94000 = $230,000

Implementation Costs

Design works with approvals, overheads included	$5,000
Boiler dept equipment, overheads included	$100,000
Installation and commissioning works, overheads included	$50,000
TOTAL COSTS	$155,000

Simple Payback

Annual heat energy cost savings	$230,000
Implementation costs	$155,000

Simple payback of this ECO is

155,000 /230,000 = 0 7 year

A 9 ECO#9 - Installation of Back Pressure Steam Turbine and Overhaul of Process Ovens

Description of Opportunity

During the visit the audit team observed operation of 10 aluminum casting furnaces On most furnaces visible flame tips were reaching the fume-collecting hood Outside surface temperature of the metal hood was as high as 360°C, despite air inflows from the outside Expert estimate of furnace efficiency is not more than 25%

There's no doubt that this aluminum casting process needs to be improved Plant's management wishes to improve technology by using a complex casting unit consisting of two ovens A gas oven will be used for melting aluminum and an electric oven for chemical composition conditioning This will allow production of aluminum alloy of desired composition

In order to combine improved technology of producing quality aluminum alloy with optimum energy consumption we recommend to

Equip the gas oven of a proposed system with a firebrick envelope and smoke fumes evaporation cooling unit This will recover 60-65% of heat produced

The heat recovered will allow to produce steam with characteristics suitable for producing electricity with a screw-rotor steam turbine This electricity could be used either for electric oven of complex casting unit or for other purposes

Exhaust steam after steam turbine is condensed

in an air heater which heats the air supplied to gas oven burner,
in a water heater which heats delivery water for district heat purposes
in a water heater for hot water supply

Excess heat could also be sold to outside organizations on mutually beneficial conditions using external heat networks, especially in summer period

Accurate distribution of heat recovered will be possible after a full energy audit check which will allow to calculate the energy balance Having this balance sheet will make it easier to make a decision on excess heat utilization

Annual Energy Savings

Basing on plant's actual consumption figures we would assume that annual gas consumption for ovens is 3,000,000 m^3 or 24,900 Gcal/yr in heat equivalent with gas heating value at 8,300 Ccal/m^3 Recovering 60% of heat energy will save annually

$24{,}900 \times 0\ 6 \cong 15{,}000$ Gcal

Converting 10% of heat energy into electric energy will produce up to

$15{,}000 \times 0\ 1 \times K = 15{,}000 \times 0\ 1 \times 1\ 163 \times 1{,}000 = 1{,}700{,}000$ kWh

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where

K=1 163×1000 - conversion coefficient of 1Gcal of heat energy into 1,163 kW of electric power

Annual heat energy savings will come to
15,000 × 0 9 = 13,500 Gcal

P S As the enterprises' annual heat energy need is 8,500 Gcal, it will be possible to sell annually as much as

13,500 - 8,500 = 5,000 Gcal

Annual Cost Savings

At current electricity price of $0 042 per 1 kWh annual electricity cost savings will be
1,700,000 × 0 042 = $71,400

Heat energy cost savings at $38 per 1 Gcal and 8,500 Gcal annual consumption will be
8,500 × 38 ≅ $320,000

Selling 5,000 Gcal of excess heat at $10 per 1 Gcal will bring
5,000 × 10 = $50,000

TOTAL annual energy cost savings may come up to

71,400 + 320,000 + 50,000 = $441,400

Implementation Costs

The following calculations is based upon expert evaluation of equipment and work costs

1	Comprehensive energy audit	$50,000
2	Design	$100,000
3	Oven equipment	$500,000
4	Disposal evaporation unit	$100,000
5	Steam turbine with 250 kW generator	$200,000
6	"Turn-key" installation and commissioning	$300,000
7	Overhead and unforeseen expenses @ 30%	$350,000
TOTAL COSTS		**$1,600,000**

Simple Payback

Annual cost savings	$438,000
Implementation costs	$1,600,000

Simple payback for this ECO is

1,600,000 / 441,400 = 3 6 year

APPENDIX B. PRELIMINARY SPECIFICATIONS

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B 1 Equipment and work specifications ECO#1 Institution of Energy Management

#	Equipment/Works Description	Model or Type	Manufacturer, Country of Origin	Basic Parameters	Quantity	Cost per Item US$	Shipping Costs US$	Contractor	Cost of Works US$	Total Costs US$	Notes
1	Implementing Energy Management program and introducing energy consumption record keeping system							"Elta" Consulting Kharkiv, Ukraine		70,000	Financing from the"Piston Plant's" funds
	TOTAL									**70,000**	

B 2 Equipment and Works Specification, ECO#2 - Monitoring and Recording of Power Consumption

#	Equipment/Works Description	Model or Type	Manufacturer, Country of Origin	Basic Parameters	Quantity	Cost per Item US$	Shipping Costs US$	Contractor	Cost of Works US$	Total Costs US$	Notes
1	Technical equipment				1 set			JSC "Stroysnabsbyt" Kharkiv, Ukraine	12,850	12,850	
2	Specialized subcontractors services							"Elta" Consulting Kharkiv, Ukraine	7,150	7,150	
	TOTAL									**20,000**	

B 3 Equipment and Works Specification, ECO#3 - Monitoring and Recording Consumption of Compressed Air

#	Equipment/Works Description	Model or Type	Manufacturer, Country of Origin	Basic Parameters	Quantity	Cost per Item US$	Shipping Costs US$	Contractor	Cost of Works US$	Total Costs US$	Notes
1	In-Line Vortex Shedding Flowmeter	EMCO Phd-90S-10F-150-LOC-TOT- T1"	Industrial Representatives, Int PO Box 421 Clifton, NJ 07015	Power 24 VDC with 4-20 mA/Pulse output	3	1,400		"Kharkiv Piston Plant" Kharkiv, Ukraine		4,200	
2	In-Line Vortex Shedding Flowmeter	EMCO Phd-90S-40F-150-LOC-TOT- T3"	Industrial Representatives, Int PO Box 421 Clifton, NJ 07015	Power 24 VDC with 4-20 mA/Pulse output	9	1,729		"Kharkiv Piston Plant" Kharkiv, Ukraine		15,561	
3	In-Line Vortex Shedding Flowmeter	EMCO Phd-90S-40F-150-LOC-TOT- T4"	Industrial Representatives, Int PO Box 421 Clifton, NJ 07015	Power 24 VDC with 4-20 mA/Pulse output	1	2,744		"Kharkiv Piston Plant" Kharkiv, Ukraine		2,744	
4	In-Line Vortex Shedding Flowmeter	EMCO Phd-92S-60F-150-LOC-TOT- T6"	Industrial Representatives, Int PO Box 421 Clifton, NJ 07015	Power 24 VDC with 4-20 mA/Pulse output	1	2,032		"Kharkiv Piston Plant" Kharkiv, Ukraine		2,032	
	TOTAL									**24,537**	

B 4 Equipment and Works Specification, ECO#4 - Monitoring and Recording of Natural Gas Consumption

#	Equipment/Works Description	Model or Type	Manufacturer, Country of Origin	Basic Parameters	Quantity	Cost per Item US$	Shipping Costs US$	Contractor	Cost of Works US$	Total Costs US$	Notes
1	Rotary gas meter	RG - 100	I Open JSC "Promprибor" Ivanofrankivsk, Ukraine	$P_y = 0,1$ MPa $Q_{nom} = 100$ m^3/hr	3	436		"Kharkiv Piston Plant" Kharkiv, Ukraine		1,308	Shopment costs included
		RG - 100	II JSC "Energia" Yenakiyevo, Ukraine	$P_y = 0,1$ MPa $Q_{nom} = 100$ m^3/hr	3	703		"Kharkiv Piston Plant" Kharkiv, Ukraine		2,109	Shopment costs included

B 5 Equipment and Works Specification, ECO#5 - Overhaul of the Plant Hot Water System

#	Equipment/Works Description	Model or Type	Manufacturer, Country of Origin	Basic Parameters	Quantity	Cost per Item US$	Shipping Costs US$	Contractor	Cost of Works US$	Total Costs US$	Notes
1	Water boiler	ELGA	"Sovenergoresource" Center, Nikolayev, Ukraine	N=250 kW	1	3,200	700			3,900	
2	Plate-type heat exchanger w/ temperature control	N0,1-(2,5+2,5)-K	Open JSC "Ancor-Teploenergo"	N=200 kW		2000	300			2,300	
3	Design, registration, approval, shipment, installation, testing, commissioning							"Elta" Consulting Kharkiv, Ukraine	4,000	4,000	
	TOTAL									**10,200**	

B 6 Equipment and Works Specification, ECO#6 - Thermal Insulation of the Hot Water Tanks

#	Equipment/Works Description	Model or Type	Manufacturer, Country of Origin	Basic Parameters	Quantity	Cost per Item US$	Shipping Costs US$	Contractor	Cost of Works US$	Total Costs US$	Notes
1	Insulating 130 m^2 surface of hot water tanks using 2 cm thick layer of foamed polyurethane							"Teploavtomatika" Company Kharkiv, Ukraine	1,560	1,560	Materials costs included in work costs
	TOTAL									**1,560**	

B 7 Equipment and Works Specification, ECO#7 - Set- back Thermostat Control for the Heating System

#	Equipment/Works Description	Model or Type	Manufacturer, Country of Origin	Basic Parameters	Quantity	Cost per Item US$	Shipping Costs US$	Contractor	Cost of Works US$	Total Costs US$	Notes
1	Infra-red Non-contact Thermometer	ST6 LS	Davis Instruments 4701 Mount Hope Drive Baltimor, MD21215, USA	t° = -20 – 500°C	1	499				499	
	TOTAL									**499**	

B 8 Equipment and Works Specification, ECO#8 - Overhaul of the Plant Boiler House

#	Equipment/Works Description	Model or Type	Manufacturer, Country of Origin	Basic Parameters	Quantity	Cost per Item US$	Shipping Costs US$	Contractor	Cost of Works US$	Total Costs US$	Notes
1	Water boiler	KBNG-2,5	"Kharkiv Teploenergo" Production association Kharkiv, Ukraine	Capacity 2,9 MW	2	38,000	500			76,500	
2	Water boiler	VK-31	Closed JSC "Promin" Kyiv, Ukraine	Capacity 1,25 MW	1	23,000	500			23,500	
3	Design, registration, approval, shipment, installation, testing, commissioning							"Elta" Consulting Kharkiv, Ukraine	55,000	55,000	
	TOTAL									**155,000**	

B 9 Equipment and Works Specification, ECO#9 - Installation of Back Pressure Steam Turbine and Overhaul of Process Ovens

#	Equipment/Works Description	Model or Type	Manufacturer, Country of Origin	Basic Parameters	Quantity	Cost per Item US$	Shipping Costs US$	Contractor	Cost of Works US$	Total Costs US$	Notes
1	Equipment for gas and electric ovens	According to the project	Electroterm Pesearch Institute, Kharkiv, Ukraine	According to the project	1	500,000	5,000			505,000	
2	Disposal evaporating station	According to the project	"Stimul" Research and production enterprise, Kharkiv, Ukraine	According to the project	1	100,000	2,000			102,000	
3	Back pressure steam turbine	PVM-200	JSC "Nezavisimaya Energetika" Moscow, Russia	N=200 kW	1	150,000	5,000			155,000	
4	Energy Audit							"Elta" Consulting Kharkiv, Ukraine	50,000	50,000	
5	Design, registration, approval, shipment, installation, testing, commissioning							"Elta" Consulting Kharkiv, Ukraine	450,000	450,000	
	TOTAL									**1262,000**	

APPENDIX "C". AUDIT RECORDS AND PLANT DATA

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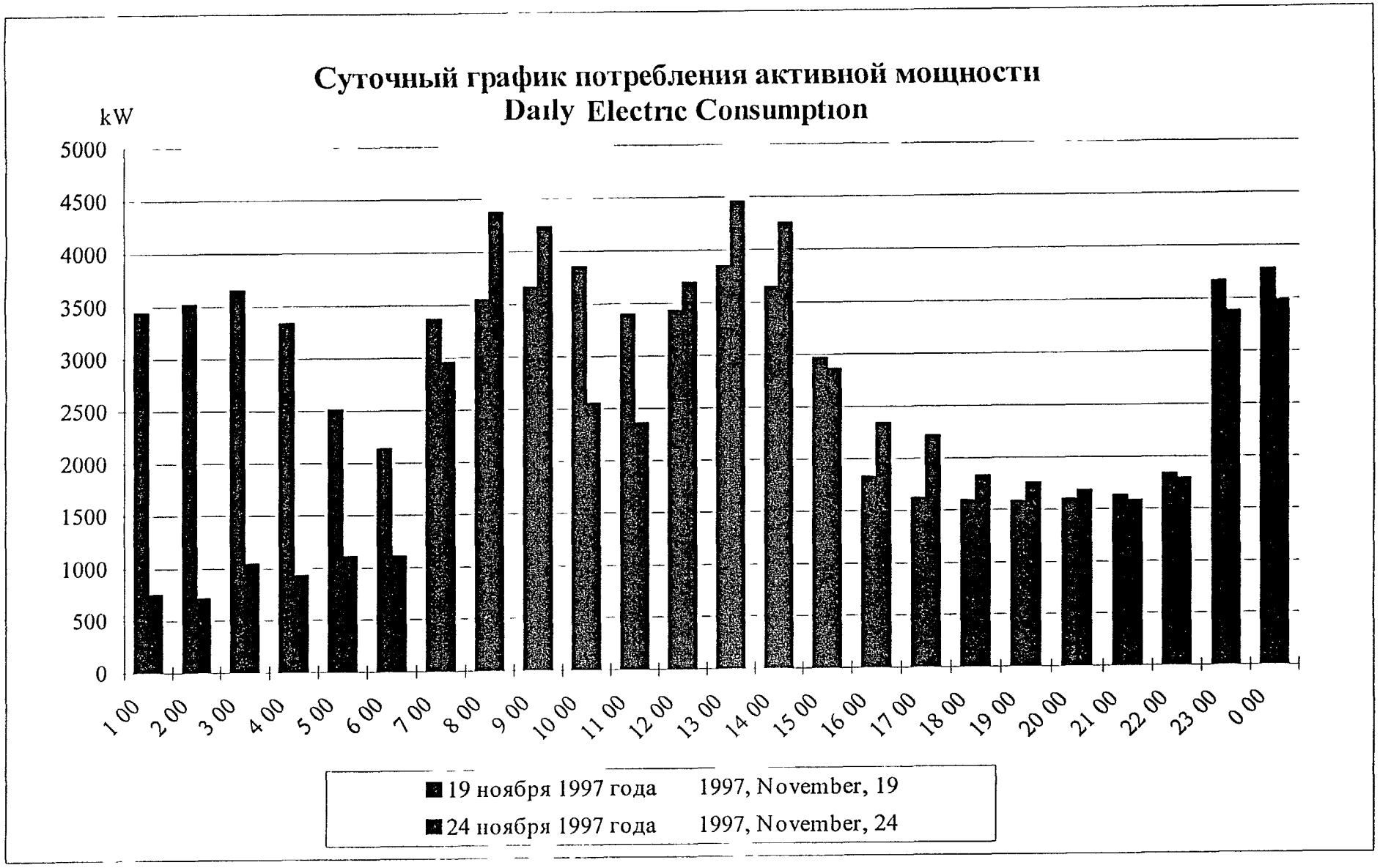
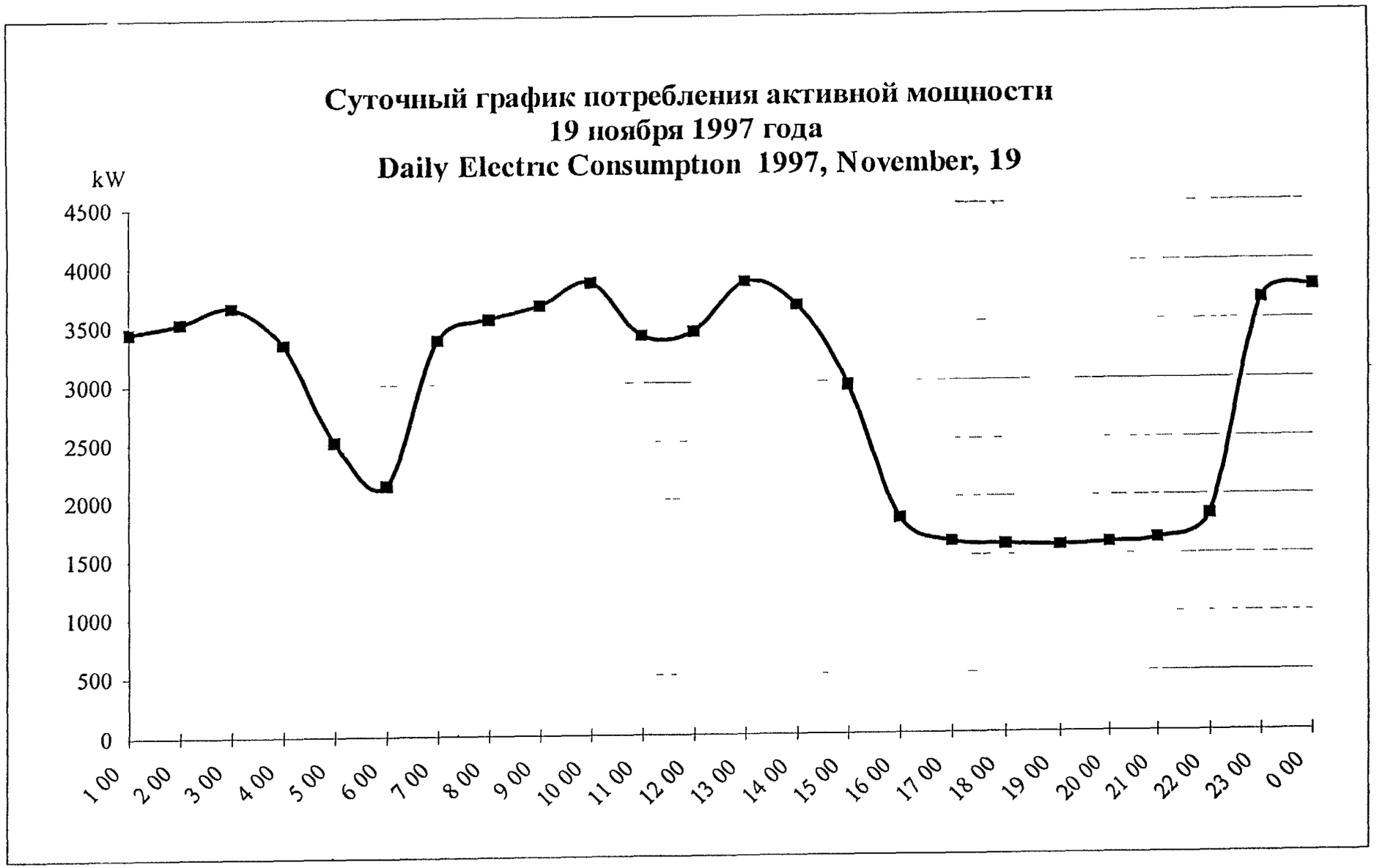

Суточный график потребления активной мощности
Daily Electric Consumption
kW
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1 00
2 00
3 00
4 00
5 00
6 00
7 00
8 00
9 00
10 00
11 00
12 00
13 00
14 00
15 00
16 00
17 00
18 00
19 00
20 00
21 00
22 00
23 00
0 00
19 ноября 1997 года 1997, November, 19
24 ноября 1997 года 1997, November, 24


Суточный график потребления активной мощности
19 ноября 1997 года
Daily Electric Consumption 1997, November, 19
kW
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1 00
2 00
3 00
4 00
5 00
6 00
7 00
8 00
9 00
10 00
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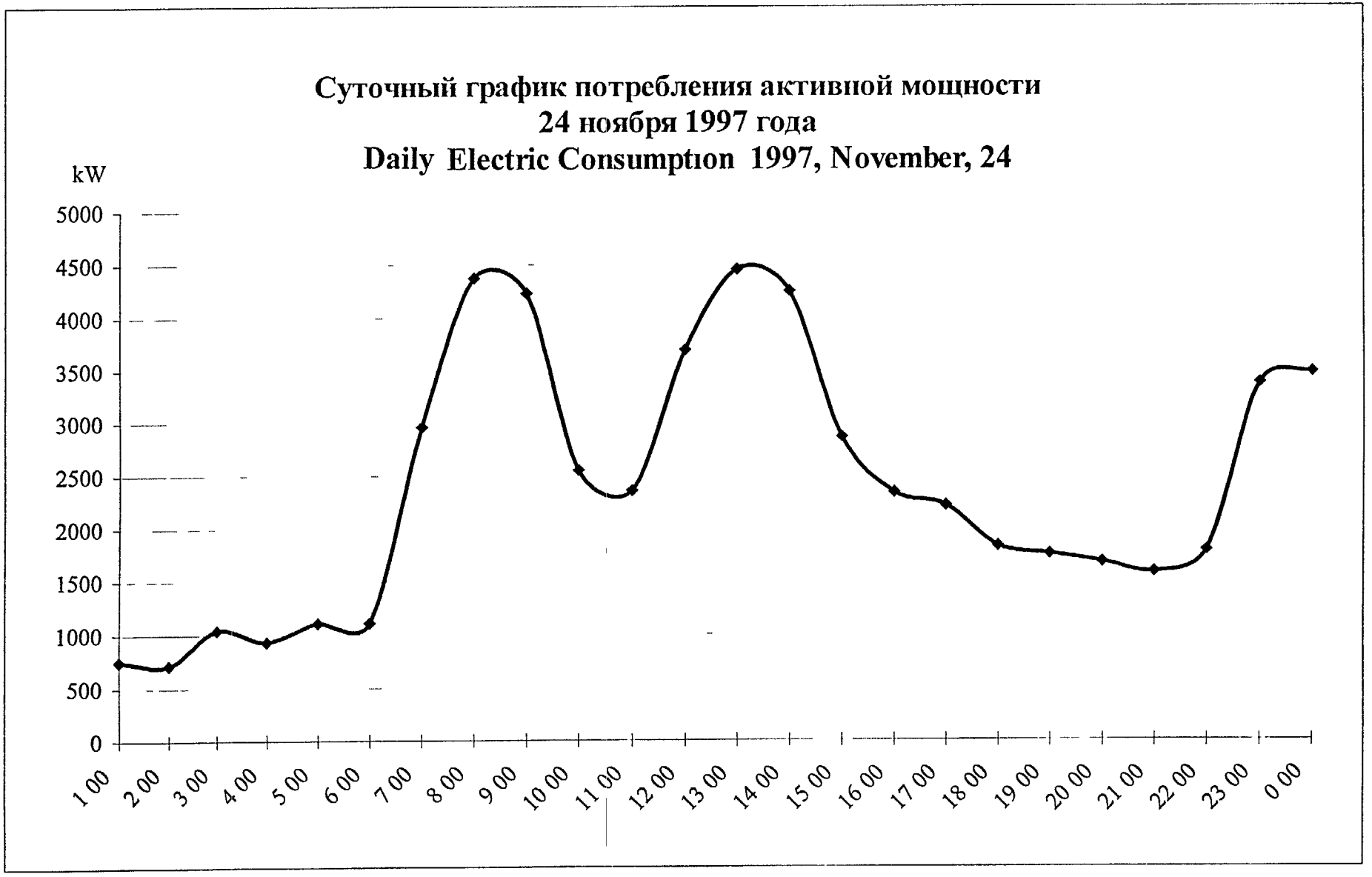
21 00
22 00
23 00
0 00

65


Суточный график потребления активной мощности
24 ноября 1997 года
Daily Electric Consumption 1997, November, 24
kW
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1 00
2 00
3 00
4 00
5 00
6 00
7 00
8 00
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22 00
23 00
0 00

8

APPENDIX D. PLANT PHOTOGRAPHS

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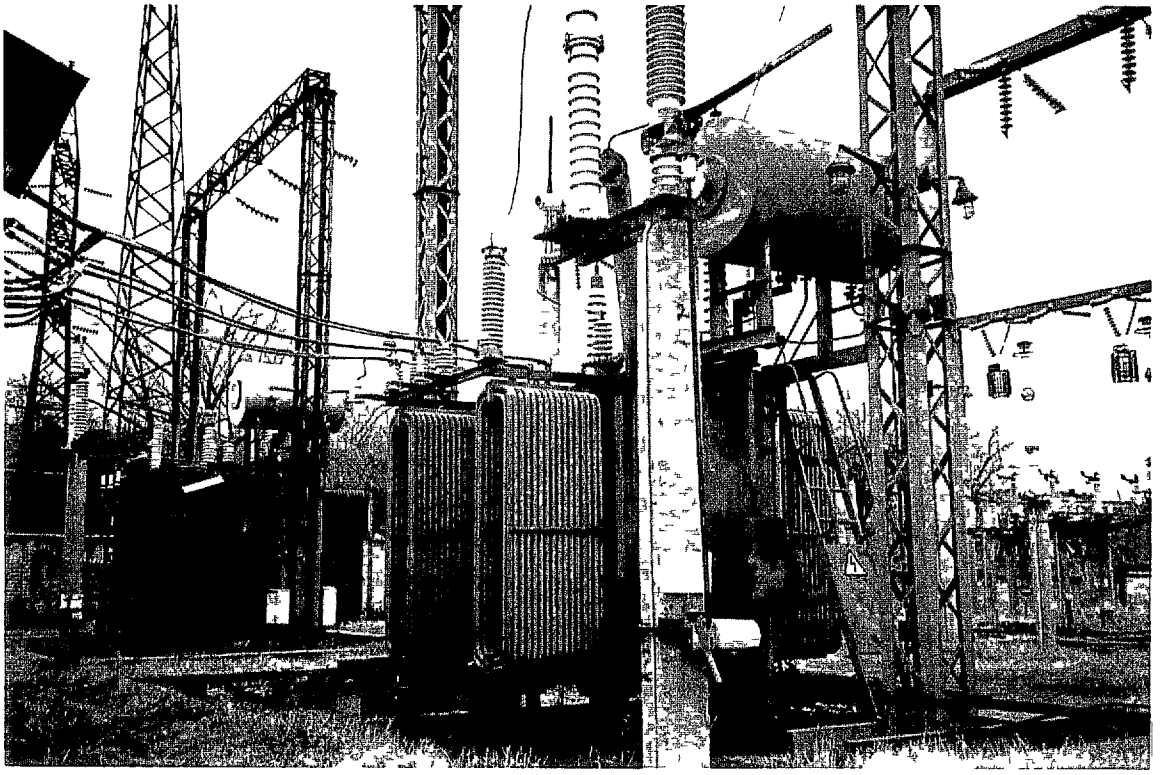
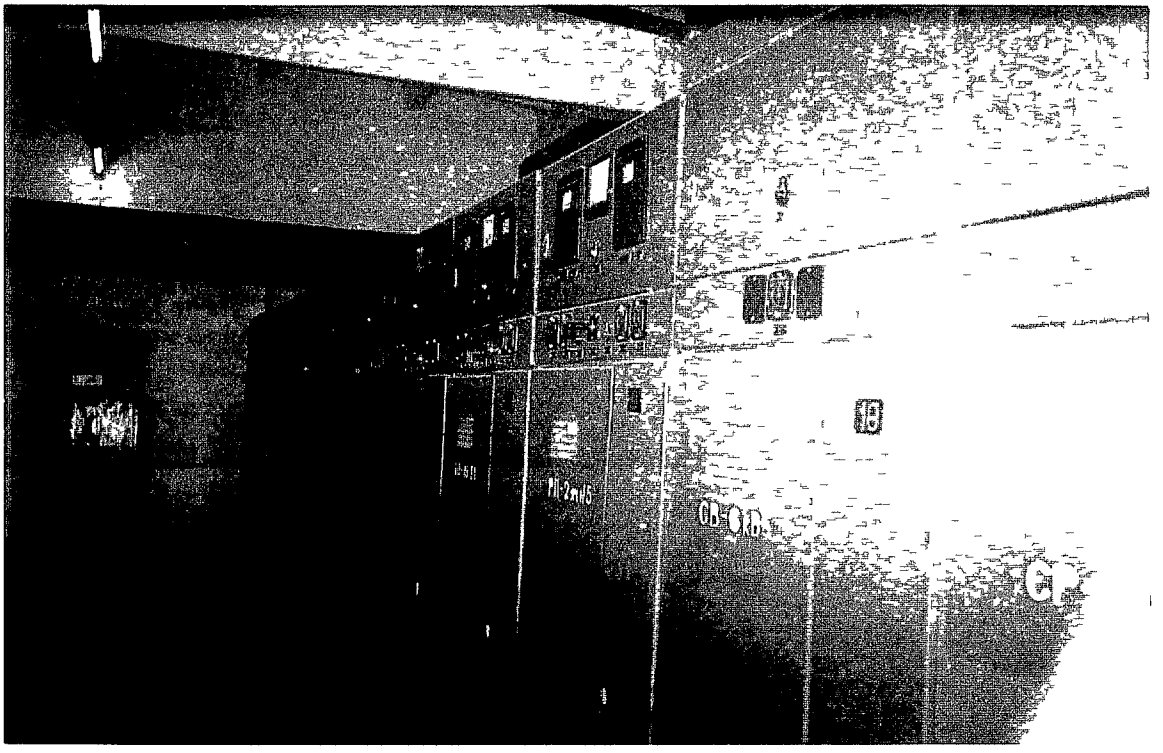
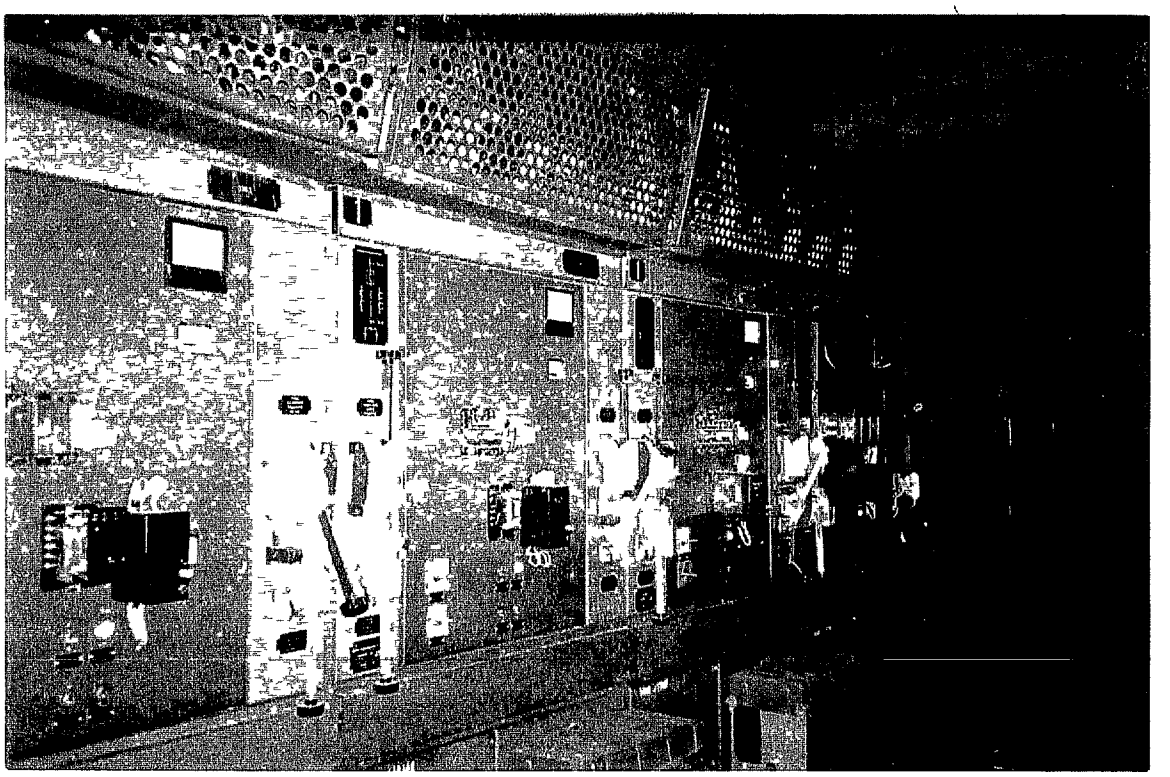


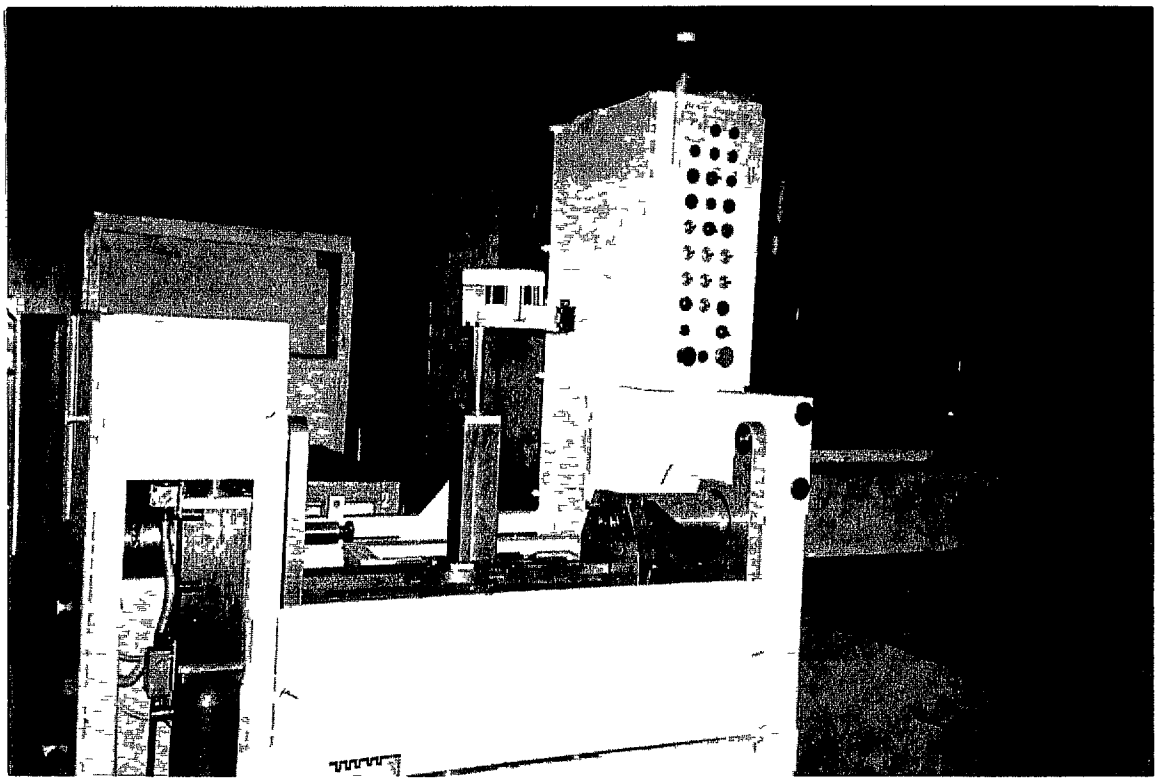
Открытое распределительное устройство
с силовыми трансформаторами 16000 кВа 110/6 кВ
An open feeder switchboard with 110/6-KV-16,000 KVA
power ful transformers



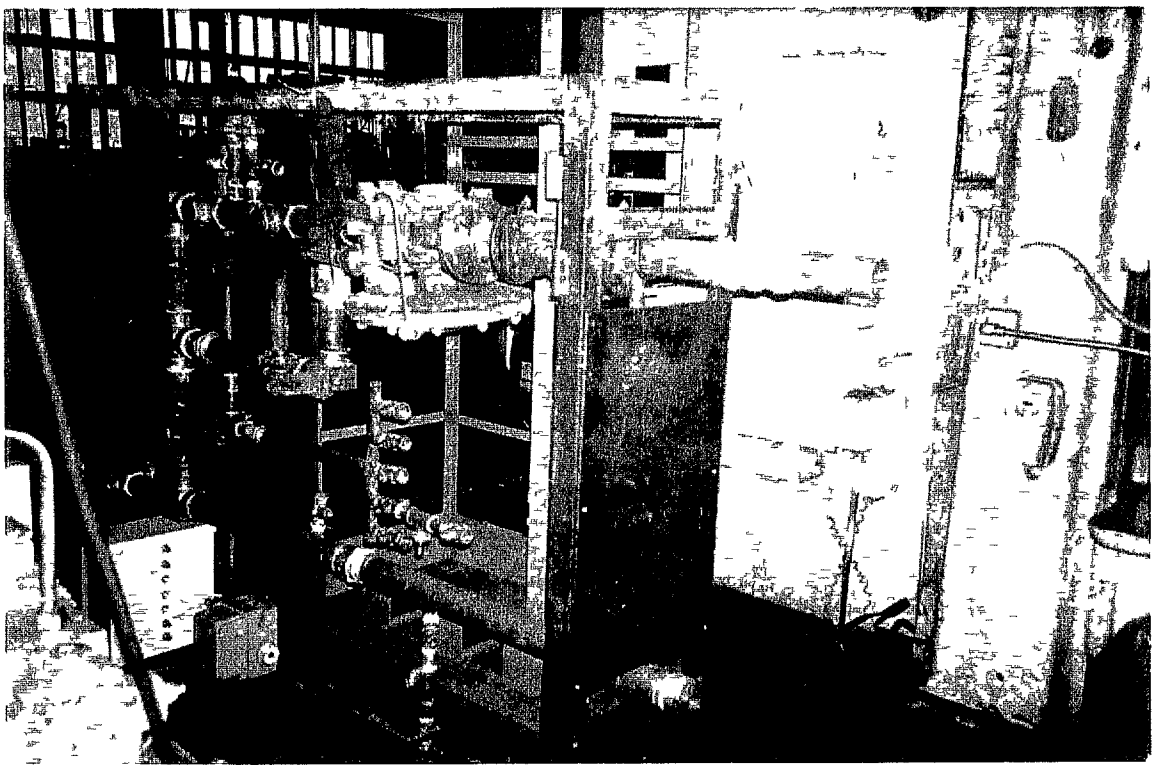
Комплексное распределительное устройство 6 кВ
с отходящими фидерами трансформаторов 16000 кВа
6-KV komplex feeder switchboard with autletting feeders
of 16,000-KVA transformers

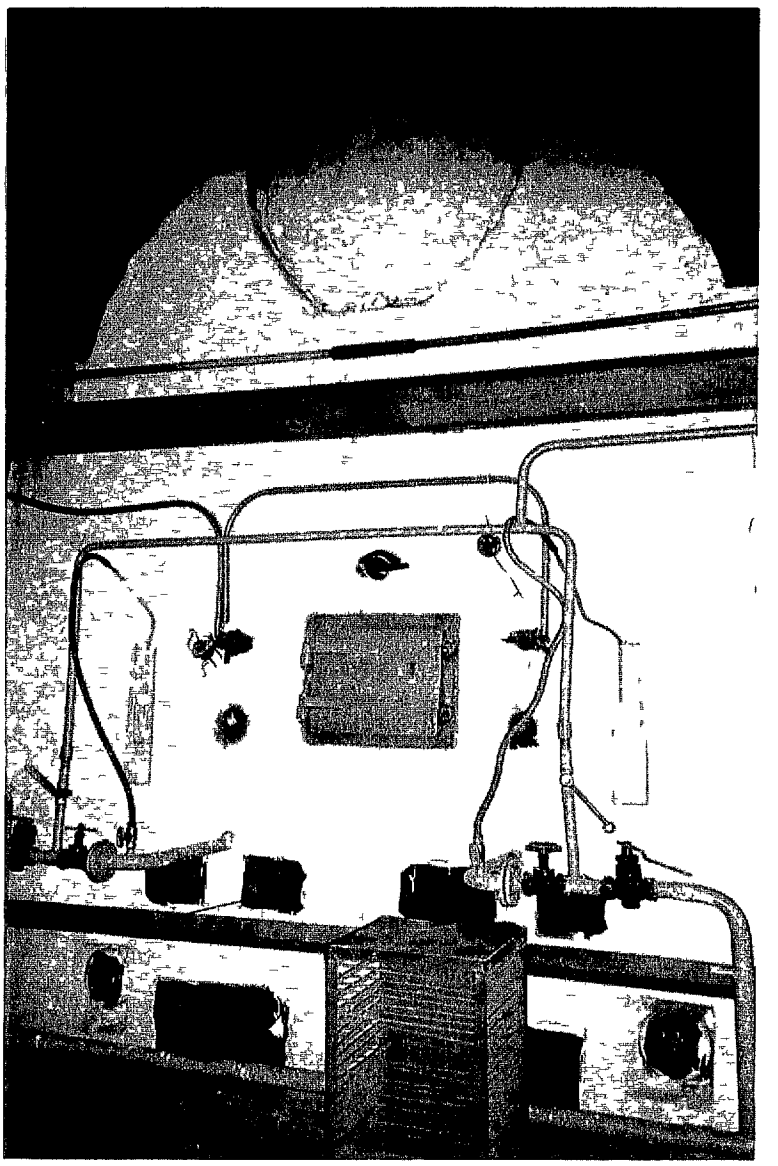


Распределительный пункт закрытого распределительного устройства
6 кВ с отходящими фидерами
A distributing unit of 6-KV closed feeder switchboard with outletting feeders

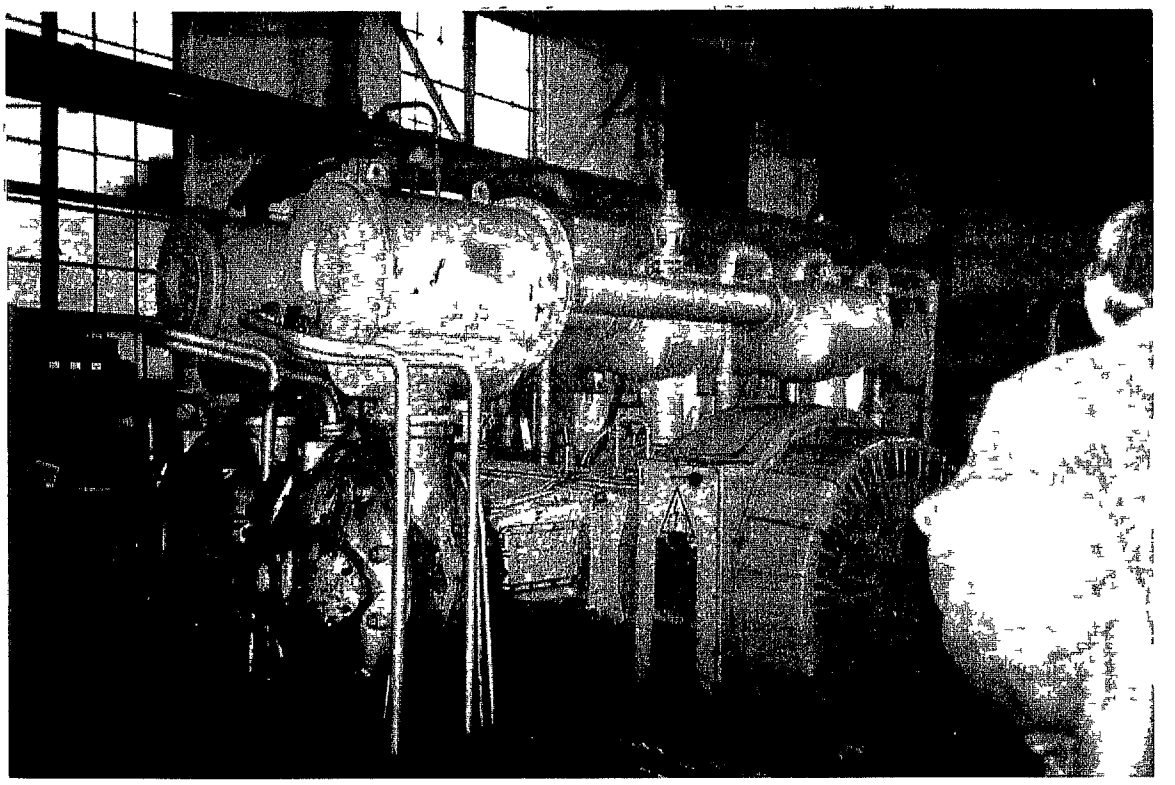


Продукция цеха нестандартного оборудования
Products of the non-standard equipment workshop

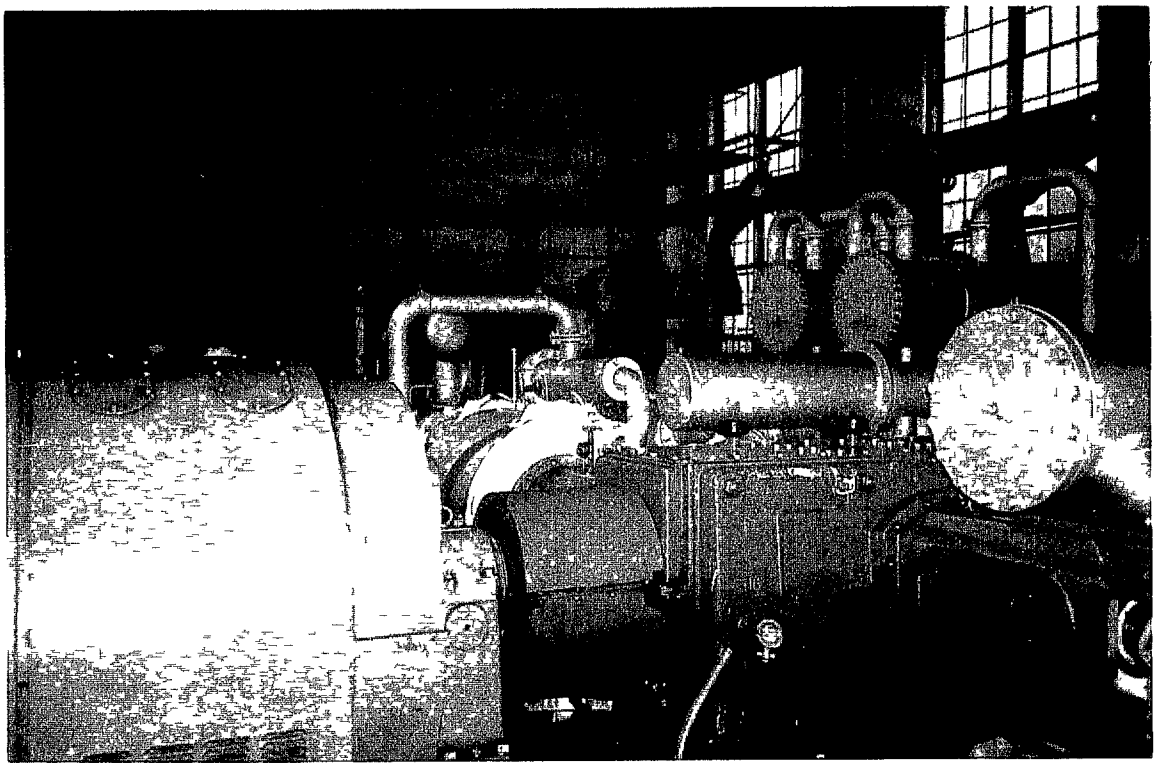


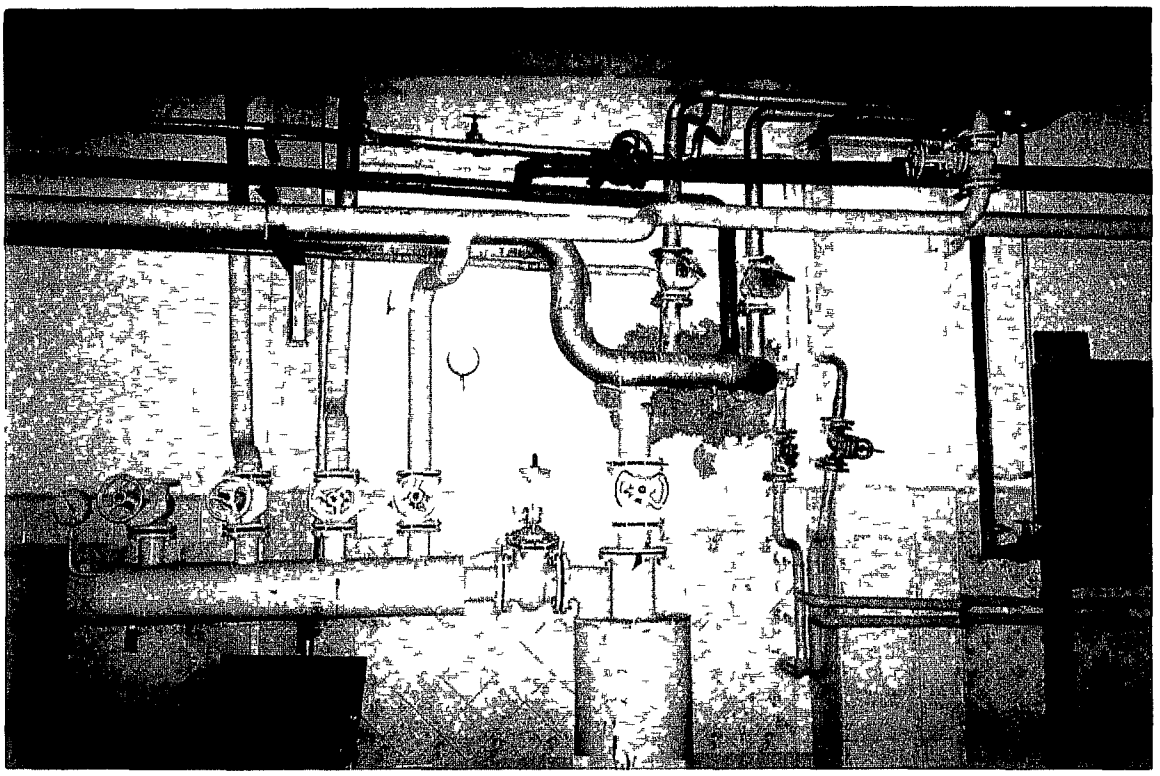


Котел ДКВР-2,5×12 котельной завода
DKVR-2,5×12 Boiler in the boiler-hous of the plant

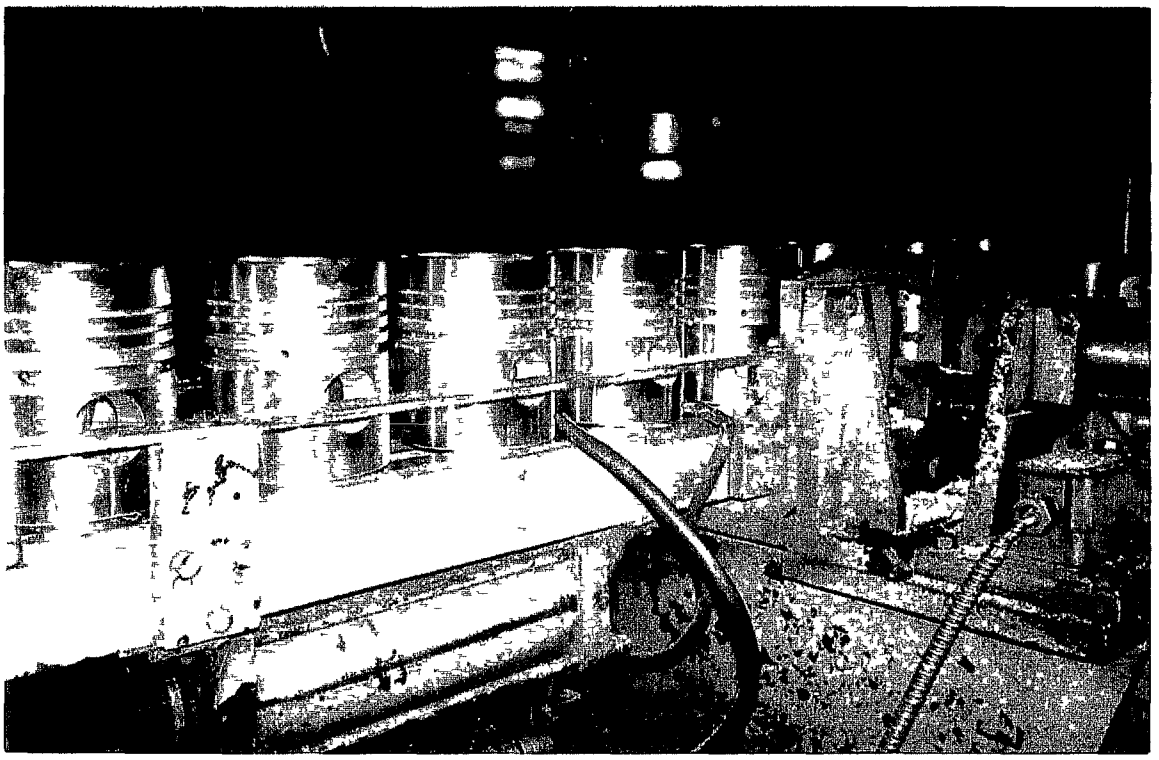


Компрессорная сжатого воздуха
The compression station for production of compressed air

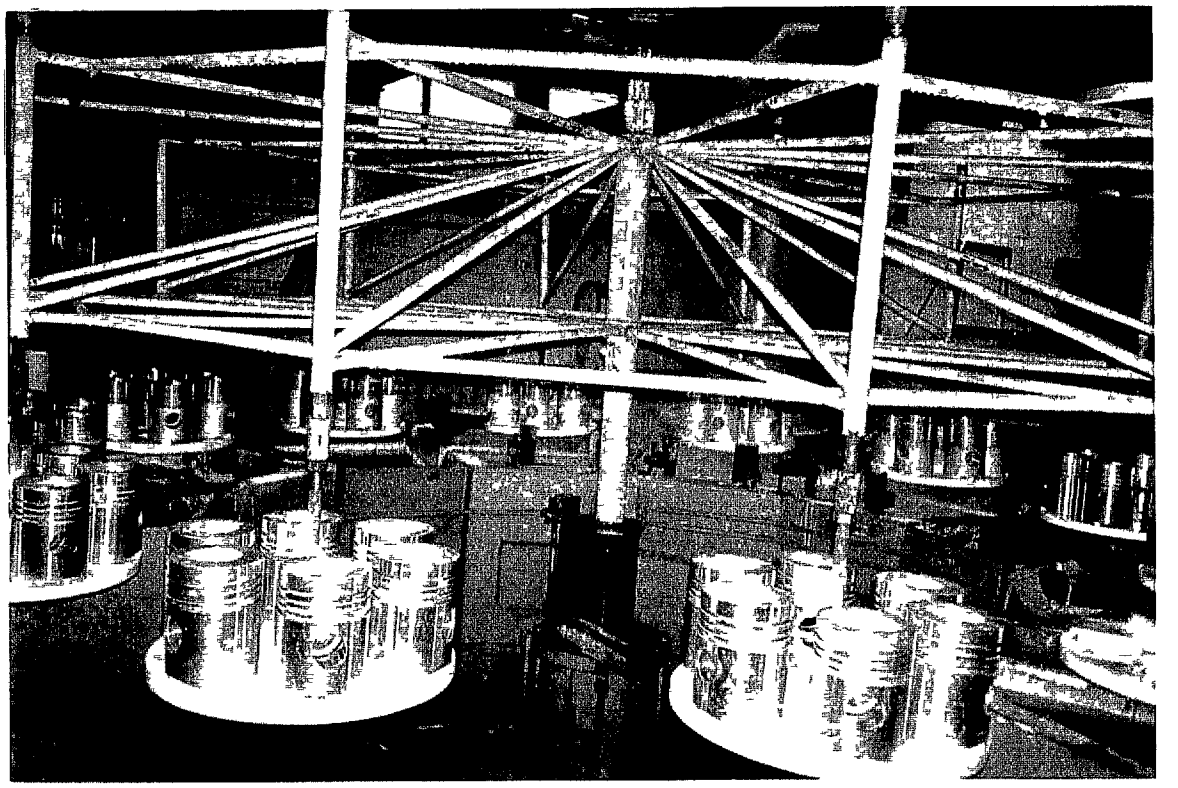




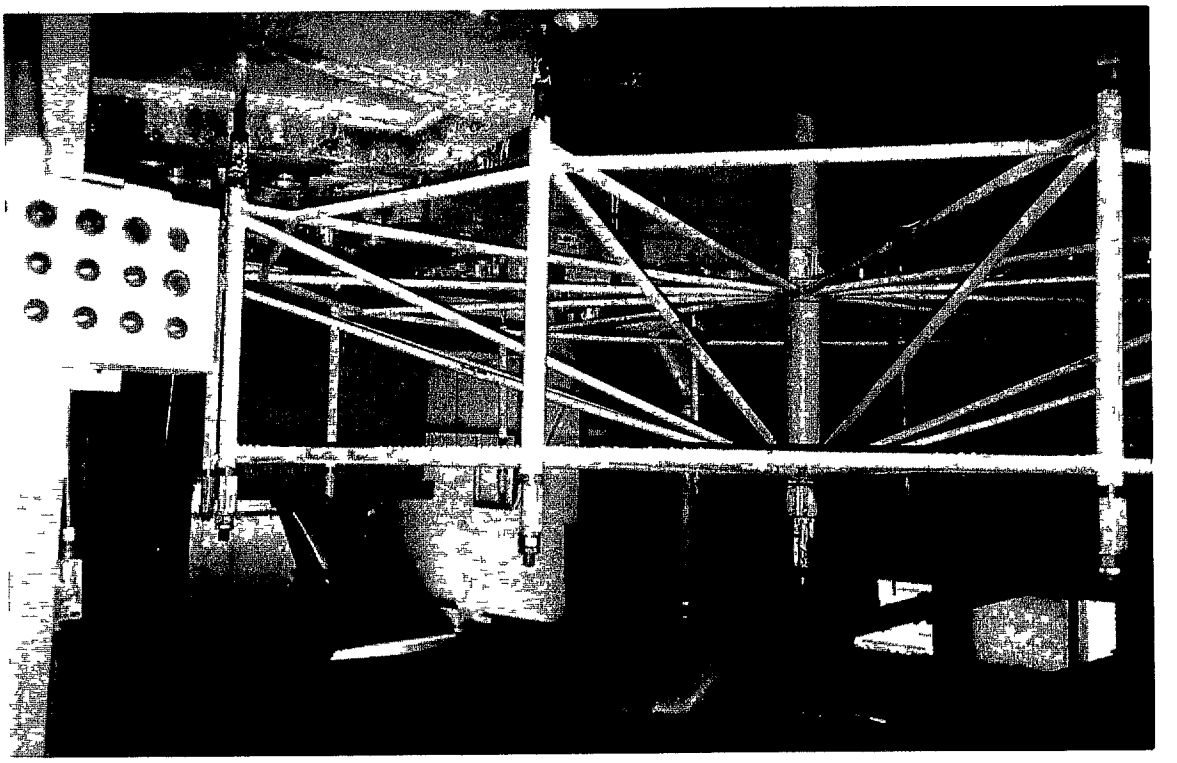
Распределительный коллектор сжатого воздуха
The compressed-air distributing collector

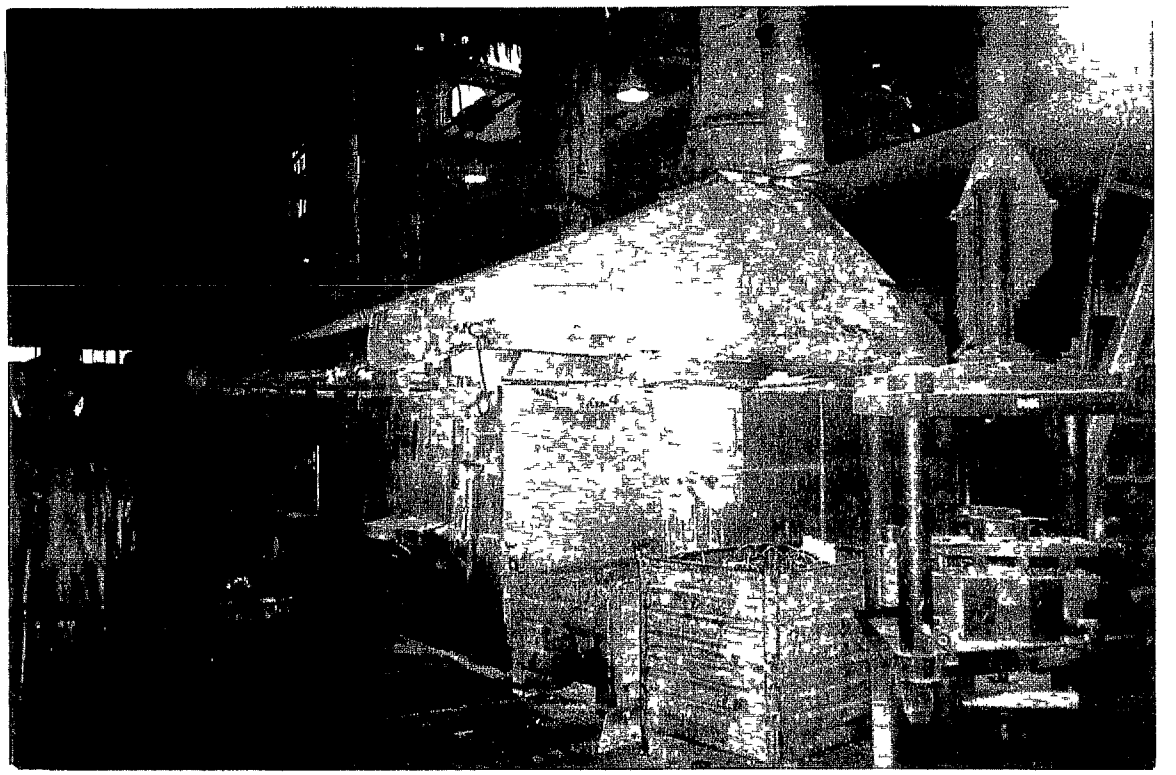


Нерегулируемая продувка поршней сжатым воздухом
Non-controlled piston blowing with compressed air

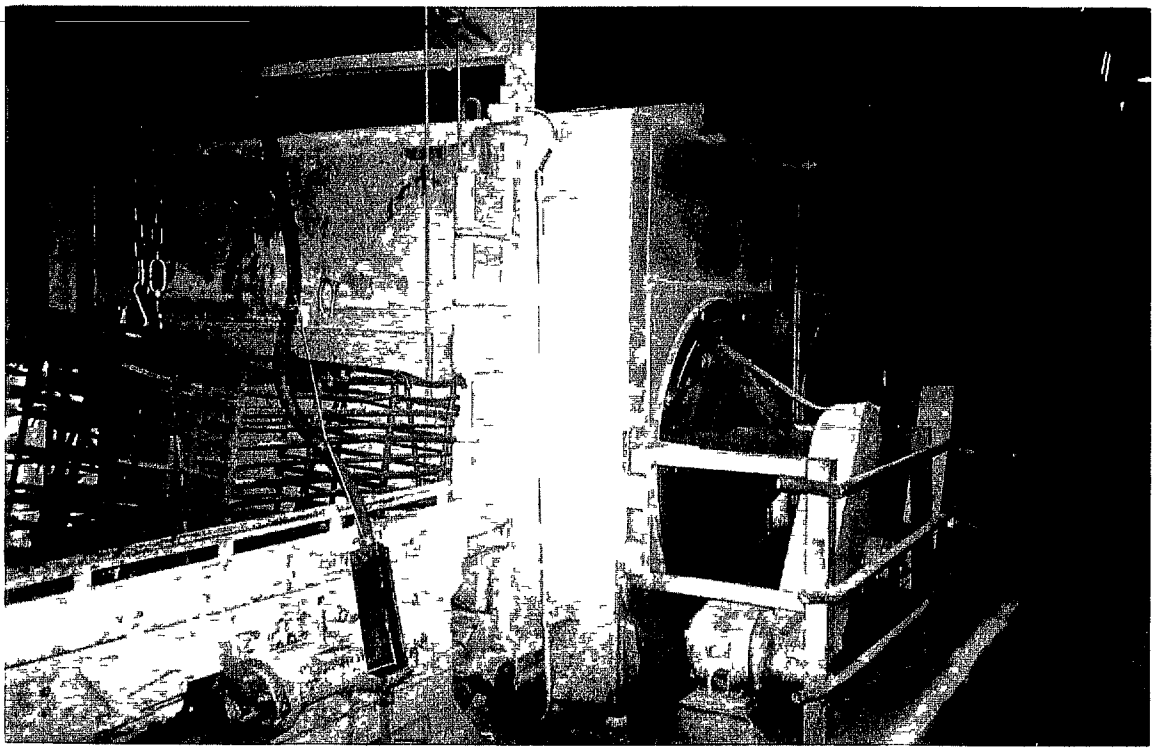


Гальваническая обработка поршней
Electroplating of pistons





Плавильная печь алюмине-литейная
Aluminum melting and casting furnace



Электрическая толкательная печь термообработки готовой продукции
Electric pusher-type furnace for the thermal processing the finished products

APPENDIX E 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 Ccal = 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

Power

1 W = 3 6 x 10^3 J = 3 6 kJ
1 kW = 3 6 x 10^3 kJ = 3 6 MJ = 860 Ccal
1 MW = 3 6 x 10^3 MJ = 860 Ccal
1 Ccal = 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

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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 Ccal/m^3 = 4,187 kJ/m^3 = 0 112 BTU/cu ft

Temperature

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

APPENDIX F. ABBREVIATIONS AND UNITS OF MEASUREMENT

ABBREVIATIONS AND UNITS OF MEASUREMENT

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 for International Development

UNITS OF MEASUREMENT

BTU - British thermal unit
^{0}C - degrees Celcium
cm^2 - centimeter squared
^{0}F - degrees Faranheit
g - gram
Gcal - gigacalory
GJ - gigajoule
h - hour
kcal - kilocalory
kg - kilogram
kgf - kilogram-force
kV - kilovolt
kV-A - kilovolt-amper
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
t/h - tonnes per hour
W - watt

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