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ENERGY AUDIT

A D SHPAGIN PERM MOTOR TROLLEY REPAIR WORKS

Perm Oblast

RUSSIA

Prepared for

US AGENCY FOR INTERNATIONAL DEVELOPMENT

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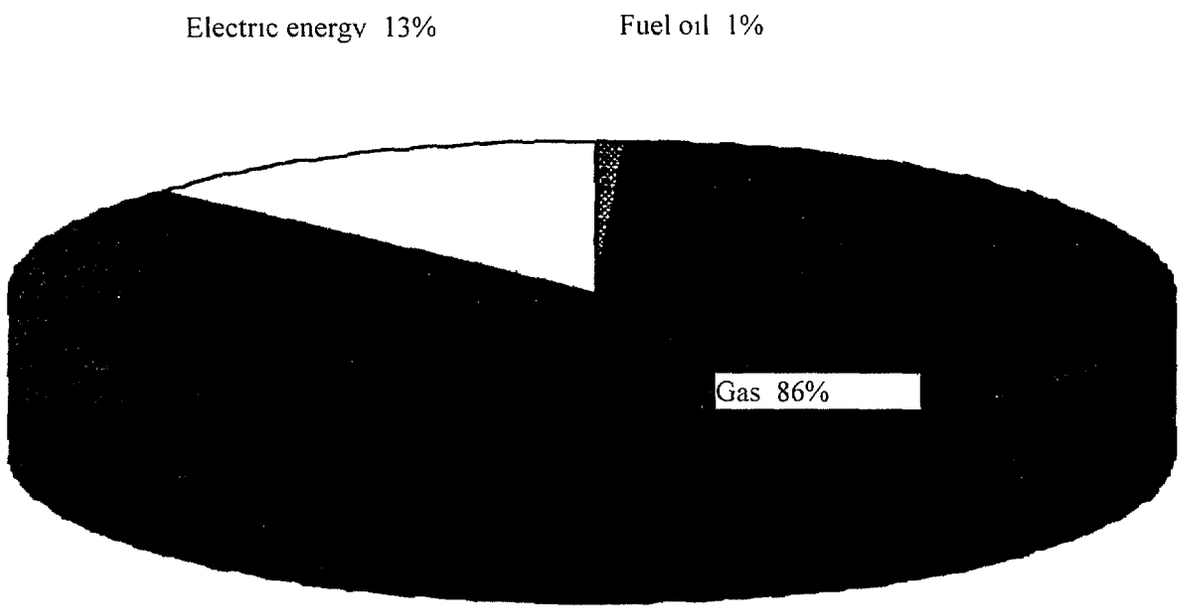
1 EXECUTIVE SUMMARY

This Report contains the results of the energy audit of the A D Shpagin Perm Motor Trolley repair works performed in March through April 1998 The work was performed in a close contact with the management of the energy service and maintenance personnel of the enterprise Specialists of the Energy Efficiency Laboratory of *AO Permenergo* and the Technical Laboratory of *Permgosenergonadzor* rendered great assistance in the carrying out of this energy audit

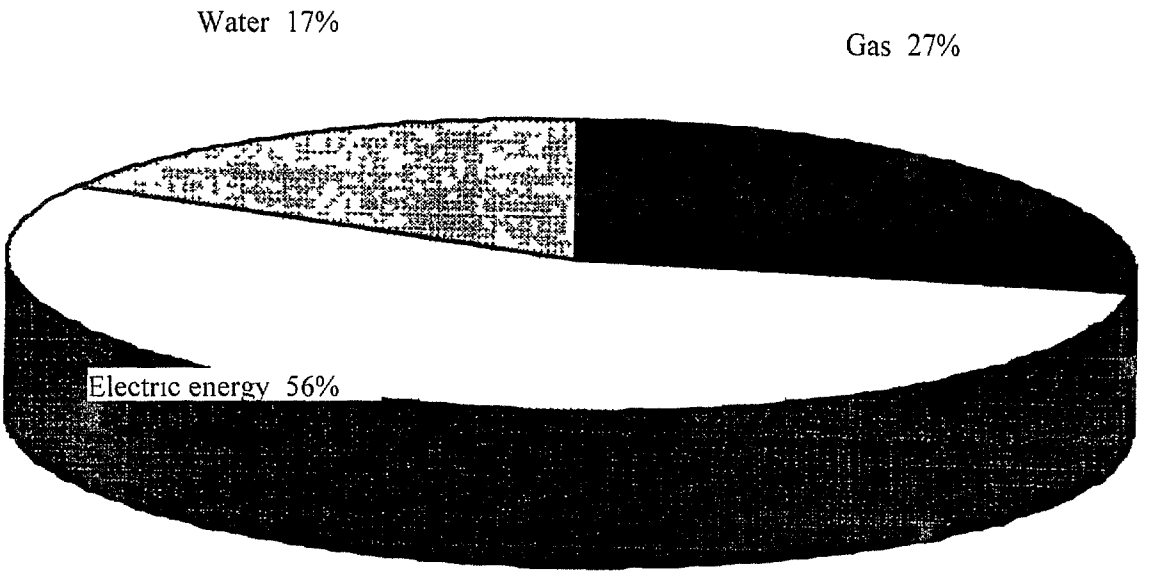
For a visual representation of the general structure of the energy consumption, the Chart 1 1 has been drawn it represents the quantitative estimate of the energy consumption in the units of energy equivalent, namely, in energy equivalent This is based on the data on the energy consumption in 1997 This Chart shows that the enterprise consumes three types of energy resources gas, fuel oil, and electric power The main share belongs to the gas This is because the enterprise has its own boiler, which fully supplies the heat to both the enterprise and certain outside consumers

Chart 1 1 Structure of energy consumption



In addition to the energy consumption structure, the structure of the payments for the energy resources should be known Chart 1 2 shows the structure of the payments for the energy resources Since gas is a relatively cheap energy resource, the share of its payments does not exceed 27% of the total sum The main share of the payments is for the electric power

Chart 1 2 Structure of payments for energy resources



Based on the results of the energy audit, the following energy saving measures may be recommended (see Table 1)

Table 1 Energy saving measures

No	Description	Energy savings		Project cost, rubles	Payback period, years
		Energy equiva-lent	rub (USD)		
Low cost and no-cost measures					
1	To optimize daily energy consumption for processing purposes	—	133,860 (21 944)	0	0
2	To eliminate leaks in the compressed air system	1,009 8	173,330 (28 416)	0	0
3	To exclude inefficient use of the lighting system	36 4	2,669 (437)	0	0
4	To disconnect fuel oil tanks heating steam pipeline	12,127 3	91,501 (15,000)	0	0
5	To reduce air suction in boilers	1,983 9	14,969 (2 454)	2,000 (328)	2
6	To properly insulate pipelines and Hot Water Supply [*GVS*] boilers	6,095 6	45 993 (7,540)	3,744 (614)	1
7	To use heated air for burners	1,585 1	11 960 (1,961)	5,000 (820)	5
8	To supply cooling water from electric ovens to the boiler room	—	31 303 (5,132)	5,000 (820)	2
9	To insulate external surfaces of gas ovens	798 2	6,023 (987)	4,000 (656)	8
Large investment projects					
10	To switch from sulphonated coal to cation resin Ku-2-8	—	114 582 (18,783)	69,600 (11,410)	8
TOTAL		**23,636 3**	**626,190 (102,654)**	**89,334 (14,646)**	**2**

The total amount demonstrates the aggregate effect of the implementation of all recommendations taking into account their interrelationship

The implementation of the above mentioned recommendations would allow the enterprise to reduce the total amount of consumed energy by 15 2% and, thus reduce energy and water bills by 14 8%

Such saving may be much higher with a complete revamp of the heat supply system

This leads to the conclusion, there is a substantial potential of energy savings at the enterprise

2 INTRODUCTION

The energy audit was performed by the group of engineers of the East-West Energy Agency, Moscow, within the framework of the USAID Project "Implementation of Energy-Saving Technologies and Market Reforms for Russia" (contract # CCN-0020-C-00-152-00) The purpose of the work is to analyze the use of the energy resources at the enterprise and their cost, to reveal the spots of the inefficient use, and to develop the set of the energy saving measures

During the visit to the enterprise large amount of information on the energy and production equipment were obtained including the conditions of operation of the equipment and the condition of the energy distribution systems This information has been systematized and is presented in this Report

The data were gathered by direct measurements (e g , of the capacities of the energy consuming equipment), by calculations based on design and normative documentation, and from the information submitted by the maintenance personnel The direct measurements were taken by the state-of-the-art portable instruments manufactured by Western companies The collected data was analyzed using spreadsheets and graphics presentations

3 DESCRIPTION OF ENTERPRISE, MAIN EQUIPMENT, AND ENERGY CONSUMPTION

3 1 General description of enterprise

The State-Owned Enterprise A D Shpagin Perm Motor Trolley repair works was founded on the basis of the railway repair shops in 1878 Since 1987, it is within the Association "Remputmash" under the RF Ministry for railroads The Association unites 9 enterprises of Russia and the affiliate of the PTKB CP This gives a series of advantages the goal-oriented cooperation, the mastering of the mechanical engineering production and consumer goods, and the centralized financing of the integrated reconstruction of the works In 1995, the works began its own R&D works

As of today the works perform the overhaul and modernization of the trolley cars DGKu, AGV, MPT, ADM, DMS, and AGMs-DM for the subway The works have extensive facilities in casting and forging Some of the spare parts for the cars (cast iron brake pads, unified wheel couples, anchor bolts for rail fixings, leaf springs) are manufactured by the works, other spare parts are purchased from other manufacturers

The works manufacture many other consumer goods, including sets of kitchen furniture, sets of children furniture, sets of soft furniture for hall, sauna oven, portable oven, watering pot, water skis, caddy-bag, etc

In 1995, the enterprise began working in the mechanical engineering and manufacturing of the rail cars, including

- MB machine for treatment of ballast layer,
- UR-1 machine for plants removal,
- MNK-1 machine for forming and cleaning ditches,
- UP-3m load-carrying trailer for motor trolleys,
- AGMS load-carrying motor trolley,
- hydraulic bending press,
- AKS-1 portable contact welder

The main materials supplied to the works is formed by the rolled metal (sheets, plates, L-shapes, H-shapes, channels, etc), cast iron, components for repair (electric motors, instruments, cables, etc), coke, limestone, clay graphite, sand, etc Lumber and other accessories are the materials for the auxiliary production (furniture)

The products manufactured by the works in 1997 (by months) are listed in Appendix 1

Table 3 1 shows the general information on the enterprise for 1995-97

Table 3 1 General information on enterprise for 1995-97

Index	Unit	1995	1996	1997
Products and services, incl main	Rbl mn	45,884 7	81,855 9	75,258 0
motor trolleys	pcs	144	131	143
wheel couples	pcs	155	126	239
auxiliary products home furniture	sets	—	355	191
Product sales	Rbl mn	13 869 828	41,093 172	60,646 2
Net profit	Rbl mn	3 039 632	9,450 159	15,091 747
Average personnel	persons	901	987	1009

Table 3 2 shows the structure of the production costs

Table 3 2 Structure of production costs by elements of expenditures

#	Elements of expenditures	Specific share, %
1	**Material expenditures, incl**	**54 9**
	feedstock and materials	20 9
	purchased components	25 8
	fuel	2 8
	electric energy	4 3
	water	1 1
2	**Labor payment**	**25 1**
3	**Allocation for social insurance**	**9 8**
4	**Depreciation**	**3 0**
5	**Other**	**7 2**
	TOTAL	**100**

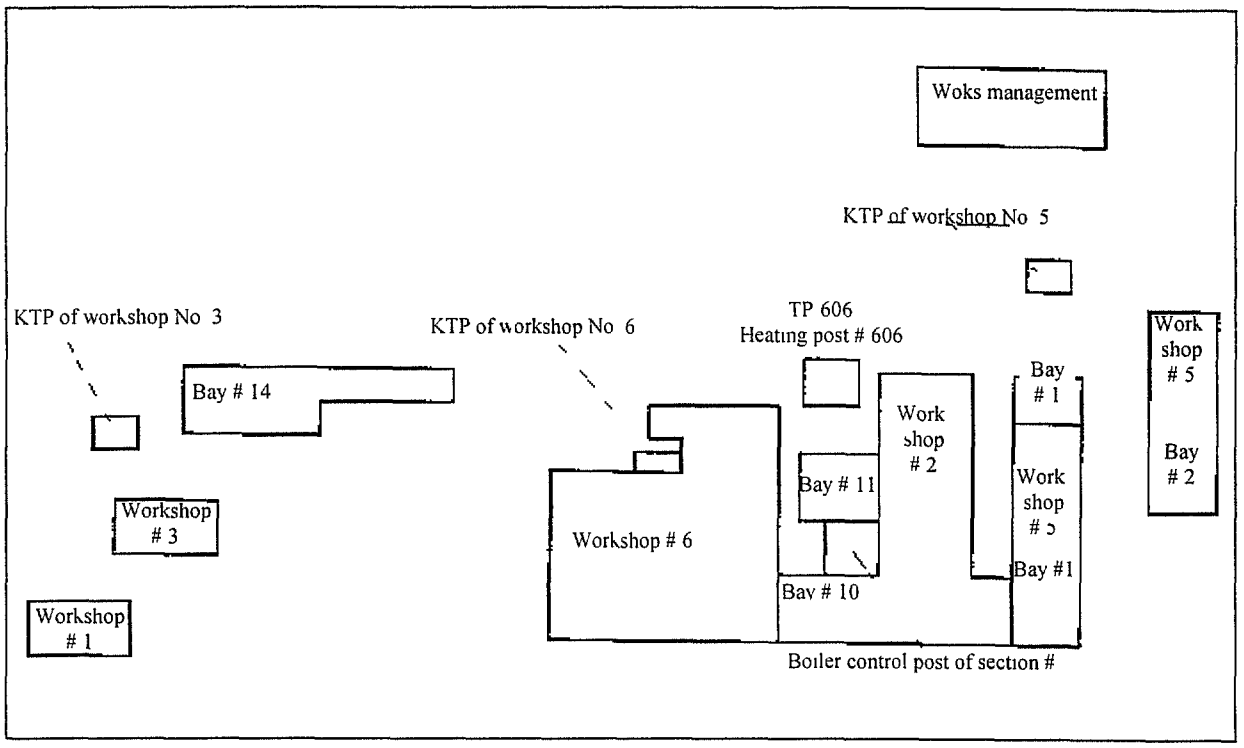
Note the total share of the energy resources and water in the production cost is 8 2%

3 2 General description

3 2 1 Description of enterprise's workshops

The total area of the enterprise is 7 3 hectares Fig 3 2 1 shows workshops layout on the territory of the enterprise

Fig 3 2 1 Plan of sections of enterprise



The construction shop (# 1) is used for the following preparation of the containers for products, covering rail cars and cabins of motor trolleys with wood, repair and construction works in the territory of the enterprise, and manufacturing of kitchen furniture

The mechanical shop # 2 is divided into several bays the mechanical bay, the wheels bay where the wheel couples for the rail cars are repaired and formed, the forging bay, and the body elements bay

The shop of cast shapes # 3 manufactures the bodies for the mechanical section and various cast shapes for both the main production line and for specific orders, e g , grills, hatches, reduction gears, cast iron brake pads, etc

The motor trolley shop # 5 is the section for the assembly of the motor trolleys This section repairs used motor trolleys and manufactures new ones

The motor trolley shop # 6 is intended only for the repair of motor trolleys and motors

The tool shop # 10 repairs and manufactures the tools and equipment, and heat-treats the articles from the main production line

The repair-mechanical-engineering bay # 12 is engaged in manufacturing the mechanization articles for the works in whole, it also overhauls the production equipment and reconstructs the metal consuming equipment bridges, under-crane rails, etc

The transport bay # 14 ensures the intake and dispatch of the products and cargoes to and from the works

The works also have the automobile transport bay, which is situated in the works management building

The main production shop are shops # 2, 5, and 6

At the time of this report, shops # 2, 6, and 10 operate in two shifts, the other bays operate in 1 shift at the 5-day working week

3 2 2 Energy equipment

The energy system of the works consists of several divisions, which form the bay # 11, with 68 staff employees

Electric energy equipment

The electric energy is delivered to the enterprise from the three 6 kV inputs

Input # 1 (main) from the feeder "Nasosnaya ZMS" of the municipal electric network through the works switchboard at TP-606 This input supports all the needs of the works in the electric energy (up to 2 MW)

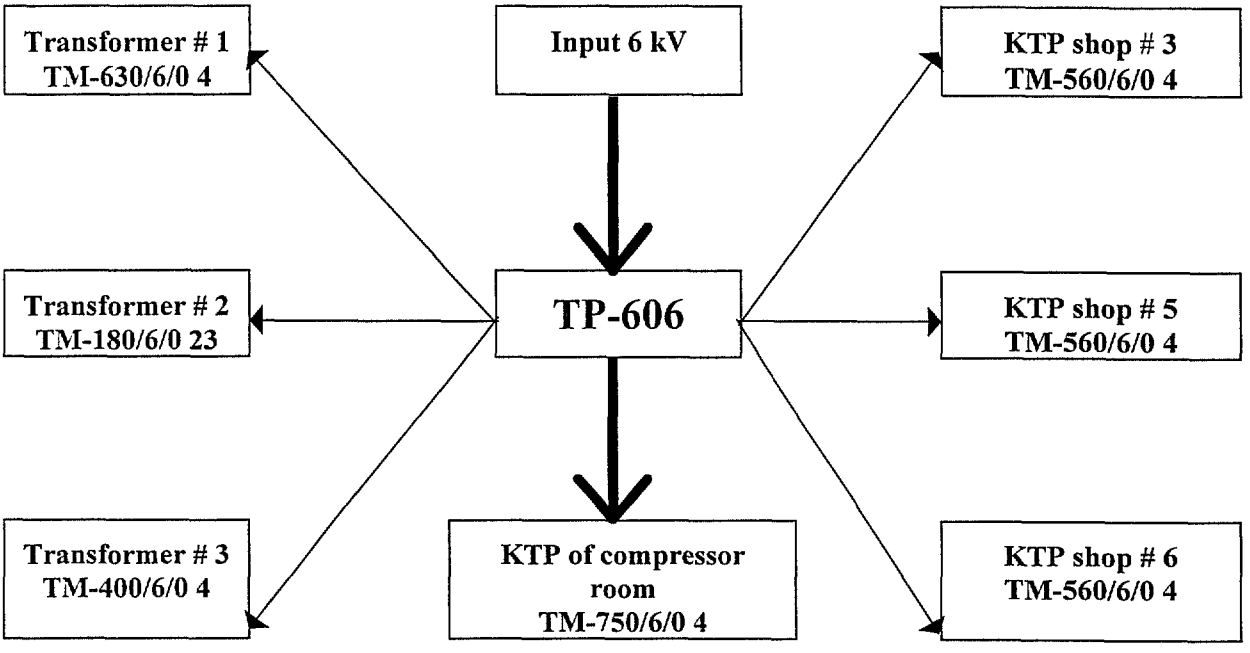
Input # 2 (back-up) from the TP-5023 "Hospital ' of the municipal electric network through the works switchboard at TP-606 This input covers 70% of the load of the whole works (up to 1 4 MW) The municipal network cannot ensure the full use of this input at any time

Input # 3 (back-up) from the TP-609 of the Perm energy supply bay at TP-606 It may cover 30% of the load on the works (up to 0 6 MW) It is used only in winter for the heating and emergency lighting This circuit is worn out and of low reliability

Hence, the electric energy supply system is category 3 and of low reliability

Fig 3 2 2 shows the flow chart of the Perm Motor Trolley repair works energy supply system

Fig 3 2 2 Flow chart of the Perm Motor Trolley repair works energy supply system



TP-606 was constructed in 1935 The last update took place in the 50's, as of today, the high voltage side requires the full replacement of the equipment because it does not support the protection of either the TP and KTP of the sections and cable lines The building of the transformer room also requires repair

The high voltage cable lines at the sections KTPs have the back-up and support their normal electric power supply

Most of the main distribution panels for 0 4 and 0 23 kV at TP-606 and in its sections are obsolete and ensure the protection only by fuses

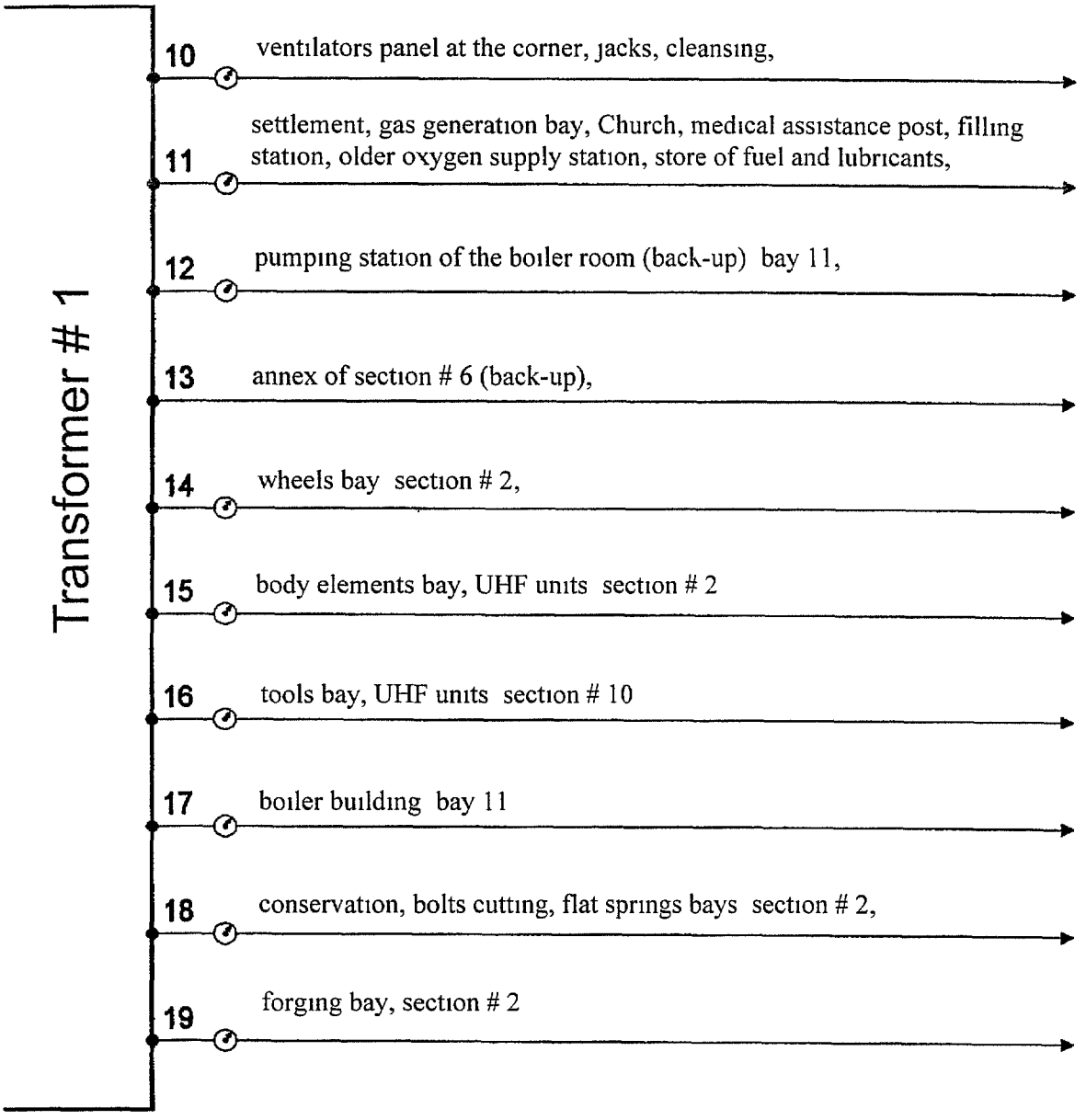
The input to the building of TP-606 has two commercial meters of the active (SAZU-I670M) and reactive (SR4U-I670M) power

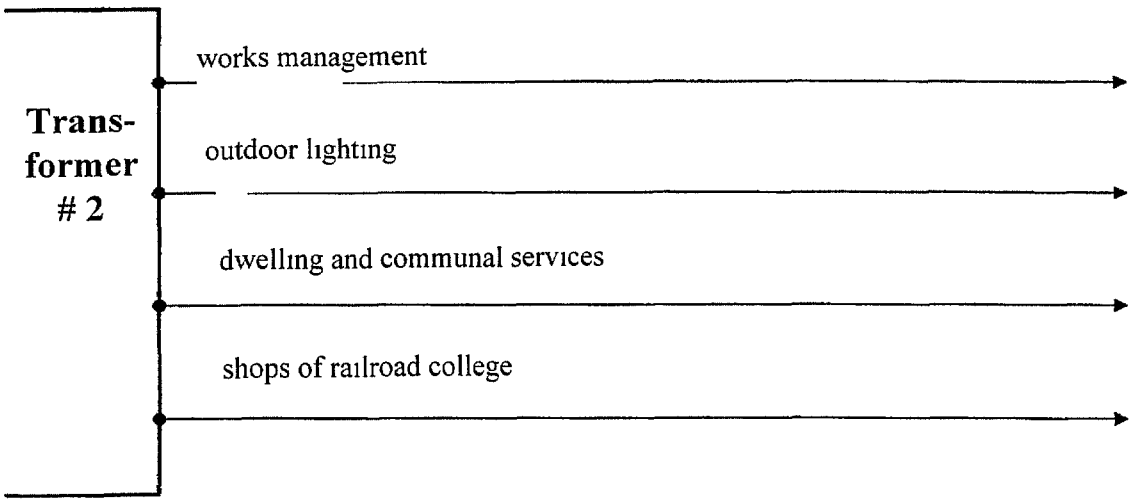
Transformer substations of the company have reactive power compensation units installed Two capacitors banks are installed at TP-606 Substation with 100 kVAR of capacity (connected) at transformer No 1, and with 120 kVAR of capacity (disconnected) at transformer No 2 There are two UKT-0 38-150UZ units (one connected) with the capacity of 148 4 kVAR and one UKM-58-0 4-100-33 1/3 Unit (disconnected) with the capacity of 100 kVAR installed at another substations

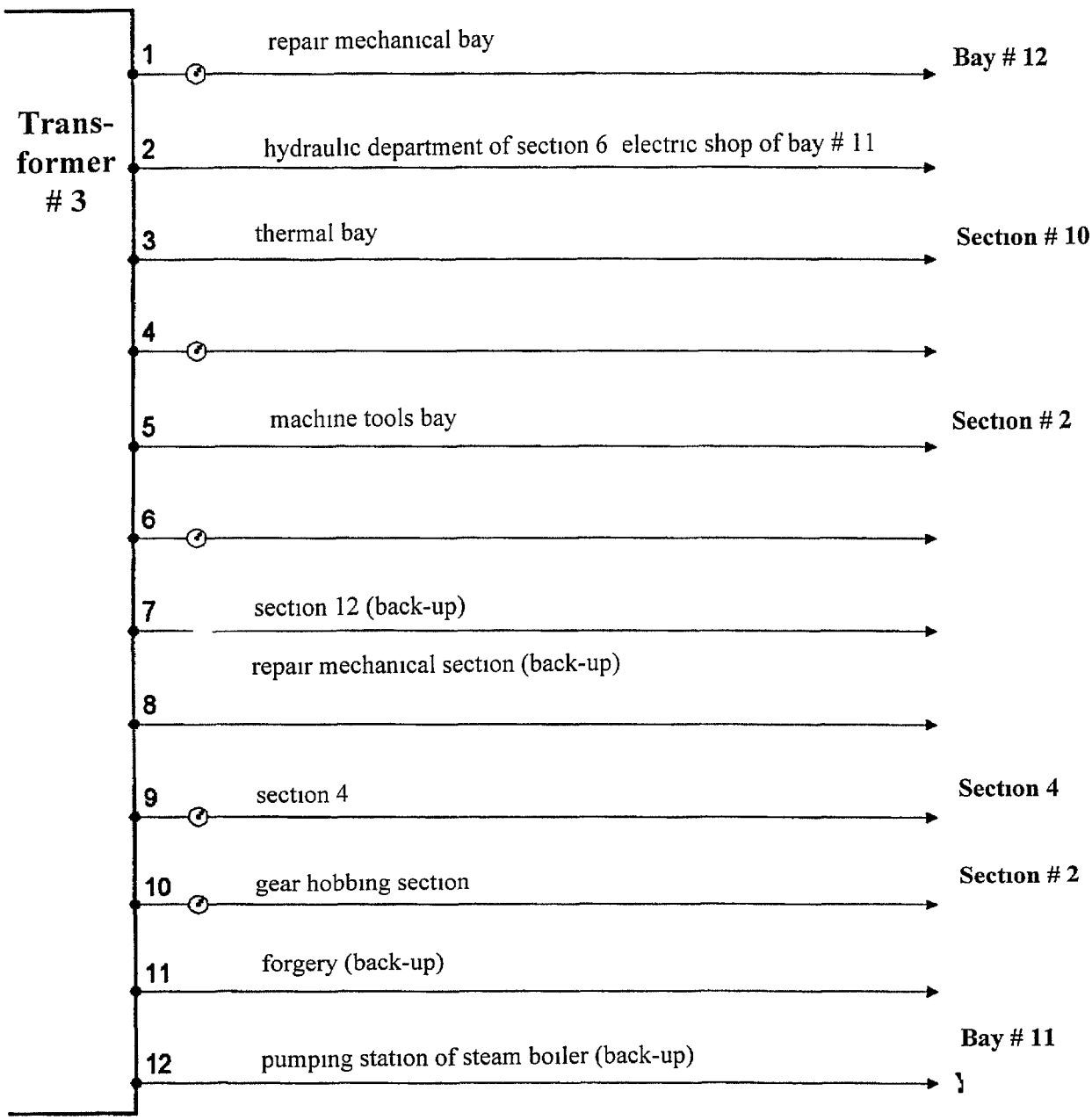
The works does not have the internal accounting of the electric power distribution although many feeders have meters installed

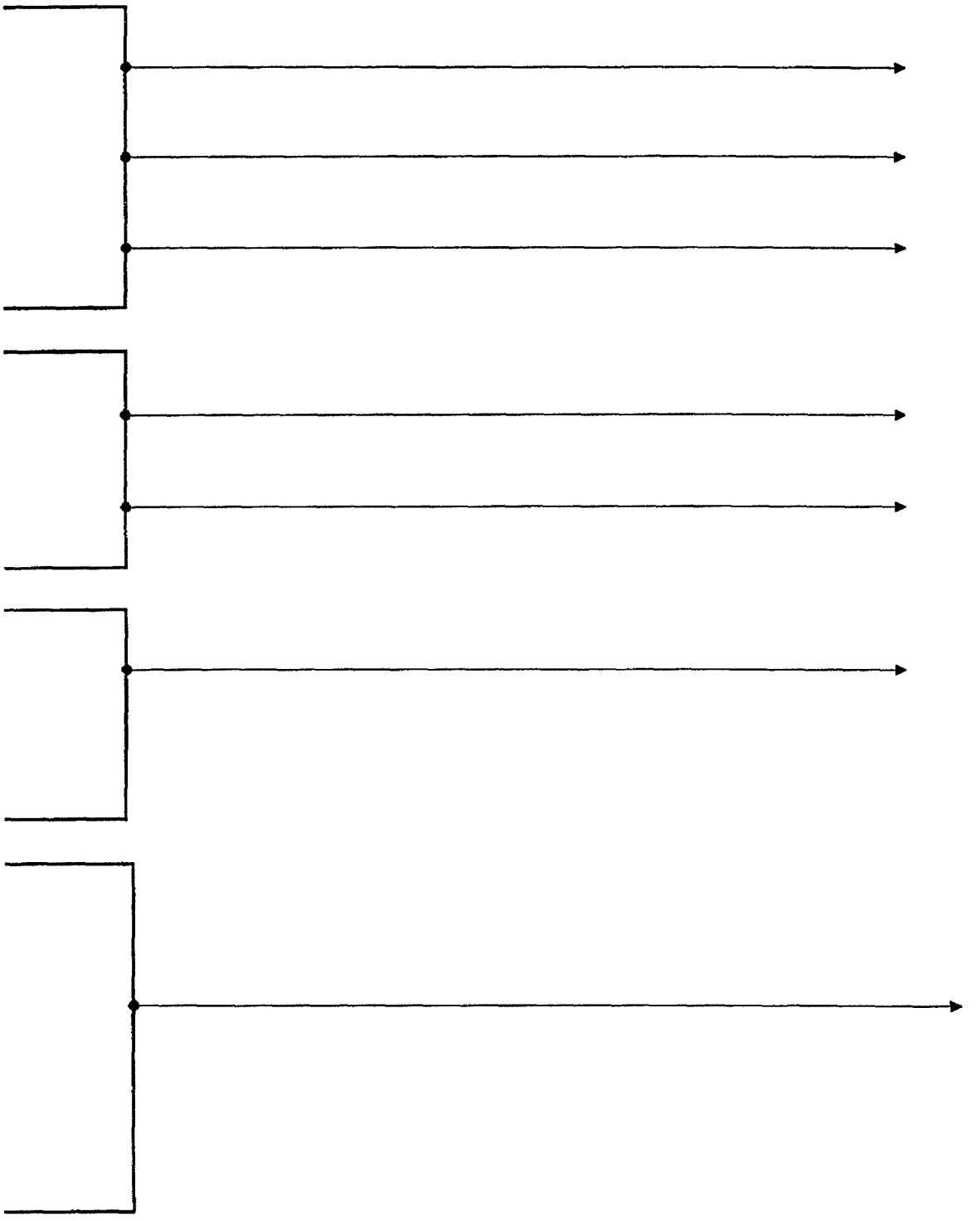
Fig 3 2 3 lists the consumers of the electric energy from every transformer indicating the locations of the meters

Fig 3 2 3 Consumers of electric energy at works




Trans-
former
2
works management
outdoor lighting
dwelling and communal services
shops of railroad college


Trans-
former
3
1
repair mechanical bay
Bay # 12
2
hydraulic department of section 6 electric shop of bay # 11
3
thermal bay
Section # 10
4
5
machine tools bay
Section # 2
6
7
section 12 (back-up)
repair mechanical section (back-up)
8
9
section 4
Section 4
10
gear hobbing section
Section # 2
11
forgery (back-up)
12
pumping station of steam boiler (back-up)
Bay # 11



Air supply system

The enterprise has an air compressor station All the needs for compressed air are covered by the two-step air compressors 103VP-20/8 (see Table 3 2 1)

Table 3 2 1 List of air compressors

#	Type	Put into operation, year	Capacity, m^3/min	Pressure, kg/cm^2	Capacity of drive, kW	Consumption of cooling water, m^3/h
1	103VP-20/8	1981	20	8	132	3
2	103VP-20/8	1970	20	8	132	3
3	103VP-20/8	1974	20	8	132	3
4	103VP-20/8	1991	20	9	132	3
5	6VV-20/9	1997	20	9	160	13 3
6	6VV-9/9	1997	9	9	75	13

Compressors 103 VP-20/8 are equipped with DSK-12-24-12 synchronous electric motors with the capacity of 125 kW and rotation speed of 500 rpm[1] After the compressors the air goes to the receivers V-10, 10 m^3 each

The enterprise has a system of circulation cooling of the compressors It has a wooden water-cooler and the circulating water tank The circulating water is circulated by pumps

Compressed air consumers are listed in Table 3 3 According to the table the largest compressed air consumer is a forging hammer

Ventilation

All access gates (19 units) of the workshops intended for trucks and railway cars are equipped with hot air blowers (hot-air curtains) with an aggregate power of 150 kW

The Paint-Drying section of Shop No 19 is equipped with a common circulation combined exhaust-input ventilation system and with the input ventilation of the air-lock chamber The Painting section is equipped with a recycle drying system in accordance with the Project Coating chambers are equipped with the exhaust ventilation system and hydro-filters

Chipping and saw dust from the wood processing equipment in Shop No 1 is transported by a pneumatic transport system with a cyclone separator OEKDM, and dust from the grinding machines is removed by the ventilation system with UTs-38 cyclone separator The total power of the ventilation systems electric drives in Shop No 1 is equal to 57 kW

Welding stations (gas welding) — a total of 4 units, are equipped with the local exhaust ventilation system with an aggregate power of 30 kW

Of all basic production shops (No 1, 2, 3, 5 and 6) three are equipped with common-circulation ventilation systems Shop No 1 (Forging Shop), No 5 and 6 of the aggregate power of 68 kW The ventilation system in Shop 3 is at the stage of ongoing reconstruction Only 6 systems are actually operating of the total amount of intake ventilation systems required for the plant There are no intake systems in the wheel and mechanic workshops The intake ventilation system operates 8 hours per day

In Shop No 5 (Welding-assembly) all 18 welding stations are equipped with local exhaust svstems with an aggregate power of 60 kW, including systems based on *Sovplim* type systems (10 pcs, 20 kW of power)

Test-run bays are completely equipped with a ventilation system (3 total systems) for exhaust gas removal with an aggregate power of 13 kW

Exhaust ventilation is provided only by local exhaust hoods installed at the work stations and natural-flow ventilation The exhaust ventilation systems in Shop No 5 (sections 1 and 2), No (forging section) and No 3 operate during the entire work shift

Calorifers of the hot air-curtains in Shops No 1 (3 pcs) and No 3 (6 pcs) are steam operated, and in Shop No 5, section No 2 there also is one steam calorifer installed at the hot-air curtain and one at the intake system All remaining calorifers at the Plant have been already switched to hot water

Water supply system

The water lines are underground outdoors and above ground indoors The main above ground lines were replaced about 5 years ago and are in satisfactory state The water line intake and the flow meter are located in the old building of the pumping station As the intake is only 2 kilometers distance from the pumps of the municipal station, there is no need for a separate pumping station At the water intake to the works there is a water pressure regulator which provides the stable pressure about 2 at in the network and prevents leaks in the lines Domestic sewage is gravity flow The production sewage is pressurized, after the treatment facilities, the normatively purified water is discharged in the municipal sewage A 15 kW pump is used for industrial effluents The Plant was allocated an annual limit of city water consumption of 180 thousand m^3 The amount of water drainage discharged is calculated as a factor of 0 58 of the total amount of consumed water

Boiler house

The enterprise has its own boiler house fully covering its heat needs Additionally, the heat is sold to outside consumers The fuel is natural gas, fuel oil is used as backup fuel

The measurement of the natural gas consumption and the settlements with the gas supplier from the city are based on the SU instrument with replaceable scale, installed at the MDP For the internal accounting, the enterprise has meters at the gas intake for the metal cutting (sections # 5 and # 6), and at the MDP for the gas for forgery The difference between the readings of the commercial meter and internal meters is for the boiler section, minus the consumption by the canteen, which is calculated

The Figure shows the scheme of the boiler section

The boiler house has the 4 boilers

Table 3 2 2 Boilers

Boiler #	1	2	3	4
Type	DE 10/14 GM	DKVR 6 5/13	Shukhov-8/13	DKVR 6 5/13
Regime	steam	steam	water heating	water heating
Year of manufacture	1986	1967	1934	1962
Nominal capacity, t/h	10 0	6 5	8	6 5
Operating pressure, at	13 0	13 0	13 0	13 0
Main fuel	natural gas			
Back-up fuel	none	fuel oil	fuel oil	fuel oil

As indicated by the Table, the service lifes of all the boilers has expired with the exception of boiler No 1 They must be replaced Boiler No 2 was allowed for use in 1998 only at a drum pressure reduced to 4 0 atm

Three make-up pumps are installed in the boiler room (two are used for stand-by) There are four network pumps and pumps for pumping raw water and chemically treated water

The Chemical water treatment unit includes two-stage soft-water treatment Two units of the first stage and two units of the second stage treatment operating in pairs are available, so that when the first stage unit is shut-down the second stage unit is in operation When the water hardness reaches 30 μg equiv /l the second pair is activated Sulphonated coal is used as chemical agent in both stages Agent in both stages of each pair is regenerated simultaneously about once each day

The regeneration process takes about 5 hours with about 40 m^3 being consumed during this time

Two accumulating tanks for raw and chemically treated water with a capacity of 10 m^3 each are installed in the Water treatment facilities Condensate from the Hot Water Supply [*GVS*] boilers installed above the water treatment facilities also flows to the chemically treated water tank

An atmospheric type deaerator is installed in the boiler room and is supplied with chemically treated water from the accumulator tank heated only to 40-60°C So, in fact, the boiler is fed with non-deaerated make-up water

Thermal insulation is either not sufficient or lacking on the large section of the steam and hot water pipelines

The enterprise has a store of the back-up, fuel oil The fuel oil tanks are listed in Table 3 2 3

Table 3 2 3 Fuel oil tanks

#	Type	Volume, t	Filling, t
1	Capacity # 1	50	0
2	Capacity # 2	40	20
3	Capacity # 3	40	0
4	Capacity # 4	90	52
5	Distribution capacity	20	20
6	Tank # 1	50	45
7	Tank # 2	50	0
8	Tank # 3	30	0
TOTAL		**370**	**137**

The fuel oil pumping station has two stationary fuel oil pumps and a heating control system The fuel oil is freeflowing to the boiler house The steam condensate used for fuel oil heating is not re-circulated and is wasted

In 1997, 38 tons of fuel oil were used in the boiler house, and no new purchases of fuel oil have been made ever since The use of fuel oil was connected with the termination of natural gas supply for payment areas

Heating and hot water supply

The heat supply system consists of the water and steam heating systems A part of the steam heating system was transformed to the water system in 1993-96 As of today, the sections # 2, 5, 6, bays # 10 and 12, and the works management have the water heating The steam heating remains in sections # 1 and 3 and bays # 11 and 14

Steam is supplied from the boiler room Condensate is recycled only in part Network water of the water heating system after its heated up in the boiler is supplied to the end user with a part of water passed through the economizer directed to the return network water line upstream

The boiler room has a temperature Chart of direct and return line temperatures in the heating system depending on ambient air temperature It should be noted that this curve is not followed

The Hot Water Supply System also includes steam boilers installed in the premises of the heating plant (4 pcs) and in Shops No 1, 3 and 5 (production bays No 1 and 2) intended for heating water for showers

3 3 Description of production process

3 3 1 Production equipment

The enterprise has two main production processes the repair of the railroad equipment and the machine building line

Current repair technology used at the Plant includes the following operations

1 Preparation of railroad equipment delivered for subsequent repair at Shop No 6 (lubricants and fuel drain, washing, etc)

2 Disassembly of machines in Shops No 5 and 6 (complete disassembly of equipment installed on platforms, washing, and the "rolling-out" of wheelpairs with their subsequent transportation to Shop No 2)

3 Inspection and preparation of a check-list specifying the scope of repair work and orders for spares and components required In the event that individual sections of equipment and units cannot be restored the order for new equipment is prepared

4 Assembly of individual sections and their installation on platforms, and wheelpairs assembly, the installation of cabins and engines and hoisting equipment, etc

5 Test run of rail motor cars at a special test bay

The Machine-building line includes the assembly of the railroad equipment with the use of components (Shop No 5, bay No 1 and 2 and a new Shop No 4) manufactured by the Plant or supplied by outside suppliers

The main power consuming production of the Plant is metal processing, including thermal treatment facilities and gas ovens Gas and electric ovens are used for the thermal treatment of metal parts at the Plant Table 3 3 1 includes parameters of the gas ovens The largest twin-chamber type gas ovens with a gas flow rate of 70 m^3/hour were made by the Plant Process parameters regulation of the ovens is carried out manually The duration of heat treatment of metal parts in the ovens is regulated by the operator in a subjective manner based on his/her experience The twin-chamber ovens are equipped with a heat-exchanger where combustion air is heated by flue gases This was also designed by the Plant

Shop No 10 includes the thermal treatment section with two HF generators VTchG1-100/0 066 and VTchG2-100/0 066, 141 kW each The cooling water flow rate is not higher than 3 5 m^3/hour The thermal treatment section also comprises electric resistance ovens The specifications of the electric ovens are given below

- electric resistance oven SNO-6 12 4/1042 (chamber type) with the capacity of $71^{+7\ 1}$ kW Internal process space dimensions 600 × 1200 × 400 mm Work temperature — 1000°C The weight of one treated batch — 0 8 ton Idle run capacity — 10 kW ,
- electric resistance oven PN-45 Capacity — 45 kW
- electric resistance oven Ts-45 with the power of $105^{+10\ 5}$ kW Internal process space dimensions diameter — 600 mm and height — 1200 mm Work temperature — 950°C Idle run capacity — 18 kW,
- two electric resistance ovens SShTsM-6 6/649 (pit-type) with the capacity of 72 2 kW Internal process space dimensions diameter — 600 mm and height — 600 mm Work temperature — 900°C The weight of one treated batch — 0 6 ton Cooling water flow rate — 0 4 m^3/hour,

In addition to the above mentioned ovens installed in Shop No 10 there are three ovens installed in the forging section of Shop No 2

- two electric resistance ovens SNO-6 12 4/1042 (chamber type) with the capacity of $71^{+7\ 1}$ kW Internal process space dimensions diameter — 600 mm and height — 600 mm Work temperature — 1000°C The weight of one treated batch — 0 8 ton Idle run capacity — 10 kW ,
- electric resistance oven SShO-10 10/10M1 UKhL-4 (pit-type) with the capacity of 72 2 kW Internal process space dimensions diameter — 1000 mm and height — 1000 mm Work temperature — 1000°C The weight of one treated batch — 1 25 ton Idle run capacity -$16^{+1\ 6}$ kW,

All ovens are equipped with automatic system regulating preset heating parameters The heat-treatment section operates in one, two and three shifts depending on the duration of the process heating cycle

Tables 3 3 1, 3 3 2, and 3 3 3 show the main equipment using steam, gas, and compressed air

Table 3 3 1 Steam-consuming equipment

#	Equipment (bays)	Shop	Steam consumption, kg/h	Pressure, kg/cm^2
1	Heaters for drying	# 6	250	3
2	Components washer	# 6	260	3
3	Wheel couples washer	# 6	260	3
4	Motor trolleys washer	# 6	260	3
5	Dry cleaning		45	3 to 4
	TOTAL		**1075**	

Table 3 3 2 Gas-consuming equipment

#	Equipment (bays)	Shop	Capacity, t/h	Gas consumption, m^3/day
1	Heating furnace, 2-chamber, # 1	# 2	260	70
2	Heating furnace, 2-chamber, # 2	# 2	260	70
3	Heating furnace, 1-chamber, # 3	# 2	60	25
4	Heating furnace, 1-chamber, # 4	# 2	60	25
5	Round furnace # 5	# 2	20	16
6	Round furnace # 6	# 2	20	16
7	Round furnace # 7	# 2	20	16
8	Round furnace # 8	# 2	20	16
9	Cutting post (20 units)	# 5, 6	—	6 to 10

Table 3 3 3 Compressed air-consuming equipment

#	Equipment	Shop	Air consumption, m^3/min	Pressure, kgf/cm^2
1	Pneumatic tools (up to 5 units)	# 1, 6, 10, bay 11	N/A	4
2	Pneumatic tools (up to 3 units)	# 2	N/A	4
3	Forging hammer	# 2	10	6
4	Pneumatic tool (1 unit)	# 3	N/A	4
5	Molding machine (up to 2 units)	# 6	3	6
6	Pneumatic tools (up to 5 units)	# 5	N/A	4
7	Pneumatic press (up to 5 units)	# 5	0 5	6
8	Pneumatic tools (up to 2 units)	bay 12	N/A	4

4 ANALYSIS OF ENERGY CONSUMPTION AND OPERATING CONDITIONS OF EQUIPMENT

4 1 Analysis of energy consumption

Table 4 1 1 shows the information on changes in production and consumption of the energy resources by the enterprise from 1994 through 1997

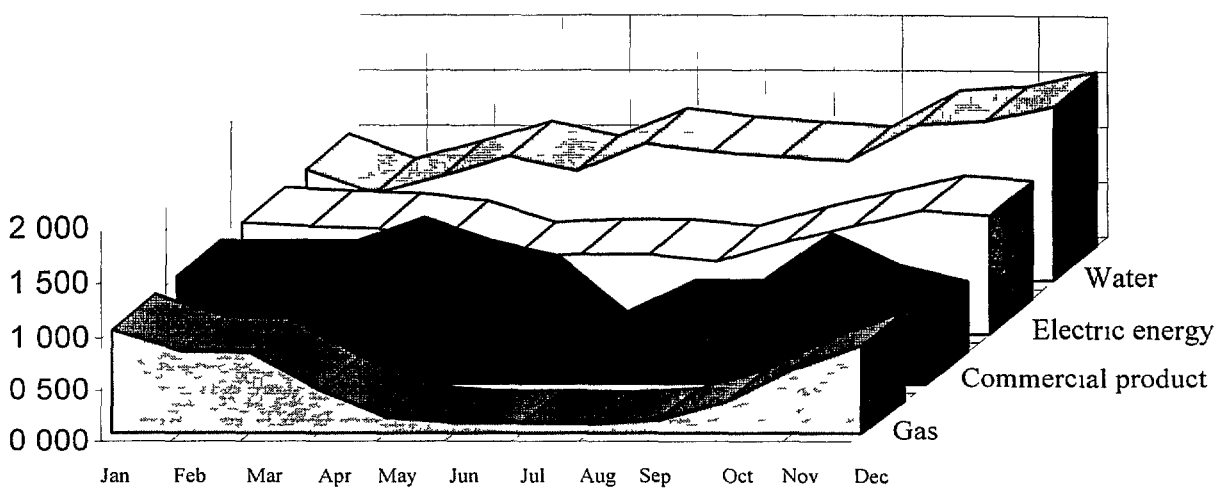
Table 4 1 1 Consumption of energy resources in 1994-97

Energy resource	Unit of measure	1994	1995	1996	1997
Gas	thousand tons of conventional fuel	4633	4297	4391	4593
Fuel oil	tons	10	—	207	28
Electric power	MWh	5130	4907	4829	5726
Municipal water	thousand m^3	162	158	142	138 166

Appendix II has the Table showing the consumption of the energy resources by months of 1997, Appendix III has the Table showing the production of heat by the boiler section in 1977

The consumption of the energy resources in 1997 is shown by the Chart 4 4 1, in conventional units, related to January 1997

Chart 4 4 1 Consumption of energy resources by months of 1997



The Chart shows that, during the year, significant seasonal variations exist in the consumption of the gas and electric energy this is due to the seasonal operation of the boiler section

Table 4 1 2 below shows the tariffs on the energy resources as of March 1998 These data were used at the calculations

Table 4 1 2 Tariffs on energy resources in 1997

#	Energy resource	Unit of measure	Tariff, Rubles	
			1997	03/01/98
1	Electric energy			
	basic rate	kW	66	69 1
	additional rate	kWh	0 1925	0 2637
2	Natural gas	thous m^3	293 5*	293 5
3	Municipal water	m^3		
	consumption		3 96	3 96
	disposal		2 324	2 324

* In 1997, the tariffs on gas changed several times, see more detailed information in Appendix II

Table 4 1 3 Consumption of and payment for energy resources in 1997

Energy resource	Unit of measure	Consum-ption	Energy		Cost	
			energy equiva-lent	%	thous Rubles	%
Gas	thous t of conventional fuel	4593	134,165 8	86 1	1,154 512	27 3
Fuel oil	thous t of conventional fuel	38	1,113 8	0 7	—	
Electric energy	MWh	5726	20,611 7	13 2	2,345 200	55 4
Municipal water	thous m^3	138 166	—	—	733 371	17 3
Total			155,891 3	100	4,233 083	100

Charts 4 1 and 4 2 below show the structure of consumption of the power resources in the energy equivalent and the structure of payment for the energy resources consumption

Chart 4 1 Structure of energy consumption

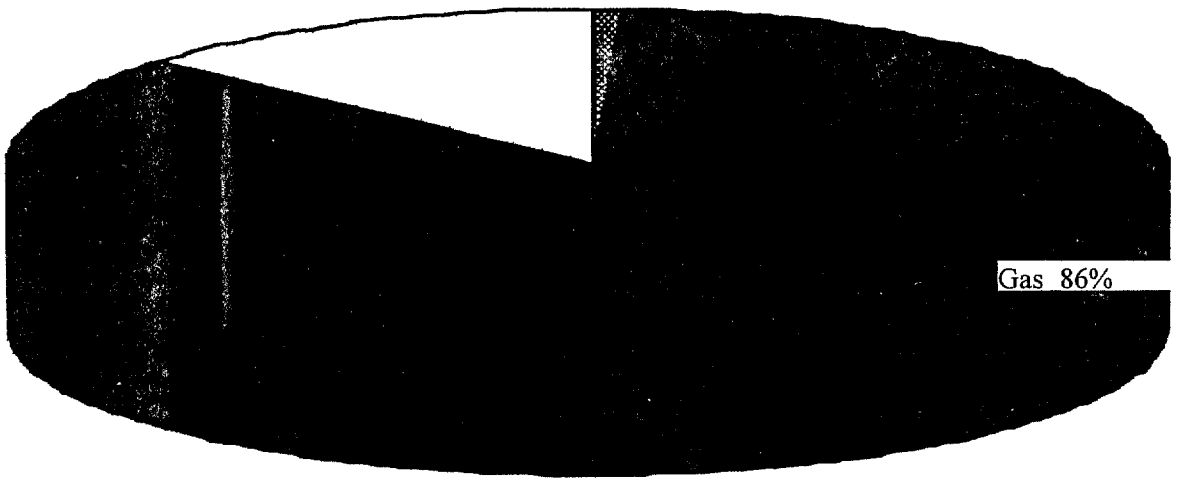
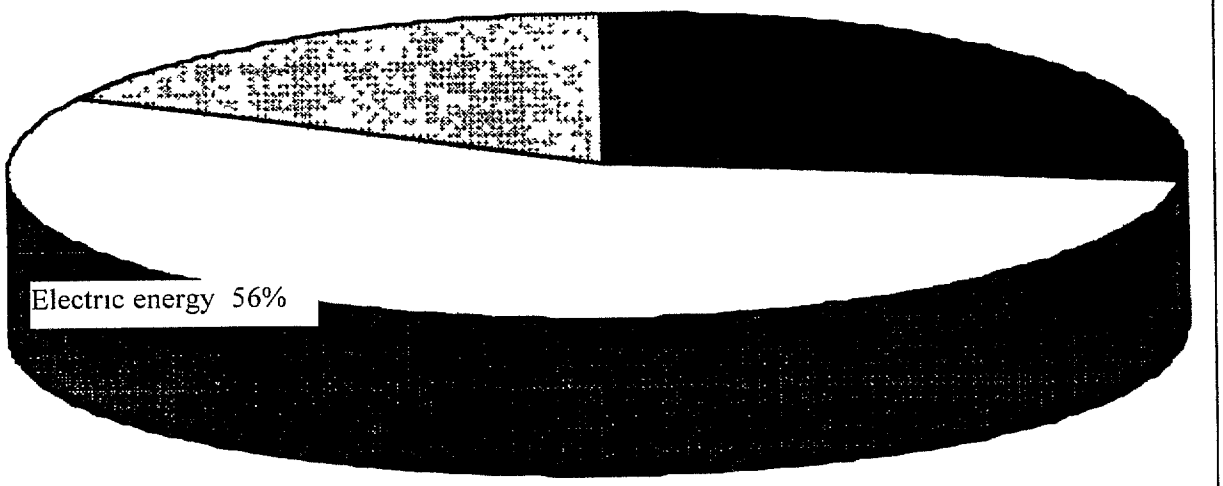


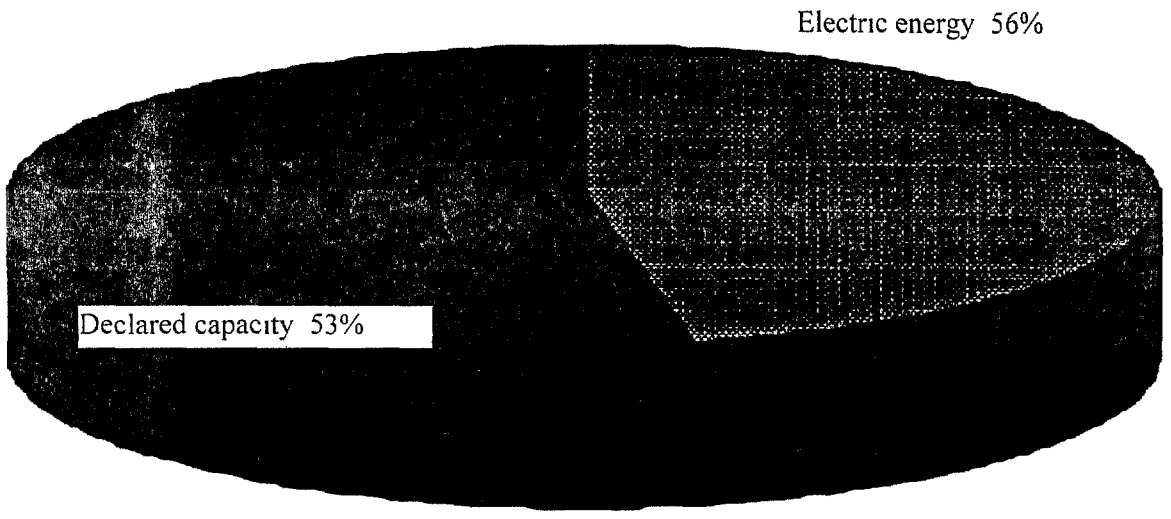
Chart 4 2 Structure of payments for energy resources



As the Chart shows, about 56% of the payments for the energy resources is for the electric power According to the agreement with the municipal energy supplier the enterprise pays for the energy at the bi-rate tariff The consumed reactive power is not paid for

According to Diagram 4 3, which represents the structure of energy bills the payment, for declared capacity is equal to more than a half of all energy costs

Chart 4 3 Structure of payment for electric energy



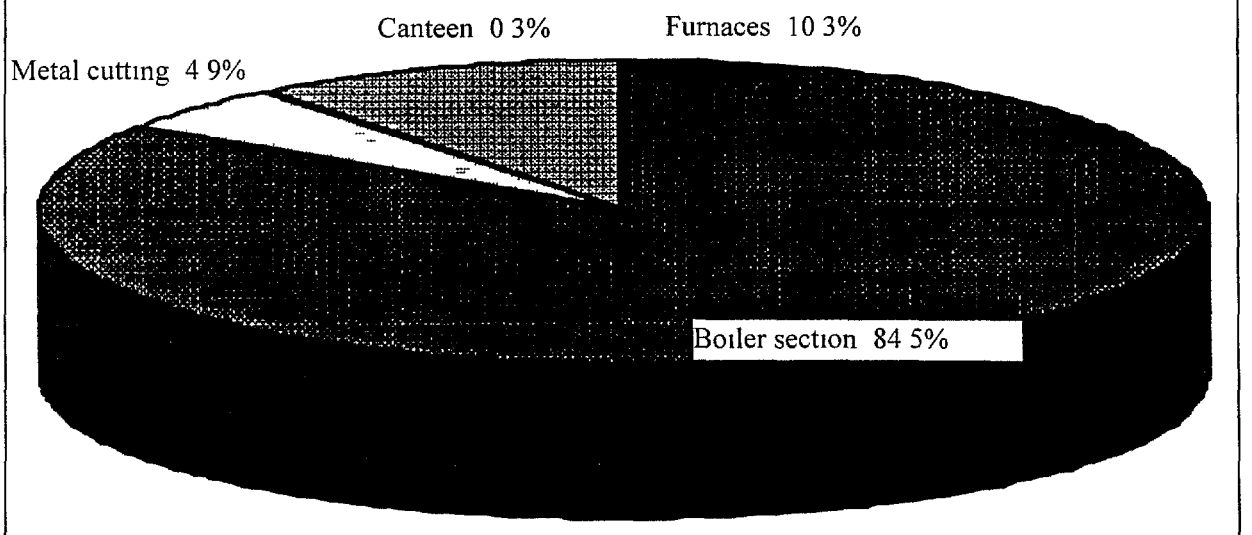
The payments for gas amounts to about 27% of all energy payments Gas is used for the boiler room, for process purposes and for the canteen Table 4 1 4 gives monthly gas consumption at the enterprise (thousand m^3)

Table 4 1 4 Gas consumption at the enterprise by months of 1997

Month	Boiler section	Metal heating (shop # 2)	Metal cutting			Canteen	Total
			shop # 5	shop # 6	shop # 3		
JAN	704	33 6	8	7	0 2	1 2	754
FEB	538	45 3	8	7	0 5	1 2	600
MAR	525	46 6	8	7	0 2	1 2	588
APR	258 3	45 5	8	7	0	1 2	320
MAY	54 8	44	8	7	0	1 2	115
JUN	23	34 8	8	7	0	1 2	74
JUL	7 8	51	8	7	0	1 2	75
AUG	36 8	12	10	5	0	1 2	65
SEP	61	15 8	10	5	0	1 2	93
OCT	197 5	14 3	12	5	0	1 2	230
NOV	427 7	23 1	15	5	0	1 2	472
DEC	572	49 8	15	5	0	1 2	643
Total	3405 9	415 8	118	74	0 9	14 4	4029

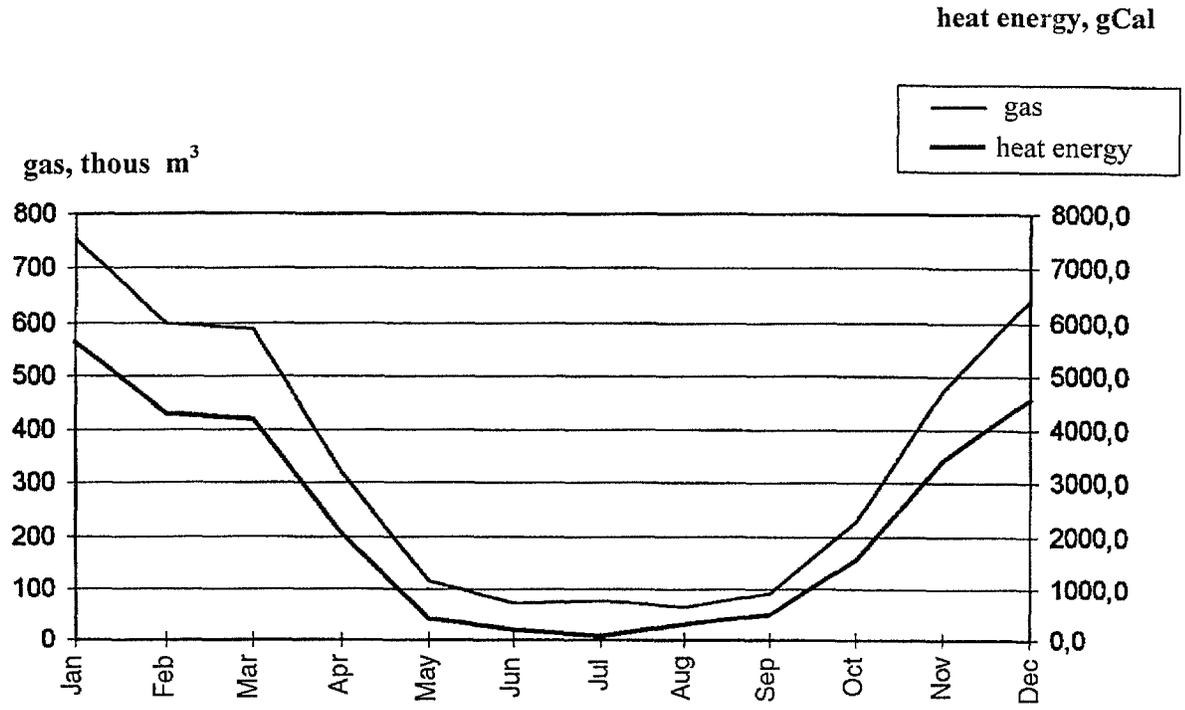
Chart 4 4 below is based on the Table above

Chart 4 4 Structure of gas consumption



The main share of the gas goes to the heat production in the boiler section Fig 4 1 shows the Chart of heat production relationship vs gas consumption in 1997

Fig 4 1 Chart of gas consumption and heat production in boiler section in 1997



4 2 Operation of energy consuming equipment

Boiler section

The boilers are controlled manually, by adjusting the pressure of the gas and air feed to burners The gas to air ratio before the burners is also controlled manually in accordance with the operation chart of every boiler The steam boiler has no steam meter installed

The air intake for the burners comes from the unheated ventilation equipment system

One particular feature of the boiler operation is that the deaerator is excluded from the make-up water system, which causes substantial scale deposition inside the boiler piping (up to 1 mm) This results in a sharp drop of heat exchange and excessive fuel consumption, and the increased possibility of pipe burning In addition, the repair time required for cleaning boiler pipes and drums is increased Scale in a lower part of boiler No 3 is connected with the lack of continuous purging

The hot water supply boilers installed in the boiler section have been manufactured by the enterprise itself They function in the following way cold water is fed to the boiler, which has a coiled pipe the middle The hot water heated by steam goes to the upper part of the boiler and is distributed to the consumers

Four boilers are installed in the boiler room, with one of them heating water mainly for the canteen and all others supplying the production shops with hot water Steam consumption is regulated manually with no temperature control of the hot water supplied to the end-users Since steam input into the boiler is done manually, the temperature of water supplied to the users is often too high

As a rule, hot water from the boilers is supplied to the showers only at the end of each shift The steam consumption rate at the Hot Water Supply [*GVS*] boilers in Shops No 1, 3 and 5 is regulated manually, and hot water is also used mainly only for showers

Heating System and Hot Water Supply [GVS]

Heating needs are provided by two water-heating boilers with an aggregate heating capacity of 3 4 GCal/hour Both boilers are approximately equally loaded, for example, in 1996 boiler No 4 was mostly used, while boiler No 3 in 1997

As we mentioned above, currently the enterprise is switching from steam to a water heating system For example, steam in Shop No 1, first, is passed through a steam register then goes to the condensate tank and only then is sent to the existing water heating system and further through the accumulator tank to sewerage Condensate is complete wasted Condensate of the heating system in St Paul and Peter Cathedral, as outside consumer, is not returned as well

Steam consumers

Steam produced in the boiler room is used for process purposes for water heating, fuel oil heating and is also supplied to the outside users (St Paul and Peter Cathedral) It should be noted that the amount of steam used for the process purposes is not large and amounts to 0 6 GCal/hour The process steam users include three washing machines (Shop No 2 and 6) Paint-Drying premises (Shop No 1) and dry cleaners In fact, steam is actually is required only for the dry-cleaners, as for the remaining users they could easily switch to hot water

Condensate return tanks are installed in Shops No 3, 5 and 6 to which condensate after the heating system, Hot Water Supply [GVS] boilers, heat-curtain blowers and two washing machines is returned Condensate is pumped by pumps from the condensate return tanks to the condensate tank in the boiler room

Air compressors

This section operates in two shifts using not more than two compressors at a time The pipeline has a pressure of 6 to 8 atmospheres, no automated control is available At the outlet from the compressor section, there are two receivers, 10 m^3 each No compressed air dryers are envisioned The two new VV type compressors have not been put into operation because of the unavailability of the filters at the circulating water circuit The circulating cooling system for the air compressors functions all year round

5 ENERGY SAVING MEASURES

5 1 Results of measurements at the enterprise

When analyzing the electric power consumption, the Energy and Elite power recorders and the Fluke multimeter were used During the audit, the recorders were installed for several days at the input to the enterprise (high voltage side) and the main consumers of the electric energy shop # 5 (bays # 1 and # 2) shop # 6, construction section, wheel bay of shop # 2, works management building, and thermal department of shop # 10 In order to form the energy balance of the enterprise, single measurements of the power and power factor were taken at all the distribution cells of the transformers For the purpose of preparing an electric power consumption balance a 24 hour data collection procedure from the meters installed at distribution cells of TP-606 was organized Data readings of the meters were registered each 30 minutes (see electric power supply scheme)

The results of the measurements and the supposed methods of improving the efficiency of the electric energy use are shown below

Table 5 1 1 Electric Power Consumption Balance of the Enterprise

No	Consumer	Electricity consumption, %
1	**Lighting, including**	**15 7**
	Plant Management Headquarters	6
	Auxiliary premises lighting	6 8
	Workshops lighting	1 5
	Yard lighting	0 4
2	**Heat supply, including**	**17 2**
	Boiler house	7 2
	Network pump	10 0
3	**Air compressor station**	**17 5**
4	**Process facilities**	**34 2**
	Construction shop	2 5
	Shop No 5	7
	Shop No 6	4 4
	Microwave Thermal Treatment Unit in Shop No 10	2 6
	Thermal section of Shop No 10	3
	Shop No 2	12 4
	Repair-mechanical shop	1 3
	Casting shop	1
6	**Ventilation**	**4 5**
7	**Outside clients and losses**	**3 4**
8	**Others**	**8 5**
	TOTAL	**100**

The main consumers of electric power are process facilities, including electric heating ovens (about 7 7%), air compressor station, network pumps of the heating system, and lighting system

Air supply system

During the audit, an experiment on determination of the volume of leaks in the compressed air distribution system was performed The experiment consisted in the following After the end of the working shift, when all the compressed air consumers had stopped working, the 7 2 at operating pressure was created in the system During the control time, the system pressure was lowered After this, the compressors were restarted and the operating pressure in the system was restored Based on the time of operation of the compressors, the volume of leaks was determined for the control time plus time of operation of the compressors The entire compressed air system was inspected in the course of the energy audit (with valves at individual production divisions turned-off), for that is the way the first shift is operating At a later stage we decided to check separate sections of the compressed air supply system During the second test, the gate valve upstream forging hammer was closed Since the hammer is operating usually only during the first shift, such an air consumption regime is also typical for the second shift After this, the experiment was performed for the whole system except the branch for the hammer this is the regime for the second shift In conclusion, the air tightness was checked for the main branches (by length and number of consumers) The results of the experiment are shown in the Table below

Date April 4, 1998
Time 20 40

#	Segment of system	Control time, minutes	Pressure drop in system, at	Time of operation of compressor, minutes	Volume of leak	
					m^3/min	%*
1	Whole system (shift 1)	5	3	20	27	67 5
2	Whole system without hammer (shift 2)	12	2 2	6	9 2	46
3	Hammer	4	2 6	7 10	17 9	44 8
4	Construction section	10	1 4	2 55	4 4	22
5	Section # 6	10	1 2	2 30	4 3	21 5

* Leakage volume in percentage is calculated as a ratio of leakage in m^3/min and air consumption in the system For example, for the first test, when we were checking the entire system, leakage amounted to 27 m^3/min, and in this case two compressors with the capacity of 20 m^3/min each were operating, so leakage volume was equal to V = 27/40 = 67 5% In the event that the compressed air pipeline to the hammer is turned-off operators of the compressor unit start up only one compressor, and leakage in tests No 2, 4 and 5 were determined basing on this consideration

Lighting

The enterprise has possibilities to reduce the energy consumption by the lighting equipment The situation was observed when all the lighting was on, however the work was going on only at individual areas This situation is typical for all the sections operating in two shifts, because during shift 2, the load on the equipment is significantly lower, but the lighting equipment is used at full load

When visiting the construction section in the daytime, both the common and individual (at every work place) lighting was operating this also leads to the excessive consumption of the electric energy

Boiler section

The main consumer of the natural gas is the boiler section, hence, here lies the main potential for fuel saving To evaluate the efficiency of the boilers operation, the boilers # 2, 3, and 4 were tested These included the measurements of the compositions of the fume gases before and after economizer, the share of CO_2, O_2, CO, and gases temperatures These evaluations used the BACHARAH gas analyzers

Two boilers are continuously operating during the heating season the steam boiler and the water heating boiler A substantial discrepancy between rated capacity of steam boilers (6 5 and 10 0 tons per hour) and the required amount of steam, which even considering the remaining part of the steam heating system amounts only to 4 0 to 5 0 tons per hour should be noted At such consumption rates the operation of boiler No 1 (DE10/14GM) results in the excessive fuel consumption of 5-8% and more As for boiler No 2 (DKVR 6 5/13), it was certified only for one more additional year of operation with steam pressure reduced to 4 0 atm, since its service life expired, which sharply reduces its efficiency The situation is aggravated by the fact that it is difficult to manually maintain efficient gas/air ratio in the burners, let alone the possibility of automation of the process

Considering the low steam consumption, boiler No 2 is mainly operated with the second boiler started up only during emergency shut-down It was used for the period of planned summer repairs (from 11 07 until 11 10 in 1997)

Boilers No 3 and 4 (DKVR 6 5/13 and *Shukhov Type* Boiler) are operated only in a water heating mode since their service life has expired and they have been removed from the official register of the state boilers supervision authorities — *KOTLONADZOR*

The following could be noted according to the results of test of the boilers (with the exception of boiler No 1)

- current gas/air ratio in burners during the operation of boilers in accordance with rated load time-tables and beyond specified parameters (lower consumption) provides for efficient gas combustion in general (with first signs of CO in flue gases),
- substantial air suction in boilers' ducts was detected, and, if in boilers No 2 and 3 such suction occurs before the economizer and amounts to 100-120%), then in boiler No 4 the air suction is big enough both before the boiler (120-130%) and in the economizer itself (50-60%) Such high air suction results in large heat losses of fuel with flue gases as well as in additional load on smoke-extractors of the boilers,
- the increase of gas pressure in the burners from 10 MPa up to 30 MPa leads to the air suction drop of 60% and the reduction of heat losses of fuel with flue gases by 1 6%,
- the reduction of the air suction down to rated values should result in 2-7% fuel savings,
- efficiency of water heating boiler No 4 is 3 3% lower than of the *Shukhov Type* Boiler

In order to define actual values of steam production, the measurement of the make-up water flow rate at Boiler No 2 were carried out, which amounted to 4 0 tons per hour No periodic purging was made during these measurements

In order to evaluate the efficiency of the heating system, we measured the flow rate of network water passing both through the boiler and economizer It amounted to 220 m^3 and 12 m^3 per hour, correspondingly The temperature of direct and return water amounted to 50°C and 55°C with the temperature drop of 5°C, correspondingly

5 2 Possible energy saving measures

According to the results of the energy audit of the enterprise we may conclude that the Plant has a large potential for energy efficiency This is connected, first of all, with the use of old and obsolete equipment of the boiler room and heating system

Boiler Room

The measurements and calculations made during the audit, demonstrated the presence of big air suction in the boilers, especially at Boiler No 4 In the event that this air suction is eliminated the Plant could save 51 thousand m^3 of natural gas per year (see Project No 5)

The poor state and the lack of insulation coating on large sections of steam pipelines, pipes of the heating system and make-up water and the Hot Water Supply [*GVS*] is obvious, including complete absence of insulation on boilers both in the boiler room and in the shops Considering the high temperatures of the surface of pipelines and boilers (up to 100°C and higher), heat radiation losses into the ambient atmosphere result in the waste of 156 7 thousand m^3 of natural gas per year (see Project No 6)

Substantial fuel savings (40 748 m^3 of gas) could be made using the hot air of the upper section of the boiler room to feed to boiler burners (see Project No 7) It should be noted that in the future it is feasible to switch from the use of sulphonated coal to cation resin in the water chemical treatment facilities, which should save about 9 5 thousand m^3 of water (see Project No 10)

In fact, a really drastic solution of the problem of efficiency of heat energy production is the total reconstruction of the boiler room We see two possible variants in this connection

1. To install a new steam boiler with the capacity of 6 5 ton per hour and two boilers for water heating and Hot Water Supply [*GVS*] (with the total investment of about 460 thousand rubles)
2. To switch the DE boiler to a water heating mode with the installation of a new water heating boiler with the capacity of 6 5 GCal/hour However, in this case, the washing facilities should be converted from steam to hot water, which will not affect normal operation of these facilities (investment should amount to about 520 thousand rubles)

It should be noted that the above mentioned variants are based on the use of Russian made boilers The selection of the most efficient solution will require additional analysis

Heating System

Currently, the Plant is converting its heating system from steam to hot water In connection with the lack of project documentation and appropriate data on required investments, it is difficult to assign these activities into a separate energy efficiency project However the following should be noted in the course of reconstructing the heating system

- in the event that the entire heating system is converted to hot water it could be feasible to replace the network pump with a pump of lesser capacity,
- according to our estimations the reduction of condensate losses, which is not now returned by the heating system and Hot Water Supply [*GVS*], should amount to not less than 1 ton per hour

We think the reconstruction of the boiler room with a partial replacement of the boilers, heat exchanging equipment and other facilities should be a priority project The conversion of the remaining part of the steam heating system into water heating will also provide substantial gains Fuel oil facilities currently used by the Plant consume a lot of steam In order to reduce the amount of steam used, we suggest to warm-up the part of the fuel oil required to maintain rated operation of the boilers in the event of gas supply shortages In addition, the currently system used for steam

injections into fuel oil tanks should be improved, for it allows big discharges of steam and steam condensate into the atmosphere, which results in direct heat losses

In addition to improvements, which required big investments, we propose a number of zero-cost energy efficiency organizing improvements, including the re-distribution of consumption load between the first and second shifts Presently, the main consumption take place during the first shift According to the results of the measurements and consumption balance made, we found that process (technological) consumption amounts to only 35% of the electric power In the event of a better distributed consumption of the main process shops, the value of declared capacity during peak hours may be reduced by 10% of the current level which should give a saving of 133,860 rubles ($21,944) Any further reduction of the declared capacity may be achieved by replacing old compressors by new and more efficient ones (see below) Inefficient use of the lighting system and lamps shall be reduced to a very minimum Considering the large amount of lighting equipment at the Plant, this is one of the possible ways to cut electricity consumption (see project No 3)

Air Supply System

The air compression and distribution system has a large potential for electricity savings Compressed air leakage detected during the audit amount to 67% The proper sealing of compressed air pipelines and improvement of the valves will also allow reductions in electricity costs A real effect of air leakage elimination in the compressed air system will be obtained only in the event that the already supplied new fan compressors with discharge regulation capabilities are put into operation There are no serious obstacles to put them into operation Substantial savings can be obtained through lesser electric power consumption of the smaller compressors as well as through the reduction of declared electricity consumption maximum (see Project No 2)

Ovens

One of the potential water saving possibilities was found during the inspection of the electric ovens, in particular, — the *SShTsM* type ovens These ovens are water cooled After the ovens are shut-down, operators do not stop the cooling water supply because there is a possibility of water coils and piping overheating due to high temperature inertia of the ovens No recycling water system is available In this situation, the heated water from both *SShTsM* type ovens is discharged into the drainage system almost 24 hours per day As a energy efficiency program, it is recommended to organize the collection of water after the electric ovens and its supply to boilers Project No 8 concerns only water saving, though in the event of a more scrupulous development of this project a recycling scheme for hot water collected from the ovens could be envisaged In addition to the *SShTsM* type ovens, water cooling is used at the VTcG units installed in the same thermal treatment section It seems feasible to supply cooling water from these units too

The gas ovens efficiencies may be increased in the following manner first, to improve the wall insulation of the oven and air heat exchanger (see project No 9) located right above the oven, and, second, to use more completely the flue gases heat for the combustion air The air temperature after the heat exchanger measured during the audit proved to be 60°C This is too low with the temperature inside the oven being about 700-900°C

5 2 Recommended energy saving measures

Project No 1

Leveling of a daily process load time table

1 **Savings**

Annual savings in cash 133,860 rubles ($21,944)

2 **Costs**

Total costs 0 00 rubles ($0 00)

3 **Simple repayment period**

Recommendations

It is proposed to evenly distribute process load between the first and second shifts in order to reduce the amount of declared capacity

Description

Currently, there is uneven process load distribution between the first and second shifts The optimization of process load between the first and second shift will make it possible to reduce the amount of payment for declared capacity

Expected savings

Under the current additional rate of a two-rate tariff equal to 69 ruble/kW a 10% reduction of declared capacity will allow to cut electricity savings by 133,860 rubles ($21,944)

Investments required

This energy efficiency project requires no additional investments

Period

This project could be implemented immediately

Technical risks related to the quality of produced goods and/or the amount of produced goods

There are no risks of this sort for this project

Initial data and estimation results

According to the results of analysis of data obtained in the course of energy audit electric consumption of the entire plant and results of the electric power consumption balance the expected reduction of declared capacity should be equal to 10% of the existing level The annual amount of the ordered maximum was equal to 19,400 kW in 1997 Annual savings of money under the tariff of 69 rubles/kW should be equal to 133,860 rubles ($21,944)

Project No 2

Elimination of leaks in the compressed air distribution system

1	**Savings**		
	Annual savings of electric power	280 5 MWh	73 970 rubles ($12,126)
	Reduction of ordered consumption maximum		99,360 rubles ($16,290)
	Total savings		173,330 rubles ($28,416)
2	**Costs**		
	Total costs		0 00 rubles ($0 00)
3	**Simple repayment period**		

Recommendations

It is proposed to eliminate air leakage in the compressed air system and install and put into operation new VV type compressors

Description

The elimination of air leakage in the system will allow to gain substantial savings under the condition that the new VV type compressors are used

Expected savings

Under the current tariff rates the annual savings of 280 5 MW of electric power will give 73 970 rubles ($12,126) The reduction of declared capacity will allow to cut electricity savings by 99,360 rubles ($16,290) under the additional rate of a two-rate tariff The total savings will amount to 173,330 rubles ($28,416)

Investments required

This energy efficiency project requires no additional investments

Period

This project could be implemented immediately

Technical risks related to the quality of produced goods and/or the amount of produced goods

There are no risks of this sort for this project

Initial data and estimation results

According to the results of tests, we found leakage reaching 67 5% with the two compressors operating in the first shift and up to 46% during the second shift Efficient capacity of the compressor amounts to 13 and 10 8 m^3/min correspondingly Taking into account the fact that actual consumption of compressed air is even less, we observed frequent operation of relief valve, discharging air into the atmosphere (it was especially typical for the second shift) In these conditions it is very crucial to eliminate leakage in the compressed air distribution system and to put into operation two fan-type compressors with a wide range of capacity regulation Assuming that VV20/9 compressor with the capacity of 13 m^3/min (65% of its rated capacity) is operating during the first shift its power consumption should amount to about 115 kW as compared with 240 kW of two old compressors During the second shift, when actual air consumption is actually equal to zero they should use VV9/9 compressor Assuming that the capacity of this new compressor is about 6-7 m^3/min its power

consumption should amount to about 55 kW as compared with 120 kW of the old compressor Operating 5 hours in the first shift and 10 hours in the second shift (at least this was the way they operated these compressors during the energy audit) the total savings should amount to 1,275 kW per day or 280 5 MWh per year

As additional benefit of this energy savings recommendation it would be possible to reduce the declared maximum by 120 kW (the difference of consumed capacity during the peak consumption hours between the two old compressors and one new one), which will result in the annual savings of 99,360 rubles ($16,290)

Project No 3

Elimination of inefficient use of the lighting system

1 **Savings**

Annual savings of electric power	10,120 kWh	2,699 rubles ($437)
Total savings		

2 **Costs**

Total costs	0 00 rubles ($0 00)

3 **Simple repayment period**

Recommendations

It is proposed to exclude the lighting equipment, which is not efficiently used now

Description

Presently the lighting equipment of the enterprise is not used efficiently during lunch break and the second shift In the event that the lamps are switched-off during lunch break and using individual or section-type lighting equipment in production shops (especially during the second shift) would result in substantial electric power savings

Expected savings

Under the current tariff rates the annual savings of 10 120 kW per hour of electric power is equivalent to 2,669 rubles ($437)

Investments required

This energy efficiency project requires no additional investments

Period

This project could be implemented immediately

Technical risks related to the quality of produced goods and/or the amount of produced goods

There are no risks of this sort for this project

Initial data and estimation results

According to the results of visual inspection of the Plant, we found that excessive lighting equipment was switched on in Shop No 1, 5 and 6 The total estimated power of the lighting equipment switched on during lunch break amounts to about 3 kW The extra electricity consumption due to the use of excessive lighting during the second shift amounts to about 4 kW The extra electricity consumption due to the use of excessive lighting in the construction Shop No 1 amounts to about 2 kW The efficient use of the lighting system will result in saving up to 10,120 kWh of electricity per year

Project No 4

Disconnection of the fuel oil tanks heating steam pipeline

1 **Savings**

Annual savings of water	311,577 m^3	91,501 rubles ($15,000)
Total savings		91,501 rubles ($15,000)

2 **Costs**

Total costs	0 00 rubles ($0 00)

3 **Simple repayment period**

Recommendations

It is proposed to disconnect the fuel oil tanks heating steam pipeline

Description

Presently, the Plant is using a continuous heating of tanks with stand-by fuel oil Since the probability of shortages of the basic fuel — natural gas is rather small, we propose to stop the continuous supply of steam to the fuel oil tanks, which will ensure substantial savings

Expected savings

The savings of 311,757 m^3 of natural gas is equivalent to 91,501 rubles ($15,000)

Investments required

This energy efficiency project requires no additional investments

Period

This project could be implemented immediately

Technical risks related to the quality of produced goods and/or the amount of produced goods

There is a small probability still that there could be interruptions of gas supply to the enterprise

Initial data and estimation results

According to the results of measurements we found that about 500 kg of steam or 0 28 kCal per hour is supplied to the fuel oil tanks In the event that steam supply to the tanks is stopped the annual heat savings should be equal to 2,453 GCal/hour or 311,757 m^3 of natural gas Efficiency was assumed to be equal to 85%

Project No 5

Reduction of air suction in boilers

1	**Savings**		
	Annual savings of gas	51 thousand m^3	14,969 rubles ($2,454)
	Total savings		14,969 rubles ($2,454)
2	**Costs**		
	Repair works		2,000 rubles ($328)
	Total costs		2,000 rubles ($328)
3	**Simple repayment period**		

Recommendations

It is proposed to reduce air suction in the flue gas duct

Description

To improve sealing of the boilers by sealing hatches and eliminating cracks

Expected savings

Under current gas tariff the savings of 51 thousands m^3 of gas is equal to 14,969 rubles ($2,454)

Investments required

The estimated cost of repair works for the three boilers should amount to 2,000 rubles ($328)

Repayment period

The estimated repayment period of investments is equal to 2 months The scale of this project does not require the calculation of the internal repayment rate

Period

This project could be implemented immediately in the course of planned annual repair works

Technical risks related to the quality of produced goods and/or the amount of produced goods

There are no risks of this sort for this project

Initial data and estimation results

According to the results of measurements made at Boilers No 2, 3 and 4 we found air suction amounting to 110, 114 and 190% correspondingly, which result in heat losses with flue gases The reduction of air suction to the amount complying with the rated values specified in efficiency operation charts for the boilers will allow for the efficiency increase of 1 5% for boilers No 2 and 3 and 3 8% for boiler No 4 In this case the total fuel savings should amount to 51 thousand m^3, which is equal to 14 969 rubles ($2,454)

Project No 6

Insulation of pipelines in boiler and water heating rooms

1	**Savings**		
	Annual savings of gas	156 7 thousands m³	45,993 rubles ($7,540)
	Total savings		45,993 rubles ($7,540)
2	**Costs, including VAT**		
	Mineral wool		2,340 rubles ($384)
	Insulation works		1,404 rubles ($230)
	Total costs		3 744 rubles ($614)
3	**Simple repayment period**		

Recommendations

To insulate noninsulated sections of pipelines in the boiler house

Description

In order to reduce heat losses caused by noninsulated sections of make-up and network water pipelines, steam pipelines and valves and Hot Water Supply [*GVS*] boilers it is proposed to insulate them, which should save 156 7 thousands m^3 of natural gas

Expected savings

Under current gas tariff the savings of 156 7 thousands m³ of gas is equal to 45,993 rubles ($7,540)

Investments required

In order to insulate 760 m of open sections of pipelines in the boiler and heating rooms 6 5 m^3 of mineral wool should be required The estimated price of insulating materials (mineral wool and asphalt board) and appropriate works is equal to 3 744 rubles ($614) including VAT

Repayment period

A simple repayment period is equal to 1 month The scale of this project does not require the calculation of the internal repayment rate

Period

This project could be implemented immediately

Technical risks related to the quality of produced goods and/or the amount of produced goods

There are no risks of this sort for this project

Initial data and estimation results

The results of measurements of length diameter and surface temperature of noninsulated or inadequately insulated sections of the pipelines and noninsulated tanks of Water Heating System in the boiler and heating rooms (see Appendix VI) were used as initial data Total heat losses are equal to 184 7 kW

Economically efficient thickness of insulation for this type of pipelines is about 35 mm After such insulation is installed the total heat losses of insulated pipelines should be about 21 2 kW Thus, the installation of insulation will allow to save about 163 5 kW, which is equal to 156 7 m^3 of natural gas and to 45 993 rubles ($7,540) Estimated efficiency was assumed to be equal to 85% The calculations of heat losses through noninsulated sections of pipelines and the evaluation of economic insulation thickness was made in accordance with standard reference tables

Project No 7

Use of warm air for burners

1	**Savings**		
	Annual savings of gas	40,748 m^3	11,960 rubles ($1,961)
	Total savings		11,960 rubles ($1,961)
2	**Costs**		
	Repair works		5,000 rubles ($820)
	Total costs		5,000 rubles ($820)
3	**Simple repayment period**		

Recommendations

It is proposed to use warm air taken from the upper section of the boiler room for burners

Description

Presently air intake for burners is carried out from the non-heated ventilation room, which reduces performance of the boilers It is proposed to use warm air taken from the upper section of the boiler room for burners

Expected savings

Under current gas tariff the savings of 40,784 m^3 of natural gas is equal to 11,960 rubles ($1,961)

Investments required

The estimated cost of repair works for the three boilers should amount to 5,000 rubles ($820)

Repayment period

The estimated repayment period of investments is equal to 5 months The scale of this project does not require the calculation of the internal repayment rate

Period

This project could be implemented immediately in the course of planned annual repair works

Technical risks related to the quality of produced goods and/or the amount of produced goods

There are no risks of this sort for this project

Initial data and estimation results

An average temperature difference between the boiler room and outdoor temperature during the year is equal to about 30°C The consumption of air for combustion was estimated basing on the annual natural gas consumption of the boiler (3,405 thousand m^3) and amounted to 39 8 million m^3 The warm air intake from the premises will allow for the savings of 377 3 GCal per year, which is equal to 40 748 m^3 of gas

Project No 8

Supply of cooling water from electric ovens to the boiler room

1	**Savings**		
	Annual savings of water	5 900 m^3	31 303 rubles ($5,132)
	Total savings		31 303 rubles ($5,132)
2	**Costs**		
	Total costs		5,000 rubles ($820)
3	**Simple repayment period**		

Recommendations

It is proposed to use water from cooling system of electric ovens for the boilers

Description

Presently, water from the cooling system of electric ovens is not used and is discharged to sewerage, which results in substantial water losses It is proposed to use water from the cooling system of electric ovens for the boilers

Expected savings

Under current water tariff the savings of 5,000 m^3 of water is equal to 31 303 rubles ($5,132)

Investments required

Investments required for the organization of the collection and supply system for cooling water from ovens to the boiler room should amount to 5,000 rubles ($820)

Repayment period

The estimated repayment period of investments is equal to 2 months The scale of this project does not require the calculation of the internal repayment rate

Period

This project could be implemented immediately

Technical risks related to the quality of produced goods and/or the amount of produced goods

There are no risks of this sort for this project

Initial data and estimation results

The cooling water flow rate for two *SShTsM* electric ovens is equal to 0 8 m^3 per hour and for *VTchG* Unit — 3 5 m^3 per hour Water supply to *SShTsM* electric ovens is carried out 24 hour a day *VTchG* Units are operating about 1 hour per day The annual consumption of cooling water is about 5900 m^3 Considering payments for water supply and water discharge the savings of water through supplying it to the boiler room should amount to 31 303 rubles ($5,132)

Project No 9

Insulation of external surfaces of the gas ovens

1	**Savings**		
	Annual savings of water	20, 520 m^3	6 023 rubles ($987)
	Total savings		6 023 rubles ($987)
2	**Costs**		
	Total costs		4,000 rubles ($656)
3	**Simple repayment period**		

Recommendations

To insulate surfaces of ovens and combustion air heat exchanger

Description

Inadequate insulation of surfaces of ovens and the combustion air heat exchanger results in big heat losses into ambient atmosphere The installation of new insulation should allow for fuel savings in ovens

Expected savings

Under current tariff the savings of 20,520 thousands m^3 of natural gas is equal to 6,023 rubles ($987)

Investments required

Investments for insulating both ovens amount to 4,000 rubles ($656)

Repayment period

A simple repayment period is equal to 8 month The scale of this project does not require the calculation of the internal repayment rate

Period

This project could be implemented immediately

Technical risks related to the quality of produced goods and/or the amount of produced goods

There are no risks of this sort for this project

Initial data and estimation results

The annual gas consumption of a two-chamber oven is about 157,500 m^3 Heat losses into ambient atmosphere — 200 GCal per year (at the average temperature of oven's surface equal to 250°C) New insulation will make it possible to reduce losses by 190 GCal per year, which means natural gas savings of 20,520 m^3

Project No 10

Transition from sulphonated coal to cation resin Ku-2-8

1 **Savings**

Annual savings of water	9411 m^3,	37,268 rubles ($6,109)
Reduction of drainage payments	5458 m^3,	12648 rubles ($2,079)
Salt savings	281 tons,	64,630 rubles ($10,595)
Total savings		114,583 rubles ($18,783)

2 **Costs**

Cation resin Ku-2-8 (including VAT)	69,600 rubles ($11,410)
Total costs	69,600 rubles ($11,410)

3 **Simple repayment period**

Recommendations

To use cation resin Ku-2-8 instead of sulphonated coal

Description

In the event that cation resin Ku-2-8 is used instead of sulphonated coal the frequency of agent regeneration is reduced, and thus, there will be savings related to a lesser consumption of water and salts

Expected savings

Under current tariff for water supply and water drainage and salt prices the total savings should be equal to 114,583 rubles ($18,783)

Investments required

Investments required for the initial for this project should amount to about 69,600 rubles ($11,410) with VAT This estimation was made on the basis of data presented by cation resin manufacturer

Repayment period

A simple repayment period is equal to 8 month The scale of this project does not require the calculation of the internal repayment rate

Period

This project could be implemented immediately

Technical risks related to the quality of produced goods and/or the amount of produced goods

There are no risks of this sort for this project

Initial data and estimation results

The results of annual water consumption for regeneration and salt prices and the price of cation resin Ku-2-8 and sulphonated coal were considered as initial data base

Material resources	Unit Price	Annual consumption	
		sulphonated coal	**cation resin Ku-2-8**
salt	230 ruble/ton	360 tons	79 tons
water consumption	3 96 ruble/m^3	14600 m^3	5189 m^3
water drainage	2 324 ruble/m^3	8468 m^3	3010 m^3

Presently, the annual consumption of sulphonated coal is equal to 10% of the total load volume (about 0 4 tons), and in the event that cation resin Ku-2-8 is used a full load should be required during the first year (4 tons) With the price of cation resin equal to 15000 rubles per ton against 5000 rubles per ton for sulphonated coal, the initial expenses minus associated costs for adding sulphonated coal should amount to the following

3 = 4 × 15,000 × 1 2 0 4 × 5000 × 1 2 = 69,600 rubles ($11,410)

APPENDIX I MAIN PRODUCTS OF STATE-OWNED ENTERPRISE A D SHPAGIN PERM MOTOR TROLLEY REPAIR WORKS IN 1997

	Product	Unit of measure	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
1	Repair and modernization of motor trolleys	pcs	14	14	14	17	14	12	5	9	9	15	11	9	143
2	Formation of wheel couples	pcs	5	6	14	16	19	12	42	32	26	11	24	14	239
3	Anchor bolts	sets	185	265	270	270	270	180	336	70	76	60	95	300	2377
4	Home furniture	sets	16	15	15	6	15	15	20	33	—	12	—	44	191

APPENDIX II CONSUMPTION OF ENERGY RESOURCES BY STATE-OWNED ENTERPRISE A D SHPAGIN PERM MOTOR TROLLEY REPAIR WORKS IN 1997

#	Energy resource		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
1	**Gas**	thous t of conventional fuel	860	684	670	365	131	84	86	74	106	262	538	733	4593
		thous m^3	754	600	588	320	115	74	75	65	93	230	472	643	4029
	tariff	Rbl /m^3	0 2892	0 2841	0 2841	0 2841	0 2841	0 2841	0 2841	0 2841	0 2841	0 2841	0 2935		
	payment for 1997	Rbl	218039	170460	167051	90912	32672	21023	21308	18467	26422	65343	134095	188721	1154512
2	**Fuel oil**	thous t of conventional fuel	0	0	12	0	5	0	0	0	0	0	21	0	38
	payment for 1997	Rbl			0	0	0	0	0	0	0	0	0	0	0
3	**Electric power**														
	declared capacity	kW	1800	1800	1800	1600	1400	1400	1400	1400	1400	1800	1800	1800	19400
	tariff	Rbl /kW	66	66	66	66	66	66	66	66	66	66	66	66	
	payment for 1997	Rbl	114048	114048	114048	101376	88704	88704	88704	88704	88704	114048	127908	114048	1243044
	electric energy	MWh	565 51	526 50	499 90	488 56	330 01	364 20	359 99	291 16	491 31	530 85	628 82	648 68	5725 5
	tariff	Rbl /kW	0 1925	0 1925	0 1925	0 1925	0 1925	0 1925	0 1925	0 1925	0 1925	0 1925	0 1925	0 1925	
	payment for 1997	Rbl	108860	101352	96230	94047	63527	70108	69299	56049	94578	102188	121047	124871	1102156
	Total	Rbl	222908	215400	210278	195423	152231	158812	158003	144753	183282	216236	248955	238919	2345200
4	**Municipal water**														
	Consumption	m^3	9985	7780	9389	11169	9825	12305	11571	11107	10742	14061	14449	15783	138166
	tariff	Rbl /m^3	3 96	3 96	3 96	3 96	3 96	3 96	3 96	3 96	3 96	3 96	3 96	3 96	3 96
	payment for 1997	Rbl	39541	30809	37180	44229	38907	48728	45821	43984	42538	55682	57218	62501	547137
	discharge	m^3	5791	4512	5446	6478	5699	7137	6711	6442	6230	8155	8380	9154	80135
	tariff	Rbl /m^3	2 324	2 324	2 324	2 324	2 324	2 324	2 324	2 324	2 324	2 324	2 324	2 324	2 324
	payment for 1997	Rbl *1,000	13458	10486	12657	15055	13244	16586	15596	14971	14479	18952	19475	21274	186234
	Total		52999	41295	49837	59284	52151	65314	61418	58955	57017	74634	76693	83775	733371

APPENDIX III PRODUCTION OF ENERGY RESOURCES BY STATE-OWNED ENTERPRISE A D SHPAGIN PERM MOTOR TROLLEY REPAIR WORKS IN 1997

#	Energy resource	Unit of measure	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
1	Heat energy	gCal	5621 0	4291 0	4186 0	2065 0	434 0	182 0	63 0	294 0	490 0	1575 0	3437 0	4564 0	27202 0
		thous t of conventional fuel	803	613 0	598 0	295 0	62 0	26 0	9 0	42 0	70 0	225 0	491 0	652 0	3886 0

APPENDIX IV DAILY CHARTS OF CONSUMPTION OF ENERGY RESOURCES BY MAIN CONSUMERS OF A D SHPAGIN PERM MOTOR TROLLEY REPAIR WORKS

Fig IV-1 Electric energy consumption by shop # 5, bay 1

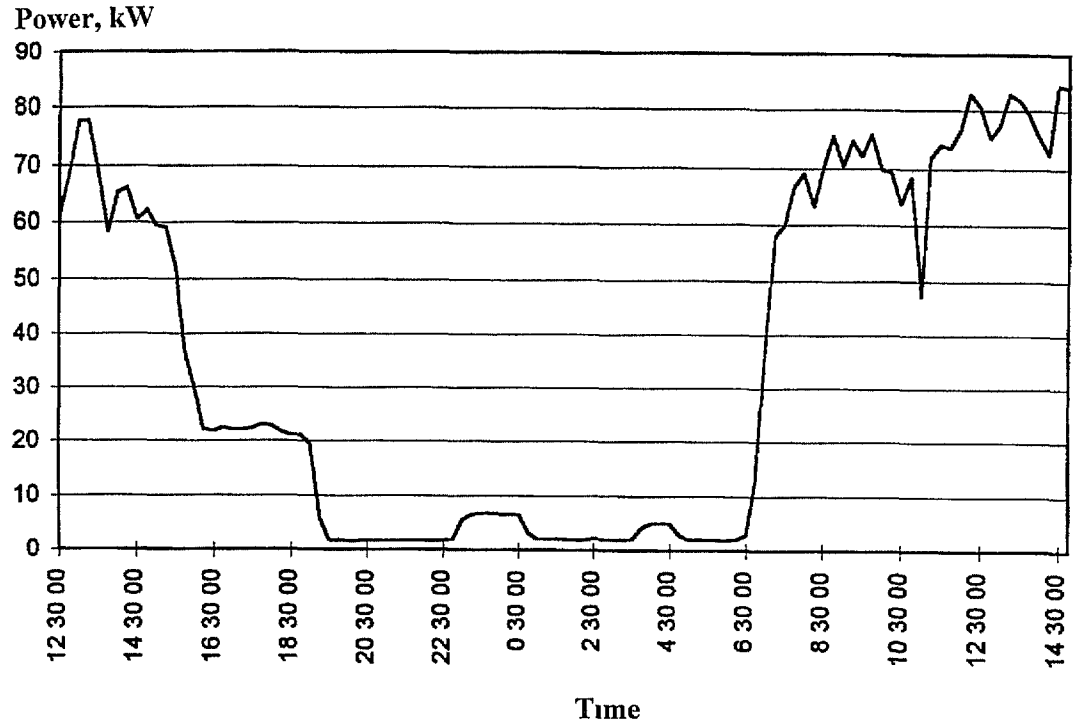


Fig IV-2 Electric energy consumption by shop # 5, bay 1

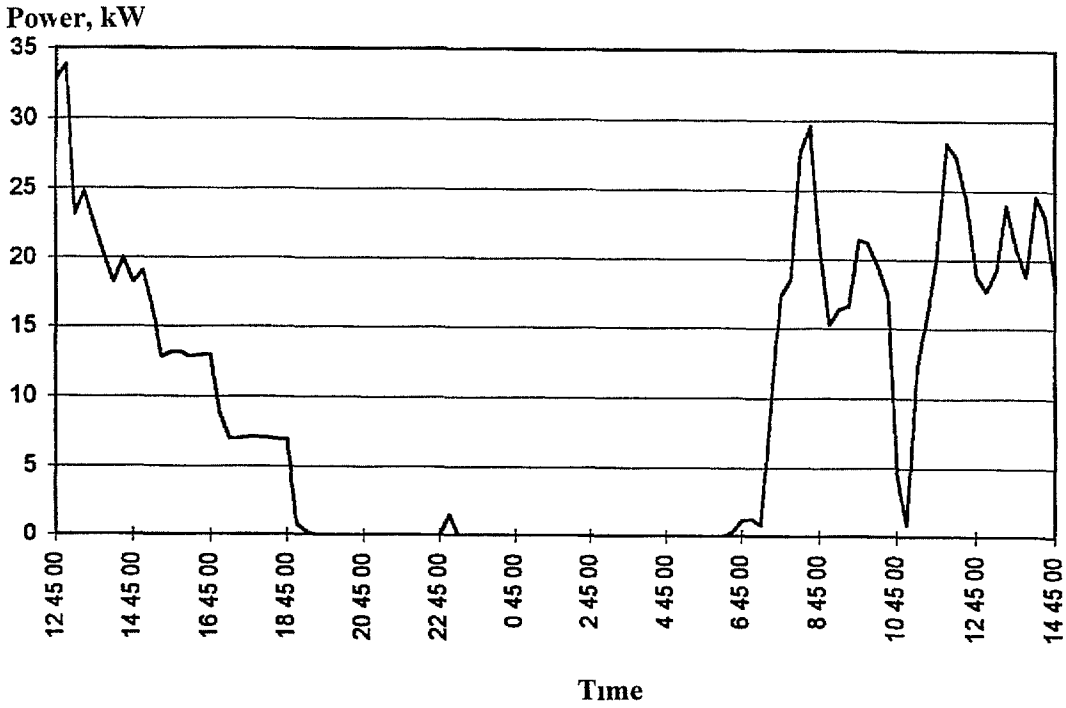


Fig IV-3 Electric energy consumption by shop # 6

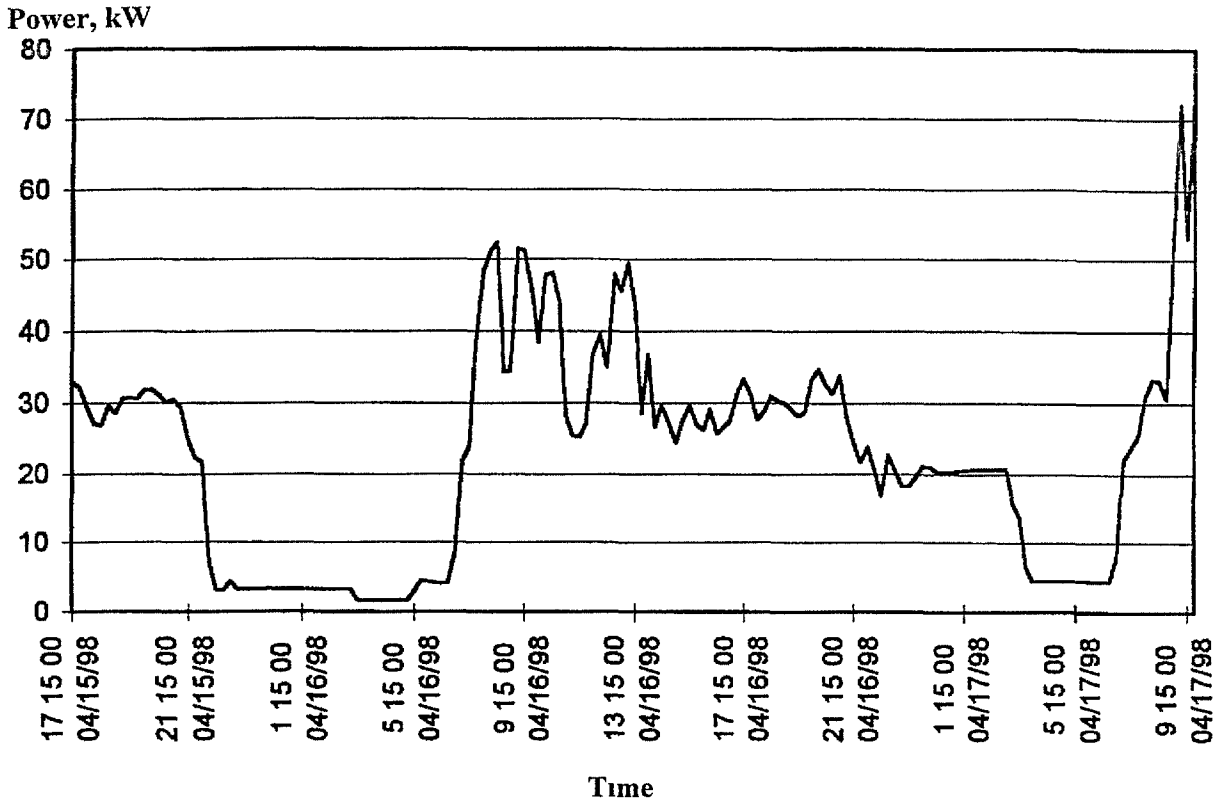


Fig IV-4 Electric energy consumption by heat treatment department of shop # 10

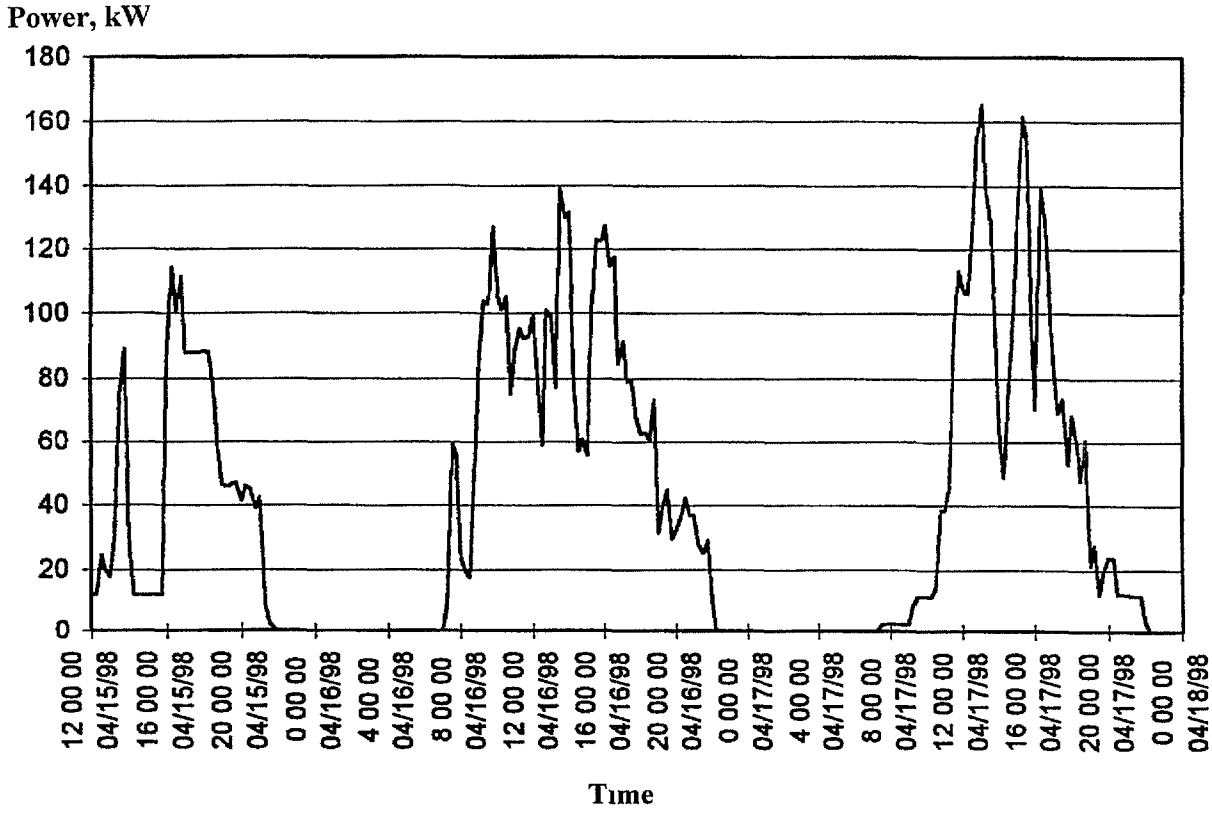


Fig IV-5 Electric energy consumption by shop # 1

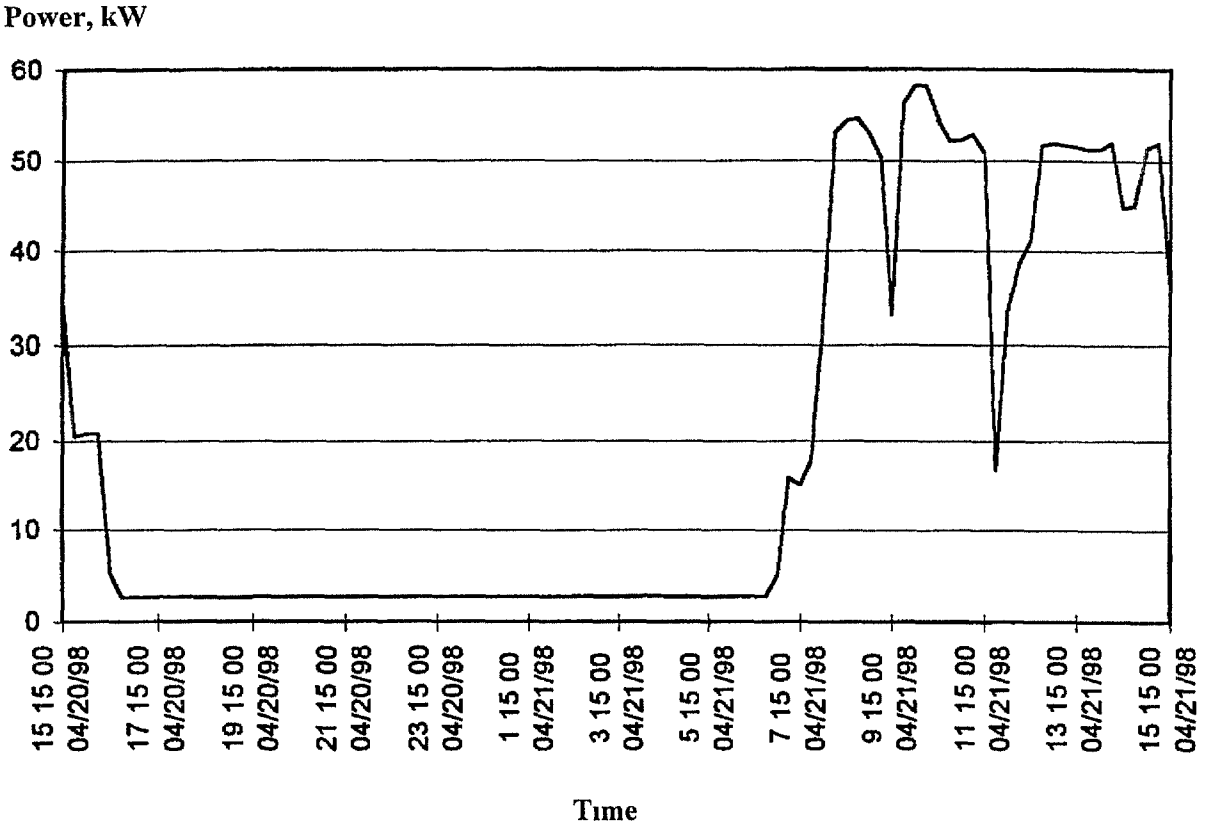


Fig IV-6 Electric energy consumption by building of works management

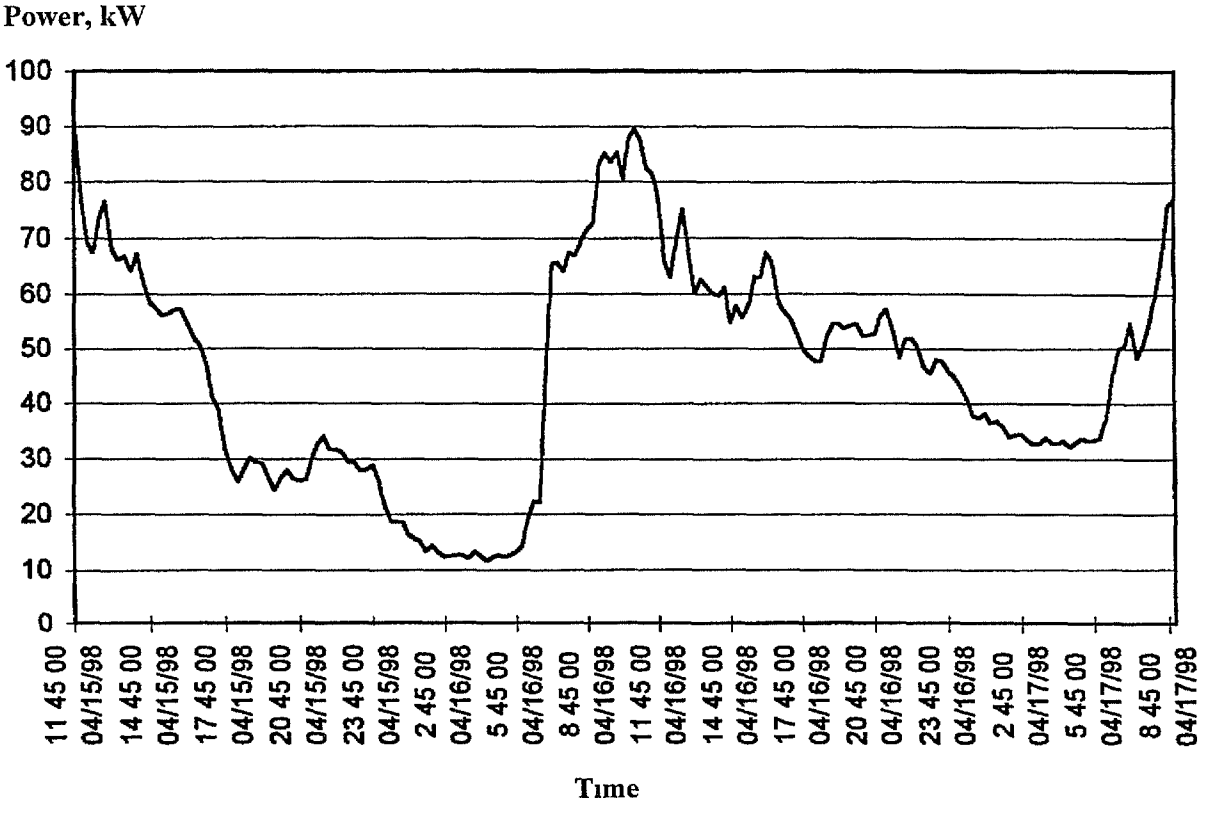


Fig IV-7 Electric energy consumption by wheels bay of shop # 2

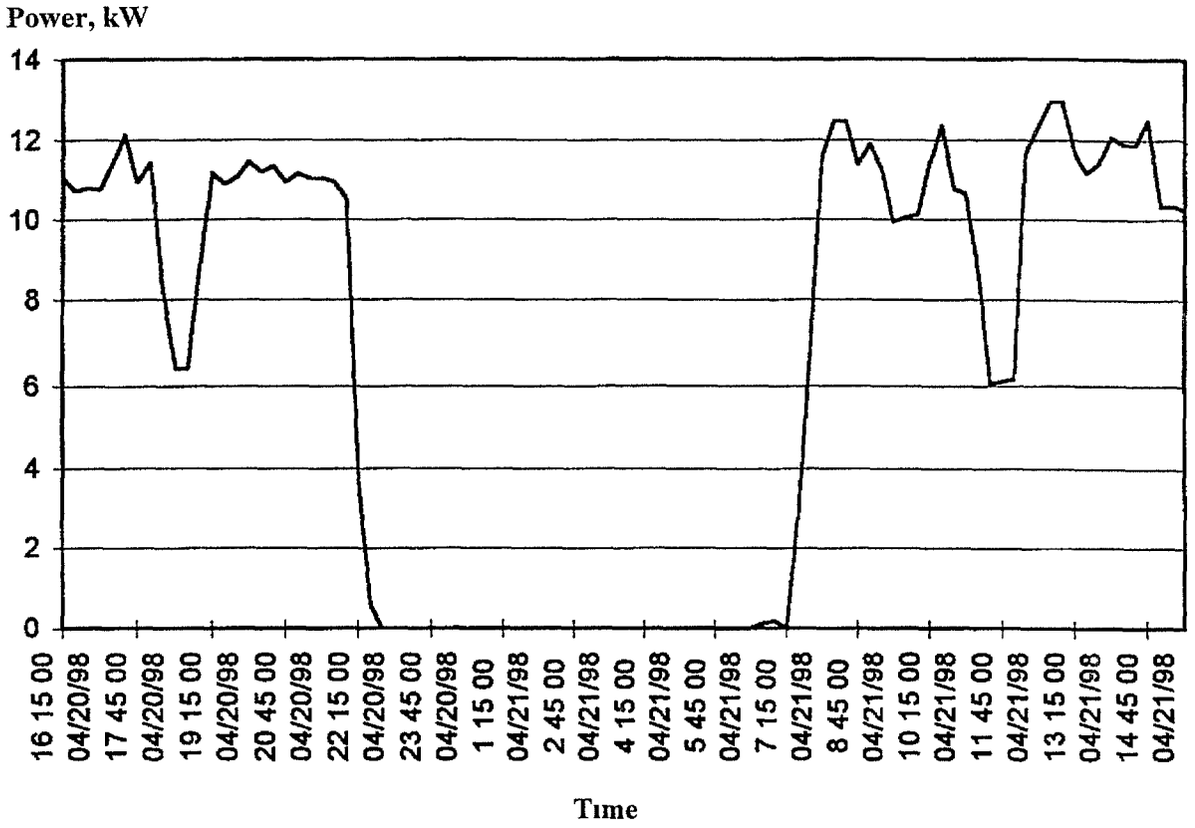
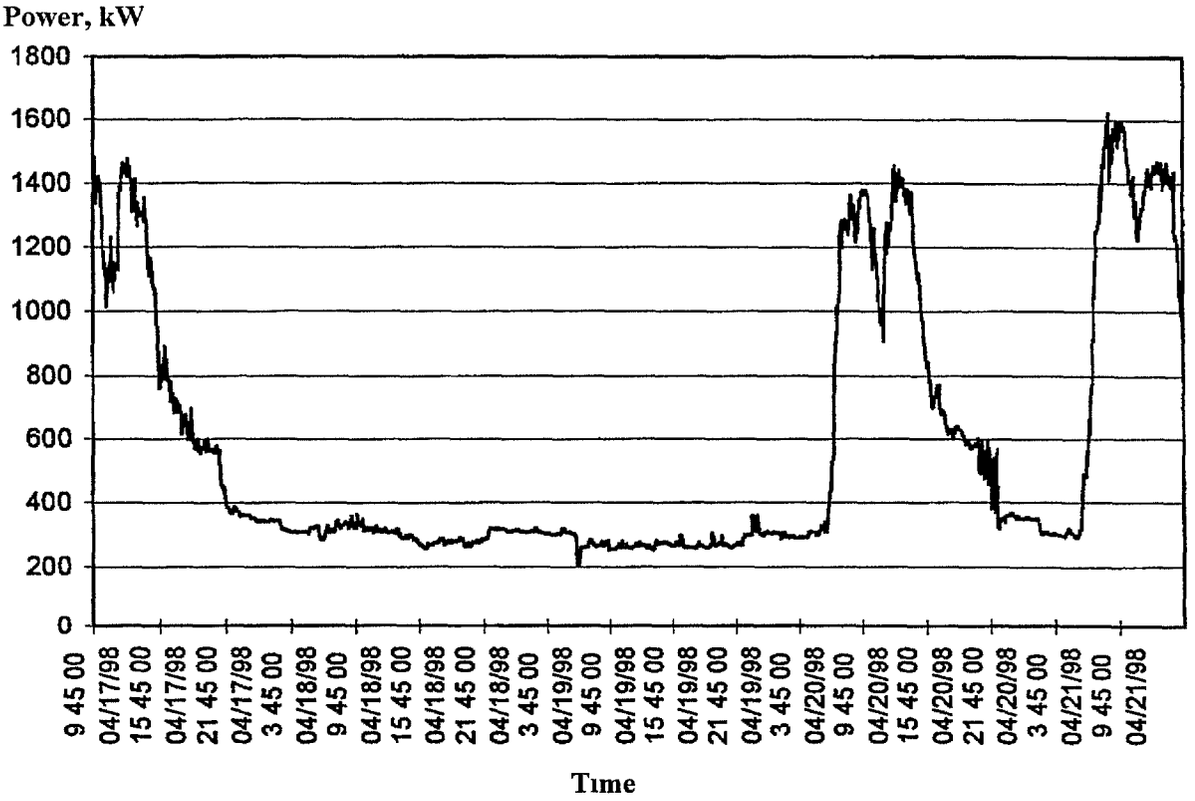


Fig IV-8 Electric energy consumption by enterprise in whole

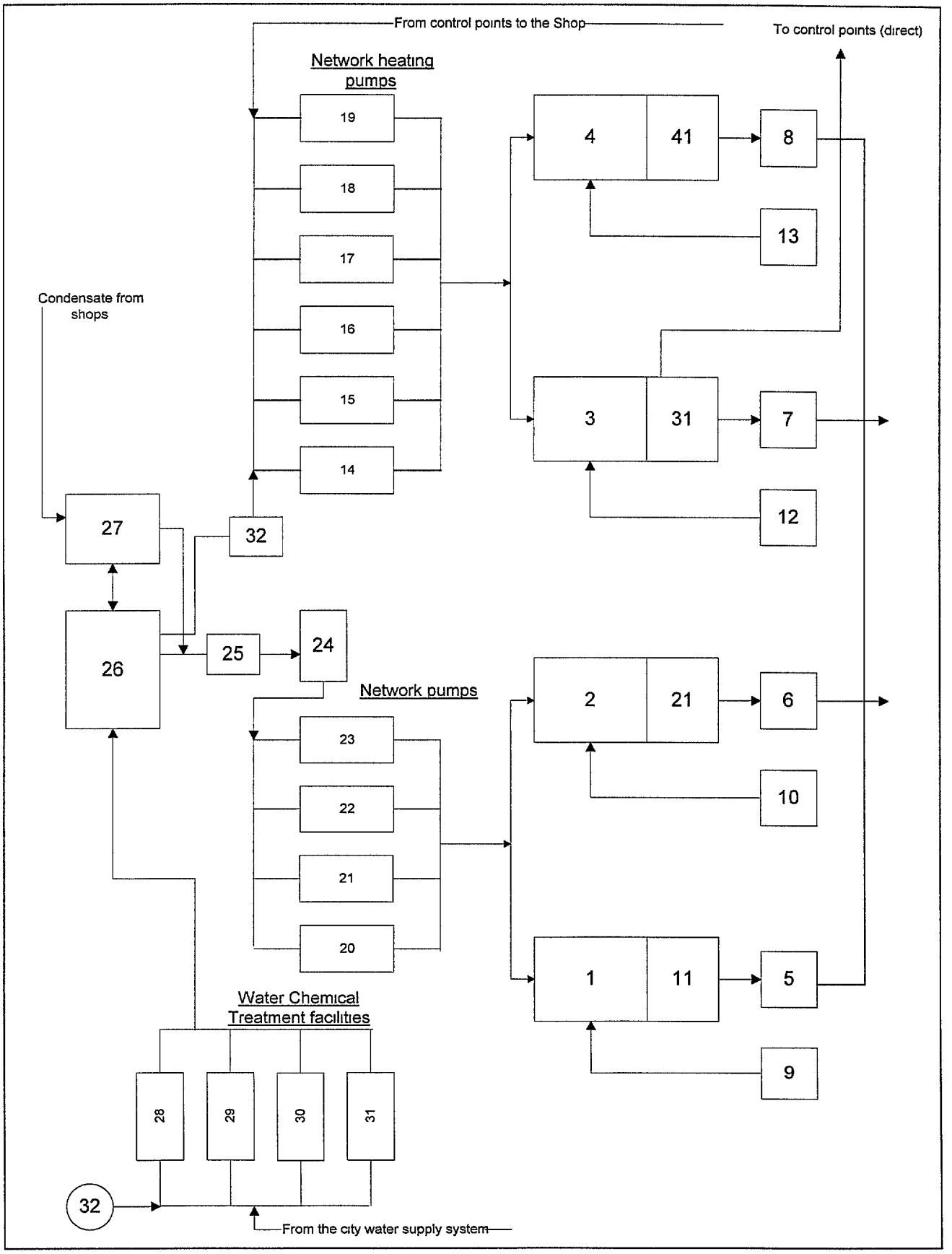


APPENDIX V TESTS OF BOILERS

The results of boilers 2, 3, and 4 testing

	Units of measure	Boiler # 2			Boiler # 3	Boiler # 4
		Test 1	Test 2	Test 3	Test 4	Test 5
Date		14/04	14/04	14/04	14/04	20/04
Time	hh mm	14 30	15 00	15 30	16 00	14 00
Steam pressure	kgf/cm^2	2 4	2 6	2 2	—	—
Burners						
Gas pressure at burner 1	kgf/cm^2	200	300	100	35	80
Gas pressure at burner 2	kgf/cm^2	200	300	100	35	80
Air pressure at burner 1	kgf/cm^2	15	15	15	25	25
Air pressure at burner 2	kgf/cm^2	45	70	30	25	30
Vacuum in boiler	mm H_2O	2	2	2	2	2
Exhaust gases after boiler						
Temperature	C	186	198	175	232	150
Oxygen, O_2	%	10 1	9 4	12	10 4	12 1
CO_2	%	6	6 4	5	5 5	4 9
Excess of air	%	85	74	123	92	128
NO_x	ppm	34	30	29	43	7
CO	ppm	6	5	9	1	82
Efficiency of boiler	%	88 9	88 8	88 0	85 6	89 6
Exhaust gases after economizer						
Temperature	C	112			90	100
Oxygen O_2	%	11 4			11 6	14 0
CO_2	%	5 3			5 2	3 9
Excess of air	%	109			114	185
NO_x	ppm	28			38	7
CO	ppm	2			1	77
Efficiency of boiler after economizer	%	94			94 8	92 2
Calculated efficiency	%	**87**			**89**	**86**

APPENDIX VI LAYOUT OF THE BOILER ROOM



Equipment Specifications for the Boiler Scheme

No	Equipment
1	Steam boiler DE-10/14GM
2	Steam boiler DKVR-6 6/13
3	*Shukhov Type* Water heating boiler 8/13
4	Water heating boiler DKVR-6 5/13
5	Smoke Extractor VDN-11 2
6	Smoke Extractor D-9
7	Smoke Extractor D-9
8	Smoke Extractor D-9
9	Smoke Extractor D-9
10	Blower No 1 VVD-11
11	Blower No 2 VDN-11
12	Blower No 3 VDN-10-1000
13	Blower No 4 DN-10U-1000
14	Network pump K100-65-250
15	Network pump 1D200-90
16	Network pump 1D200-90
17	Network pump 1D200-90
18	Network pump 1D200-90
19	Network pump KM100-65-200
20	Make-up pump KS10-55/2
21	Make-up pump TsNSG-380-132
22	Make-up pump TsNSG-380-132
23	Make-up pump KS10-55/2
24	Deaerator DA-25
25	Make up pump for the aerator KM-80-50-200
26	Make up water tank for boilers (V=35 m^3)
27	Condensate Collector Tank (V=35 m^3)
28-31	Soft-water Filter
32	Salt Dissolver C-1 0-1 0

APPENDIX VII HEAT LOSSES IN THE BOILER AND WATER HEATING EQUIPMENT

No	Length of noninsulated pipelines, m	Pipe Diameter, m	Surface temperature, °C	Heat losses, kW
1	20	0 042	110	3 9
2	70	0 053	60	5 6
3	75	0 053	110	17 2
4	50	0 160	60	14 5
5	20	0 160	110	12 0
6	70	0 219	60	25 6
Heat losses associated with noninsulated pipes in the heating plant				**78 8**
Boiler Room				
1	30	0 036	100	4 2
1	30	0 042	100	5 0
1	80	0 053	75	10 7
1	30	0 089	75	6 5
2	6	0 089	100	1 9
Heat losses through noninsulated pipes in the boiler room				**28 3**

No	Length of insulated pipes, m	Pipe diameter, m	Surface tempe-rature, °C	Insulation efficiency, %	Heat losses, kW
Heating Plant					
1	80	0 114	110	30	27 2
2	30	0 160	110	30	12 3
3	20	0 219	110	30	10 0
Heat losses through insulated pipes					**49 5**

No	Boilers surface, m^2	Surface temperature, °C	Heat losses, kW
Boiler room			
1	12 6	65	6 7
2	12 6	65	6 7
3	12 6	65	6 7
4	14 9	65	8 0
Heat losses from boilers			**28 1**
TOTAL FOR THE HEATING PLANT			**128 3**
TOTAL FOR THE BOILER ROOM			**56 4**
GRAND TOTAL			**184 7**