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Particulate Sampling Report
Task 5 - Industrial Environmental Audit of Delivery Order 10
Environmental Policy and Technology Project

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Introduction

There were two objectives for the particulate sampling for the Novokutznesk Energy Audit. One objective being to provide training in particulate sampling for the Russian participants and the other was to obtain emissions data from the various sources for later comparison. The training proved to be the easier of the two objectives due to the knowledge and skill of the Russian team members. Obtaining emissions data was a much more challenging task.

The particulate sampling personnel were divided into two teams with one American member, two Russian members and one interpreter on each team. Testing was performed over a three week period. During the first two weeks of testing, both teams worked together in order to facilitate training and sample collection. The last week of testing was performed with each team at separate facilities.

Initially, there were six facilities identified for particulate testing and this was reduced to five after it was determined that particulate testing at the cement facility would not be practicable. The facilities tested were:

- Abashevskaya District Boiler House
- Zyryanovskaya District Boiler House
- Zapsib Thermal Electric Power Station (TEPS)
- Novokutznetsk Ice Cream Factory
- Novokutznetsk Poultry Plant

Each facility was unique in its arrangement and the problems it presented for particulate testing.

There were two sets of particulate sampling equipment for performing the particulate sampling. The equipment was manufactured by Apex Instruments and was of excellent quality and construction. Each team also had the use of a laptop computer which had a spreadsheet programmed in Microsoft Excel for calculating test sampling criteria. Since the equipment arrived in Novokutznetsk at the end the first week, there was little time for training of the Russians on how to assemble and operate the equipment before the scheduled testing began.

Every effort was made to try to perform the particulate sampling according to the protocols of US Environmental Protection Agency (EPA) methods 1-5; 40 CFR 60 Appendix A. At every site there were conditions which prohibited full conformance with these methods. The problems were due mainly to port location and sampling access. There were no locations more than four diameters downstream from flow disturbances and most were less than two. In order to try and obtain particulate samples at all of the facilities, samples were taken at whatever locations were made available to the testing teams.

Diluent gas analysis was obtained from Bacharach 300 Combustion Analyzers. The sampling was performed by the energy audit teams. The diluent analysis was not always taken simultaneously with the particulate sampling, but was obtained as close to the actual sampling run as practical.

After the completion of each test run, the probes were leak checked and moved to a room for recovering the samples. The probes were rinsed with acetone and brushed with a nylon bristle brush with the rinse collected in a sample container. Filters were placed in Petri dishes and sealed with tape. Samples were then taken to a lab at the Siberian Metallurgical Academy for gravimetric analysis.

Facility Descriptions

Abashevskaya District Boiler House

At this district boiler house testing was performed on the #1 boiler. The inlet and the outlet of the boiler cyclone were tested, but only the results at the inlet were reported. The outlet results were not properly recorded and therefore they could not be quantified. Because the security of the test equipment could only be assured if it was locked in a special room of the boiler house, it was necessary to assemble and disassemble the equipment daily. This limited the amount of testing which could be performed each day. Only one test run was completed at this facility.

The inlet had one port which was located approximately 3 meters downstream from the exit of the gas from the boiler. The port was at a bend in the duct less than 1 meter before the cyclone inlet and was centered vertical on the duct. The duct measurements were 1.980 meters by 0.965 meters. Because the access to the port was limited, a five foot long probe was used for the sampling.

The gas flow is split as it passes through the cyclone and exits from one of two ducts on each side of the cyclone. Two sample ports were placed in one of the two exits from the cyclone. The ports were located approximately 2 meters downstream from the exit of the cyclone and less than 0.5 meters before the conjunction of the two exit ducts. The gas stream then passes through the induced draft fan and exits the boiler house and travels through a duct into the plants main stack.

Each test location was sampled for one hour with the duct traversed at twelve points.

Zyryanovskaya District Boiler House

Testing was performed on the #4 boiler at the inlet and outlet of the boiler's cyclone. The inlet duct measured 2.6 meters by 0.86 meters and had three sample ports. Only the middle port was traversed due to lack of adequate access at the other two ports. The outlet had two ports which were both traversed. The outlet duct measured 1.18 meters by 0.90 meters and had two sample ports.

The boiler exhaust gas exits the top of the boiler horizontally for approximately two meters. The duct then turns 90 degrees vertically for approximately 3 meters and into the cyclone. The inlet sample ports were located in middle of the vertical section along the long axis.

The exhaust exits the cyclone through a single duct that travels horizontally approximately three meters. It then turns 90 degrees downward and into the induced draft fan. This vertical section

is approximately 4 meters in length and the ports were located 1.5 meters before the fan. Only one run of one hour was performed simultaneously on the inlet and outlet.

Zapsib TEPS

At this facility, the outlets of boilers number 6 and 11 were tested. The number 11 boiler produced 420 tons per hour of steam and was equipped with two parallel electrostatic precipitators. After the exhaust gas passes through the electrostatic precipitators, it converges at the induced draft fan. It then travels through a duct into the plants 250 meter tall stack.

A single sample port was located approximately two meters downstream from the fan. The duct measured 1.52 by 1.80 meters at the sample location with the port in the center of the short side. The duct was traverse at twelve points for five minutes at each traverse point. There were two runs of one hour each performed on the boiler.

The number 6 boiler produced 210 tons of steam per hour and was fueled by pulverized coal and blast furnace gas. There are two parallel venturi wet scrubbers on the unit followed by induced draft fans. The gases then exit the boiler building through two 2.5 by 3.0 meter horizontal brick ducts. The ducts join into a common duct that goes into a 60 meter stack.

A single sample port was located in one of the two horizontal ducts. The port was located 6 meters downstream from the exit, in the center of the duct. The port was traversed at 12 points for five minutes at each point. There were two runs of one hour each performed on the boiler.

Novokutznetsk Ice Cream Factory

The number three boiler was tested at this facility. The inlet and outlet were both tested with the inlet tested on the day after the outlet testing. The boiler exhaust exits the top of the boiler and travels horizontally out the side of the boiler house. The inlet had one port which was located in the center of the duct along the horizontal section. The dimensions of the duct at the inlet were 45.7 by 45.7 centimeters. The stack was traversed at twelve points for five minutes at each point. Two test runs of one hour duration were performed on the inlet site.

After the duct exited the boiler house, it went in the multi-cyclone. This consisted of four cyclone in parallel for removing particulate in the exhaust gas. The gas exited the multi-cyclone and traveled through a duct vertically for approximately 1.5 meters before turning horizontally and returns into the boiler house. Inside the boiler house the gas passes through the induced draft fan and then into a sub-surface duct back outside the boiler house and into the main stack.

The outlet sample port was located along the vertical duct immediately after the cyclone. There was one port in the middle of the short duct wall. The duct measured 81.3 by 40.6 centimeters, with the port approximately 1.5 meters downstream from the downward bend in the duct. The stack was traversed at twelve points for five minutes at each point. Two test runs of one hour duration were performed on the inlet site.

Novokutznetsk Poultry Plant

The number two boiler was tested at this facility. The inlet and outlet were both tested with the inlet tested on the day after the outlet testing. At both sites, duplicate test runs of one hour duration were performed.

At the inlet, the duct dimensions were 1.3 by 0.9 meters, with a single port in the center of the short wall. The port was traversed at twelve points during each run. Each traverse point was sampled for five minutes.

At the outlet, the duct dimensions were 1.4 by 0.9 meters, with a single port in the center of the stack wall. The port was traversed at twelve points during each run. Each traverse point was sampled for five minutes.

Test Schedule

Date	Location	Facility
4-May-95	Outlet - Boiler #1	Abashevskaya
6-May-95	Inlet - Boiler #4	Zyryanovskaya
6-May-95	Outlet - Boiler #4	Zyryanovskaya
11-May-95	Outlet - Boiler #11	Zapsib TEPS
12-May-95	Outlet - Boiler #6	Zapsib TEPS
13-May-95	Outlet - Boiler #6	Zapsib TEPS
16-May-95	Outlet - Boiler #3	Ice Cream Plant
17-May-95	Inlet - Boiler #3	Ice Cream Plant
17-May-95	Outlet - Boiler #4	Poultry Plant
18-May-95	Inlet - Boiler #4	Poultry Plant

Results Summary

	Particulate Loading g/SCM Inlet	Particulate Loading g/SCM Outlet	Removal Efficiency %
Abashevskaya	2.656	-	NA
Zyryanovskaya	4.193	1.339	68.1
Zapsib TEPS - 210	-	0.807	NA
Zapsib TEPS - 400	-	1.024	NA
City Refrigerator	2.073	1.190	42.6
Poultry Plant	6.532	1.138	82.6

	Emission Rate kg/hr Inlet	Emission Rate kg/hr Outlet
Abashevskaya	128.86	-
Zyryanovskaya	172.27	71.78
Zapsib TEPS - 210	-	164.57
Zapsib TEPS - 400	-	212.74
City Refrigerator	16.96	12.37
Poultry Plant	172.67	34.53

	Flow Rate ACMM Inlet	Flow Rate ACMM Outlet
Abashevskaya	2023	-
Zyryanovskaya	1068	1349
Zapsib TEPS - 210	-	4647

Zapsib TEPS - 400	-	5526
City Refrigerator	195	243
Poultry Plant	665	720

	Flow Rate SDCMM Inlet	Flow Rate SDCMM Outlet
Abashevskaya	809	-
Zyryanovskaya	685	893
Zapsib TEPS - 210	-	3401
Zapsib TEPS - 400	-	3439
City Refrigerator	137	172
Poultry Plant	441	509

Results Discussion

The test results reported, although less than ideal, give a relatively accurate representation of the emissions from each of the sites tested. Several of the test runs were not within +/- 10% of the 100% isokinetic sampling rate as required under EPA Method 5 protocol, however they were consistent with the other test runs.

The results show that the Zapsib TEPS Boiler #6 had the lowest particulate loading, 0.807 grams per Standard Dry Cubic Meter (g/sdcm). The next lowest particulate loading was the Zapsib TEPS Boiler #11 at 1.024 g/sdcm. Of the units tested, these units were the only ones not equipped with cyclones. Boiler #6 had a wet venturi scrubber and Boiler #11 had an electrostatic precipitator. These loadings were 29 % and 14 % respectively, lower than the lowest cyclone equipped boiler (Poultry Plant Boiler # 2, 1.138 gm/SDCM).

Recommendations

There are three recommendations for future testing at these facilities:

- Integrated Orsat samples with each test run.
- Performing three runs at each sampling site.
- Performing testing on each facilities main stack to obtain total emissions data for each facility.

The integrated Orsat samples would provide for more accurate flow and fuel usage data. By relying on data from the combustion gas analyzers, there is room for errors in the flow measurements if combustion conditions change during a test. An integrated Orsat sample would account for any changes in the exhaust gas stream during a test.

Performing three runs at each site will give better statistical representation of the actual emissions. The test schedule and lack of facility preparedness were the main factors for fewer than three runs being performed. Since all the sites have now been tested, it should be quite easy to get three runs in at each site.

Even though this recommendation may fall outside the scope of this projects task, the data will be invaluable for providing future data on the actual health impact from these facilities. Obtaining this data can probably be done with fairly minimal effort and cost. Although most of the facilities do not currently have sampling ports installed, there installation is now a familiar job.

PARTICULATE SPREADSHEETS

Particulate Spreadsheets

EPA Method 5 Calcualtions

STP = 20C, 760 mm Hg

Date	04-May-95	
Time	1426	
Run #	1	
Unit I.D.	Abashevskaya	Boiler #1 Inlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	7.6	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	12.5	%
3 Impinger Volume Gain, #1-#3	86.0	ml	21 Stack O2	8.2	%
4 Silica Weight Gain, #4	27.8	g	22 Stack CO	0.2	%
5 Total H2O Volume Gain	113.8	ml	23 Dry Molecular Weight	30.3	g/gmole
6 Average DGM Temperature	39.0	C	24 Stack Molecular Weight	29.4	g/gmole
7 Initial DGM Volume	2.7108	acm	25 Average Stack Gas Velocity	17.65	m/sec
8 Final DGM Volume	4.6594	acm	26 Stack Area	1.911	m2
9 Total DGM Volume	1.9486	acm	27 Actual Stack Flow Rate	2023	acmm
10 Total Sample Time	60	Θ	28 Standard Wet Stack Flow Rate	875	scmm
11 Barometric Pressure	747	mm Hg	29 Standard Dry Stack Flow Rate	809	sdcmm
12 Static Pressure	-76.0	mm Hg	30 Nozzle Diameter	9.3	mm
13 Stack Pressure	741	mm Hg	31 % Isokinetic Variation	106.7	%
14 Average Stack Temperature	388	C	32 Mass Of Particulate On Filter	0.4865	g
15 Average Orifice Pressure Drop	96.6	mm H2O	33 Mass Of Particulate In Probe	4.4044	g
16 Avg Sqrt Pitot Tube Pressure	3.4	mm H2O	34 Total Mass Of Particulate	4.8909	g
17 Vol Of H2O As Gas At STP	0.1522	scm	35 Stack Particualte Concentration	2.656	g/scm
18 Meter Volume At STP	1.8416	scm	36 Particulate Emission Rate	128.860	kg/hr

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EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	06-May-95
Time	1153
Run #	1
Unit I.D.	Zyryanovskaya Boiler #4 Inlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	4.6	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	6.5	%
3 Impinger Volume Gain, #1-#3	16.0	ml	21 Stack O2	14.5	%
4 Silica Weight Gain, #4	5.8	g	22 Stack CO	0.2	%
5 Total H2O Volume Gain	21.8	ml	23 Dry Molecular Weight	29.6	g/gmole
6 Average DGM Temperature	23.7	C	24 Stack Molecular Weight	29.1	g/gmole
7 Initial DGM Volume	4.7051	acm	25 Average Stack Gas Velocity	7.96	m/sec
8 Final DGM Volume	5.3171	acm	26 Stack Area	2.236	m2
9 Total DGM Volume	0.6120	acm	27 Actual Stack Flow Rate	1068	acmm
10 Total Sample Time	60	Θ	28 Standard Wet Stack Flow Rate	718	scmm
11 Barometric Pressure	747	mm Hg	29 Standard Dry Stack Flow Rate	685	sdcmm
12 Static Pressure	-50.8	mm H2O	30 Nozzle Diameter	6.3	mm
13 Stack Pressure	743	mm Hg	31 % Isokinetic Variation	105.3	%
14 Average Stack Temperature	154	C	32 Mass Of Particulate On Filter	0.5167	g
15 Average Orifice Pressure Drop	9.0	mm H2O	33 Mass Of Particulate In Probe	2.01215	g
16 Avg. Sqrt Pitot Tube Pressure	1.9	mm H2O	34 Total Mass Of Particulate	2.52885	g
17 Vol. Of H2O As Gas At STP	0.0291	scm	35 Stack Particulate Concentration	4.193	g/scm
18 Meter Volume At STP	0.6031	scm	36 Particulate Emission Rate	172.272	kg/hr

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EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	06-May-95
Time	1153
Run #	1
Unit I.D.	Zyryanovskaya Boiler #4 Outlet

Parameter	Value	Units	Parameter	Value	Units
Pitot Tube Constant	0.84	-	19 Stack Moisture Content	2.2	%
DGM Correction Factor	1.013	-	20 Stack CO2	6.5	%
Impinger Volume Gain, #1-#3	5.0	ml	21 Stack O2	14.5	%
Silica Weight Gain, #4	5.4	g	22 Stack CO	0.2	%
Total H2O Volume Gain	10.4	ml	23 Dry Molecular Weight	29.6	g/gmole
Average DGM Temperature	34.2	C	24 Stack Molecular Weight	29.4	g/gmole
Initial DGM Volume	1.9716	acm	25 Average Stack Gas Velocity	21.18	m/sec
Final DGM Volume	2.6350	acm	26 Stack Area	1.062	m2
Total DGM Volume	0.6634	acm	27 Actual Stack Flow Rate	1349	acmm
Total Sample Time	60	Θ	28 Standard Wet Stack Flow Rate	913	scmm
Barometric Pressure	747	mm Hg	29 Standard Dry Stack Flow Rate	893	sdcmm
Static Pressure	-173.0	mm H2O	30 Nozzle Diameter	4.2	mm
Stack Pressure	734	mm Hg	31 % Isokinetic Variation	90.3	%
Average Stack Temperature	146	C	32 Mass Of Particulate On Filter	0.23415	g
Average Orifice Pressure Drop	15.6	mm H2O	33 Mass Of Particulate In Probe	0.61185	g
Avg. Sqrt Pitot Tube Pressure	5.2	mm H2O	34 Total Mass Of Particulate	0.846	g
Vol. Of H2O As Gas At STP	0.0139	scm	35 Stack Particulate Concentration	1.339	g/scm
Meter Volume At STP	0.6318	scm	36 Particulate Emission Rate	71.778	kg/hr

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EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	12-May-95
Time	1233
Run #	1
Unit I.D.	Zapsib TEPS Boiler #6 Outlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	5.8	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	8.0	%
3 Impinger Volume Gain, #1-#3	42.0	ml	21 Stack O2	8.0	%
4 Silica Weight Gain, #4	4.0	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	46.0	ml	23 Dry Molecular Weight	29.6	g/gmole
6 Average DGM Temperature	22.7	C	24 Stack Molecular Weight	28.9	g/gmole
7 Initial DGM Volume	5.3407	acm	25 Average Stack Gas Velocity	4.70	m/sec
8 Final DGM Volume	6.3656	acm	26 Stack Area	7.500	m2
9 Total DGM Volume	1.0249	acm	27 Actual Stack Flow Rate	2116	acmm
10 Total Sample Time	60	min.	28 Standard Wet Stack Flow Rate	1682	scmm
11 Barometric Pressure	738	mm Hg	29 Standard Dry Stack Flow Rate	1585	sdcmm
12 Static Pressure	50.8	mm H2O	30 Nozzle Diameter	9.3	mm
13 Stack Pressure	742	mm Hg	31 % Isokinetic Variation	116.5	%
14 Average Stack Temperature	87	C	32 Mass Of Particulate On Filter	0.2541	g
15 Average Orifice Pressure Drop	31.5	mm H2O	33 Mass Of Particulate In Probe	0.5524	g
16 Avg. Sqrt Pitot Tube Pressure	1.2	mm H2O	34 Total Mass Of Particulate	0.8065	g
17 Vol. Of H2O As Gas At STP	0.0615	scm	35 Stack Particulate Concentration	0.804	g/scm
18 Meter Volume At STP	1.0034	scm	36 Particulate Emission Rate	76.428	kg/hr

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EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	13-May-95
Time	1020
Run #	2
Unit I.D.	Zapsib TEPS Boiler #6 Outlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	10.5	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	8.0	%
3 Impinger Volume Gain, #1-#3	84.0	ml	21 Stack O2	8.0	%
4 Silica Weight Gain, #4	8.8	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	92.8	ml	23 Dry Molecular Weight	29.6	g/gmole
6 Average DGM Temperature	19.0	C	24 Stack Molecular Weight	28.4	g/gmole
7 Initial DGM Volume	6.3922	acm	25 Average Stack Gas Velocity	5.62	m/sec
8 Final DGM Volume	7.4562	acm	26 Stack Area	7.500	m2
9 Total DGM Volume	1.0640	acm	27 Actual Stack Flow Rate	2531	acmm
10 Total Sample Time	60	min.	28 Standard Wet Stack Flow Rate	2029	scmm
11 Barometric Pressure	738	mm Hg	29 Standard Dry Stack Flow Rate	1816	sdcmm
12 Static Pressure	50.8	mm H2O	30 Nozzle Diameter	9.3	mm
13 Stack Pressure	742	mm Hg	31 % Isokinetic Variation	106.9	%
14 Average Stack Temperature	84	C	32 Mass Of Particulate On Filter	0.55515	g
15 Average Orifice Pressure Drop	31.0	mm H2O	33 Mass Of Particulate In Probe	0.29825	g
16 Avg. Sqrt Pitot Tube Pressure	1.5	mm H2O	34 Total Mass Of Particulate	0.8534	g
17 Vol. Of H2O As Gas At STP	0.1241	scm	35 Stack Particulate Concentration	0.809	g/scm
18 Meter Volume At STP	1.0548	scm	36 Particulate Emission Rate	88.146	kg/hr

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EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	11-May-95
Time	1247
Run #	1
Unit I.D.	Zapsib Boiler #11 Outlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	7.3	%
2 DGM Correction Factor	1.013	-	20 Stack CO2		%
3 Impinger Volume Gain, #1-#3	29.0	ml	21 Stack O2		%
4 Silica Weight Gain, #4	4.5	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	33.5	ml	23 Dry Molecular Weight	28.0	g/gmole
6 Average DGM Temperature	37.2	C	24 Stack Molecular Weight	27.3	g/gmole
7 Initial DGM Volume	2.7324	acm	25 Average Stack Gas Velocity	31.24	m/sec
8 Final DGM Volume	3.3410	acm	26 Stack Area	2.748	m2
9 Total DGM Volume	0.6086	acm	27 Actual Stack Flow Rate	5152	acmm
10 Total Sample Time	60	Θ	28 Standard Wet Stack Flow Rate	3521	scmm
11 Barometric Pressure	738	mm Hg	29 Standard Dry Stack Flow Rate	3263	sdcmm
12 Static Pressure	51.0	mm H2O	30 Nozzle Diameter	3.1	mm
13 Stack Pressure	742	mm Hg	31 % Isokinetic Variation	105.4	%
14 Average Stack Temperature	146	C	32 Mass Of Particulate On Filter	0.13615	g
15 Average Orifice Pressure Drop	8.7	mm H2O	33 Mass Of Particulate In Probe	0.36315	g
16 Avg. Sqrt Pitot Tube Pressure	7.4	mm H2O	34 Total Mass Of Particulate	0.4993	g
17 Vol. Of H2O As Gas At STP	0.0448	scm	35 Stack Particulate Concentration	0.881	g/scm
18 Meter Volume At STP	0.5667	scm	36 Particulate Emission Rate	172.476	kg/hr

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EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	11-May-95
Time	1247
Run #	2
Unit I.D.	Zapsib Boiler #11 Outlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	10.0	%
2 DGM Correction Factor	1.013	-	20 Stack CO2		%
3 Impinger Volume Gain, #1-#3	41.0	ml	21 Stack O2		%
4 Silica Weight Gain, #4	3.7	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	44.7	ml	23 Dry Molecular Weight	28.0	g/gmole
6 Average DGM Temperature	37.8	C	24 Stack Molecular Weight	27.0	g/gmole
7 Initial DGM Volume	3.3463	acm	25 Average Stack Gas Velocity	35.77	m/sec
8 Final DGM Volume	3.9262	acm	26 Stack Area	2.748	m2
9 Total DGM Volume	0.5799	acm	27 Actual Stack Flow Rate	5899	acmm
10 Total Sample Time	60	Θ	28 Standard Wet Stack Flow Rate	4015	scmm
11 Barometric Pressure	738	mm Hg	29 Standard Dry Stack Flow Rate	3614	sdcmm
12 Static Pressure	51.0	mm H2O	30 Nozzle Diameter	3.1	mm
13 Stack Pressure	742	mm Hg	31 % Isokinetic Variation	90.5	%
14 Average Stack Temperature	148	C	32 Mass Of Particulate On Filter	0.15415	g
15 Average Orifice Pressure Drop	11.3	mm H2O	33 Mass Of Particulate In Probe	0.4747	g
16 Avg. Sqrt Pitot Tube Pressure	8.4	mm H2O	34 Total Mass Of Particulate	0.62885	g
17 Vol. Of H2O As Gas At STP	0.0598	scm	35 Stack Particulate Concentration	1.167	g/scm
18 Meter Volume At STP	0.5390	scm	36 Particulate Emission Rate	253.007	kg/hr

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EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	17-May-95
Time	1305
Run #	1
Unit I.D.	City Refridgerator Boiler #3 Inlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	1.9	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	4.3	%
3 Impinger Volume Gain, #1-#3	3.0	ml	21 Stack O2	14.5	%
4 Silica Weight Gain, #4	6.1	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	9.1	ml	23 Dry Molecular Weight	29.3	g/gmole
6 Average DGM Temperature	41.3	C	24 Stack Molecular Weight	29.1	g/gmole
7 Initial DGM Volume	6.7822	acm	25 Average Stack Gas Velocity	15.18	m/sec
8 Final DGM Volume	7.4790	acm	26 Stack Area	0.209	m2
9 Total DGM Volume	0.6968	acm	27 Actual Stack Flow Rate	190	acmm
10 Total Sample Time	60	min.	28 Standard Wet Stack Flow Rate	138	scmm
11 Barometric Pressure	731	mm Hg	29 Standard Dry Stack Flow Rate	136	sdcmm
12 Static Pressure	-72.0	mm H2O	30 Nozzle Diameter	4.4	mm
13 Stack Pressure	726	mm Hg	31 % Isokinetic Variation	107.2	%
14 Average Stack Temperature	113	C	32 Mass Of Particulate On Filter	0.094	g
15 Average Orifice Pressure Drop	11.3	mm H2O	33 Mass Of Particulate In Probe	1.37825	g
16 Avg. Sqrt Pitot Tube Pressure	3.8	mm H2O	34 Total Mass Of Particulate	1.47225	g
17 Vol. Of H2O As Gas At STP	0.0122	scm	35 Stack Particulate Concentration	2.320	g/scm
18 Meter Volume At STP	0.6345	scm	36 Particulate Emission Rate	18.867	kg/hr

EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	17-May-95
Time	1527
Run #	2
Unit I.D.	City Refridgerator Boiler #3 Inlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	2.8	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	4.3	%
3 Impinger Volume Gain, #1-#3	9.0	ml	21 Stack O2	14.5	%
4 Silica Weight Gain, #4	3.8	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	12.8	ml	23 Dry Molecular Weight	29.3	g/gmole
6 Average DGM Temperature	42.8	C	24 Stack Molecular Weight	29.0	g/gmole
7 Initial DGM Volume	7.5300	acm	25 Average Stack Gas Velocity	15.98	m/sec
8 Final DGM Volume	8.1834	acm	26 Stack Area	0.209	m2
9 Total DGM Volume	0.6534	acm	27 Actual Stack Flow Rate	200	acmm
10 Total Sample Time	60	min.	28 Standard Wet Stack Flow Rate	141	scmm
11 Barometric Pressure	731	mm Hg	29 Standard Dry Stack Flow Rate	137	sdcmm
12 Static Pressure	-72.0	mm H2O	30 Nozzle Diameter	4.4	mm
13 Stack Pressure	726	mm Hg	31 % Isokinetic Variation	98.7	%
14 Average Stack Temperature	124	C	32 Mass Of Particulate On Filter	0.11365	g
15 Average Orifice Pressure Drop	11.6	mm H2O	33 Mass Of Particulate In Probe	0.96745	g
16 Avg. Sqrt Pitot Tube Pressure	4.0	mm H2O	34 Total Mass Of Particulate	1.0811	g
17 Vol. Of H2O As Gas At STP	0.0171	scm	35 Stack Particulate Concentration	1.826	g/scm
18 Meter Volume At STP	0.5922	scm	36 Particulate Emission Rate	15.057	kg/hr

EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	16-May-95
Time	1100
Run #	1
Unit I.D.	City Refridgerator Boiler #3 Outlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	1.4	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	4.3	%
3 Impinger Volume Gain, #1-#3	5.0	ml	21 Stack O2	14.6	%
4 Silica Weight Gain, #4	9.3	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	14.3	ml	23 Dry Molecular Weight	29.3	g/gmole
6 Average DGM Temperature	27.6	C	24 Stack Molecular Weight	29.1	g/gmole
7 Initial DGM Volume	3.9300	acm	25 Average Stack Gas Velocity	12.40	m/sec
8 Final DGM Volume	5.3162	acm	26 Stack Area	0.330	m2
9 Total DGM Volume	1.3862	acm	27 Actual Stack Flow Rate	246	acmm
10 Total Sample Time	60	min.	28 Standard Wet Stack Flow Rate	177	scmm
11 Barometric Pressure	740	mm Hg	29 Standard Dry Stack Flow Rate	175	sdcmm
12 Static Pressure	-135.0	mm H2O	30 Nozzle Diameter	7.6	mm
13 Stack Pressure	730	mm Hg	31 % Isokinetic Variation	93.1	%
14 Average Stack Temperature	118	C	32 Mass Of Particulate On Filter	0.36625	g
15 Average Orifice Pressure Drop	57.7	mm H2O	33 Mass Of Particulate In Probe	1.90485	g
16 Avg. Sqrt Pitot Tube Pressure	3.1	mm H2O	34 Total Mass Of Particulate	2.2711	g
17 Vol. Of H2O As Gas At STP	0.0191	scm	35 Stack Particulate Concentration	1.692	g/scm
18 Meter Volume At STP	1.3421	scm	36 Particulate Emission Rate	17.753	kg/hr

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EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	16-May-95
Time	1340
Run #	2
Unit I.D.	City Refridgerator Boiler #3 Outlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	1.5	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	4.3	%
3 Impinger Volume Gain, #1-#3	7.0	ml	21 Stack O2	14.6	%
4 Silica Weight Gain, #4	8.2	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	15.2	ml	23 Dry Molecular Weight	29.3	g/gmole
6 Average DGM Temperature	32.2	C	24 Stack Molecular Weight	29.1	g/gmole
7 Initial DGM Volume	5.3180	acm	25 Average Stack Gas Velocity	12.13	m/sec
8 Final DGM Volume	6.7108	acm	26 Stack Area	0.330	m2
9 Total DGM Volume	1.3928	acm	27 Actual Stack Flow Rate	240	acmm
10 Total Sample Time	60	min.	28 Standard Wet Stack Flow Rate	172	scmm
11 Barometric Pressure	740	mm Hg	29 Standard Dry Stack Flow Rate	169	sdcmm
12 Static Pressure	-135.0	mm H2O	30 Nozzle Diameter	7.6	mm
13 Stack Pressure	730	mm Hg	31 % Isokinetic Variation	95.2	%
14 Average Stack Temperature	122	C	32 Mass Of Particulate On Filter	0.2904	g
15 Average Orifice Pressure Drop	54.5	mm H2O	33 Mass Of Particulate In Probe	0.6234	g
16 Avg. Sqrt Pitot Tube Pressure	3.0	mm H2O	34 Total Mass Of Particulate	0.9138	g
17 Vol. Of H2O As Gas At STP	0.0203	scm	35 Stack Particulate Concentration	0.688	g/scm
18 Meter Volume At STP	1.3278	scm	36 Particulate Emission Rate	6.984	kg/hr

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EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	18-May-95
Time	1247
Run #	1
Unit I.D.	Poultry Plant Boiler #2 Inlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	5.6	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	10.0	%
3 Impinger Volume Gain, #1-#3	15.0	ml	21 Stack O2	8.0	%
4 Silica Weight Gain, #4	2.8	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	17.8	ml	23 Dry Molecular Weight	29.9	g/gmole
6 Average DGM Temperature	22.1	C	24 Stack Molecular Weight	29.3	g/gmole
7 Initial DGM Volume	10.9534	acm	25 Average Stack Gas Velocity	9.55	m/sec
8 Final DGM Volume	11.3660	acm	26 Stack Area	1.170	m2
9 Total DGM Volume	0.4126	acm	27 Actual Stack Flow Rate	670	acmm
10 Total Sample Time	60	min.	28 Standard Wet Stack Flow Rate	471	scmm
11 Barometric Pressure	731	mm Hg	29 Standard Dry Stack Flow Rate	445	sdcmm
12 Static Pressure	-60.0	mm H2O	30 Nozzle Diameter	4.6	mm
13 Stack Pressure	727	mm Hg	31 % Isokinetic Variation	105.5	%
14 Average Stack Temperature	126	C	32 Mass Of Particulate On Filter	0.14505	g
15 Average Orifice Pressure Drop	3.9	mm H2O	33 Mass Of Particulate In Probe	2.64455	g
16 Avg. Sqrt Pitot Tube Pressure	2.4	mm H2O	34 Total Mass Of Particulate	2.7896	g
17 Vol. Of H2O As Gas At STP	0.0238	scm	35 Stack Particulate Concentration	6.977	g/scm
18 Meter Volume At STP	0.3998	scm	36 Particulate Emission Rate	186.151	kg/hr

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EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	18-May-95
Time	1452
Run #	2
Unit I.D.	Poultry Plant Boiler #2 Inlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	5.8	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	10.0	%
3 Impinger Volume Gain, #1-#3	17.0	ml	21 Stack O2	8.0	%
4 Silica Weight Gain, #4	2.8	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	19.8	ml	23 Dry Molecular Weight	29.9	g/gmole
6 Average DGM Temperature	23.9	C	24 Stack Molecular Weight	29.2	g/gmole
7 Initial DGM Volume	11.3704	acm	25 Average Stack Gas Velocity	9.40	m/sec
8 Final DGM Volume	11.8176	acm	26 Stack Area	1.170	m2
9 Total DGM Volume	0.4472	acm	27 Actual Stack Flow Rate	660	acmm
10 Total Sample Time	60	min.	28 Standard Wet Stack Flow Rate	463	scmm
11 Barometric Pressure	731	mm Hg	29 Standard Dry Stack Flow Rate	436	sdcmm
12 Static Pressure	-60.0	mm H2O	30 Nozzle Diameter	4.6	mm
13 Stack Pressure	727	mm Hg	31 % Isokinetic Variation	115.9	%
14 Average Stack Temperature	127	C	32 Mass Of Particulate On Filter	0.43615	g
15 Average Orifice Pressure Drop	3.8	mm H2O	33 Mass Of Particulate In Probe	2.18505	g
16 Avg. Sqrt Pitot Tube Pressure	2.3	mm H2O	34 Total Mass Of Particulate	2.6212	g
17 Vol. Of H2O As Gas At STP	0.0265	scm	35 Stack Particulate Concentration	6.086	g/scm
18 Meter Volume At STP	0.4307	scm	36 Particulate Emission Rate	159.195	kg/hr

EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	17-May-95
Time	1108
Run #	2
Unit I.D.	Poultry Plant Boiler #2 Outlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	3.7	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	10.0	%
3 Impinger Volume Gain, #1-#3	22.0	ml	21 Stack O2	8.0	%
4 Silica Weight Gain, #4	4.4	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	26.4	ml	23 Dry Molecular Weight	29.9	g/gmole
6 Average DGM Temperature	15.6	C	24 Stack Molecular Weight	29.5	g/gmole
7 Initial DGM Volume	8.9103	acm	25 Average Stack Gas Velocity	9.56	m/sec
8 Final DGM Volume	9.8224	acm	26 Stack Area	1.260	m2
9 Total DGM Volume	0.9121	acm	27 Actual Stack Flow Rate	722	acmm
10 Total Sample Time	60	min.	28 Standard Wet Stack Flow Rate	537	scmm
11 Barometric Pressure	731	mm Hg	29 Standard Dry Stack Flow Rate	517	sdcmm
12 Static Pressure	-4.8	mm H2O	30 Nozzle Diameter	7.5	mm
13 Stack Pressure	731	mm Hg	31 % Isokinetic Variation	83.3	%
14 Average Stack Temperature	106	C	32 Mass Of Particulate On Filter	0.5881	g
15 Average Orifice Pressure Drop	36.9	mm H2O	33 Mass Of Particulate In Probe	0.07555	g
16 Avg. Sqrt Pitot Tube Pressure	2.5	mm H2O	34 Total Mass Of Particulate	0.66365	g
17 Vol. Of H2O As Gas At STP	0.0353	scm	35 Stack Particulate Concentration	0.732	g/scm
18 Meter Volume At STP	0.9068	scm	36 Particulate Emission Rate	22.717	kg/hr

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EPA Method 5 Calculations

STP = 20C, 760 mm Hg

Date	17-May-95
Time	1545
Run #	3
Unit I.D.	Poultry Plant Boiler #2 Outlet

Parameter	Value	Units	Parameter	Value	Units
1 Pitot Tube Constant	0.84	-	19 Stack Moisture Content	3.8	%
2 DGM Correction Factor	1.013	-	20 Stack CO2	10.0	%
3 Impinger Volume Gain, #1-#3	22.0	ml	21 Stack O2	8.0	%
4 Silica Weight Gain, #4	7.8	g	22 Stack CO	0.0	%
5 Total H2O Volume Gain	29.8	ml	23 Dry Molecular Weight	29.9	g/gmole
6 Average DGM Temperature	17.7	C	24 Stack Molecular Weight	29.5	g/gmole
7 Initial DGM Volume	9.8952	acm	25 Average Stack Gas Velocity	9.49	m/sec
8 Final DGM Volume	10.9291	acm	26 Stack Area	1.260	m2
9 Total DGM Volume	1.0339	acm	27 Actual Stack Flow Rate	717	acmm
10 Total Sample Time	60	min.	28 Standard Wet Stack Flow Rate	520	scmm
11 Barometric Pressure	731	mm Hg	29 Standard Dry Stack Flow Rate	500	sdcmm
12 Static Pressure	-4.8	mm H2O	30 Nozzle Diameter	7.5	mm
13 Stack Pressure	731	mm Hg	31 % Isokinetic Variation	97.0	%
14 Average Stack Temperature	116	C	32 Mass Of Particulate On Filter	0.77085	g
15 Average Orifice Pressure Drop	34.4	mm H2O	33 Mass Of Particulate In Probe	0.80485	g
16 Avg. Sqrt Pitot Tube Pressure	2.4	mm H2O	34 Total Mass Of Particulate	1.5757	g
17 Vol. Of H2O As Gas At STP	0.0398	scm	35 Stack Particulate Concentration	1.544	g/scm
18 Meter Volume At STP	1.0202	scm	36 Particulate Emission Rate	46.333	kg/hr

Equations

B_{ws} = moisture fraction (0-1.0 volume basis)
C_p = pitot tube coefficient (dimentionless)
D_n = nozzle diameter (mm)
ΔH = pressure difference of orifice meter (mm H_2O)
$\Delta H@$ = orifice meter coefficient (21.2 liters/min)
M = molecular weight (g/gmole)
M_d = molecular weight of dry stack gas (g/gmole)
M_s = molecular weight of wet stack gas (g/gmole)
P = absolute pressure (mm Hg a)
P_B = barometric pressure (mm Hg a)
ΔP = pressure difference of pitot tube (mm H_2O)
Q_m = flow rate through dry gas meter (liters/min)
T = absolute temperature (^oK)
Y_d = dry gas meter coefficient (dimentionless)

subscripts:

c = corrected
d = dry
m = meter
n = nozzle
p = pitot
s = stack
w = wet

Standard Temperature and Pressure (STP) = 293°K and 760 mm Hg

Meter Volume @ STP,

$$V_{mc} = 0.386 V_m \left(\frac{P_B + \frac{\Delta Havg}{13.6}}{Tm} \right) \qquad \text{(scm)}$$

Stack Moisture Content,

$$Bws = \frac{Vwc}{Vwc = Vmc} * (100) \qquad (\%)$$

Dry Molecular Weight,

$$Md = 0.44\ (\%CO_2) + 0.32(\%O_2) + 0.28(\%CO + \%\ N_2) \qquad \text{(g/gmole)}$$

Stack Molecular Weight,

$$Ms = 0.18\ (Bws) + \frac{Md}{100}(100 - Bws) \qquad \text{(g/gmole)}$$

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Equations (continued)

Average Stack Gas Velocity,

$$(Vs)_{avg} = 34.96\ C_p\ (\sqrt{\Delta P}\ )_{avg} \sqrt{\frac{Ts}{Ps * Ms}} \qquad \text{(m/sec)}$$

Stack Area,

$$A = \frac{\pi Ds^2}{4} \qquad (m^2)$$

where Ds = duct diameter (m), or

$$A = \text{Length (m)} * \text{Width (m)} \qquad (m^2)$$

Actual Stack Flow Rate,

$$Q_{sa} = 60 * (Vs)_{avg} * A \qquad \text{(acmm)}$$

Standard Wet Stack Flow Rate

$$Q_{sw} = 0.386 \left(\frac{Ps}{Ts}\right) Q_{sa} \qquad \text{(scmm)}$$

Standard Dry Stack Flow Rate

$$Q_{sd} = \left(\frac{100 - Bws}{100}\right) * Q_{sw} \qquad \text{(sdcmm)}$$

% Isokinetic Variation,

$$I = \frac{5.496 * 10^8 * Ts * Vmc}{\Theta * (Vs)avg * Ps * Dn^2 * (100 - Bws)} \qquad (\%)$$

Stack Particulate Concentration,

$$C_s = \frac{Mn}{Vmc} \qquad \text{(gm/scm)}$$

where: Mn = total mass of particulate collected (gm)

Particulate Mass Rate,

$$pmr = Cs * Qsd \qquad (kg/hr)$$

PREFACE
Audit Report
Communal Ziryanovskaya District Heating Boiler

This report is the result of an Industrial Environmental Audit carried out April 25 - May 26, 1995 at Ziryanovskaya District. The audit was made by a joint US - Russian team with the support of the United States Agency for International Development USAID) Environmental Policy and Technology (EPT) Project. There were 6 Americans consultants and 17 Russian specialists from the scientific research and design institutes, enterprises and environmental regulatory agencies on the team.

This audit was performed as a part of a training program for the Russian team members on conducting industrial environmental audits.

Factual information provided by Ziryanovskaya District formed the basis for evaluating environmental, energy efficiency and worker health and safety conditions at the facility. Opinions formed from this information are the authors and do not necessarily reflect the views of USAID or EPT.....

AUDIT REPORT
Communal Ziryanovskaya District Heating Boiler

Description of the overall Industrial Audit Program

There is an immediate need for rapid improvement in industrial energy efficiency due to a variety of poor energy utilization practices and lack of proper maintenance of energy systems. Related to the low energy efficiency of facilities is a higher emission of particulate to the atmosphere from the coal-fired boilers. Higher than design coal burning rates subsequently overload the flue gas clean-up equipment which worsens the emission problem. Emission penalties do not alone provide sufficient economic incentive to proceed with projects to reduce emissions. Energy efficiency improvements are cost-effective within the current energy economy and can provide economic incentives that support the concern to clean-up the environment. These energy efficiency improvements will also result in a improvement in air quality by reducing emissions at the source.

Increases in energy prices to equivalent world prices have put additional pressures on industrial firms to conserve energy. Changes within the economic system (energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Along with the industrial audit program to demonstrate the effectiveness of energy efficiency improvements, the overall EPT program provided training on energy efficiency audit practices, use of energy performance measurement equipment and evaluation of energy conservation opportunities.

The Industrial Audit Project is comprised on four distinct tasks:

1. Industrial plant screening
2. Industrial plant energy audit
3. Purchase, ship, and receive equipment to implement audit recommendations
4. Implementation and monitoring

Screening of fifteen industrial plants and communal boilers, the cement plant and the ZapSib Combined Heat and Power Plant was accomplished to provide a basis for selecting the plants to be audited. Criteria used in this selection included;

1. Opportunity for energy savings (with a focus on emission reduction),

2. Reasonable payback period in Ruble energy economy (also calculated in world prices),

3. Potential replicability of energy saving options in similar plants or systems,

4. Future viability of the plant in the changing economy and operation of the district

heating system,

5. Size of the plant,

6. Ownership,

7. Location and impact on local ambient air quality and

8. Other activities such as joint ventures or other bi-lateral aid projects.

The cement plant audit is given due to it's significant impact on the local environment of Novokuznetsk. The additional plants selected for the audit phase are:

1. Abashevkaya Communal Boiler,
2. Ziryanovskaya Communal Boiler,
3. Selected boilers at the ZapSib Combine Heat and Power Plant,
4. The ice cream and cold storage plant, and
5. The poultry processing plant.

An energy audit report has been prepared for each of the six facilities audited and a seventh report summarizing the results of the stack particulate sampling accomplished at each of the five facilities other than the cement plant. The seven reports represent the complete reporting of the energy/environmental audit activities conducted in Novokuznetsk, Russia during the period of April 25 - May 26, 1995.

The energy audit activity, described in detail in each facility report, consisted of a determination of the overall energy efficiency of the plant to identify no/low cost equipment opportunities with short term payback. An assessment was made of the technical and management capabilities and capital investment decision-making process regarding energy conservation applications. At the completion of the energy audit, equipment specifications and other documents required for procurement of U.S. and NIS manufactured equipment or materials will be prepared. Particulate sampling of the stack gasses of the five facilities with coal-fired boiler systems was conducted to determine the current stack gas loading of particulates and particulate emission rates.

Equipment specified in the energy audit will be procured, cleared through customs, and delivered to the plant. Purchased authorization requests will be prepared for approval by USAID/Washington and USAID/Moscow. Requests for Quotes or Tenders as well as purchase orders when suppliers are selected will be issued from the EPT/Moscow office to support the interest in identifying the maximum ability for these demonstration projects to be replicated by other facilities in Novokuznetsk. Equipment will be shipped to the audited sites in Novokuznetsk and technical support will be provided by the Russian team members working on these audits.

In the implementation phase, requirements for installation of the material will be identified. Where possible, this will be done by the personnel of each facility, or alternatively, by

Novokuznetsk contractors. Following completion of the installation, an assessment will be made of the effectiveness of the energy conservation application and the effect on emission reduction.

Results of the audit conducted in the Ziryanovskaya Communal Boiler House are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit.

Section 1

Executive Summary

The industrial sector in Novokuznetsk is very well developed, with many large and heavy industries. In addition, there are 160 boiler houses at medium size industries and district heating systems that consume a large percentage of the regional energy use and are major contributors to the particulate emissions within the residential districts of the city. The facilities chosen for the EPT Industrial Audit project are representative of many companies or similar facilities within the city, making them ideal targets for the industrial energy audit work since potential replication is very high. Many of these medium size plants are very viable, but have not yet implemented energy conservation activities. Changes within the system (increased energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Parallel emission reductions can be expected with increases in energy efficiency

Results of the audit conducted in the Ziryanovskaya Communal Boiler House are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit.

The boiler plant supplies hot water for space heating and domestic hot water for the residential community of employees of the Ugolnaya Company coal mines in the Ziryanovskaya District. The residential community currently has a population of 40,000 people living in 12,000 apartments; the apartments are the typical high rise apartment blocks common.throughout Russia. Additional apartment units are under construction to provide additional and upgraded living space. It is anticipated in 30 percent increase in boiler capacity will be needed to service the new apartment space if the existing boilers continue to operate at their current low capacity levels. If the existing boilers can be made to operate at their rated capacities, no new boiler facilities would be required.

The coal mine company currently owns and operates the boiler plant, but it is anticipated that the plant will be turned over to the City Administration in the foreseeable future. The supply of hot water for space heating and domestic hot water for the residential complex is the only purpose of the boiler facility.

The boiler plant has six coal fired KBTC-20 boilers rated at 20 Goal per hour each. However, due to various operational difficulties, the actual capacities of each boiler is limited to about 12 Gcal per hour. Because of the low operating capacities of the boilers all boiler capacity is needed to meet demand during winter months.

Four boilers have individual cyclone stack gas clean-up systems and two have wet scrubber systems. Notwithstanding the existing attempts to clean the stack gases, the stacks continuously emit dense black smoke. Visual estimates of the smoke quality rated the smoke as having full opacity or a Ringleman Number of 5, a rating for maximum opacity.

The boilers operate at a maximum of approximately 60 percent of the design capacities and less than design combustion efficiency (estimated 50-60 percent combustion efficiency) and release excessive particles to the atmosphere. The audit team identified the following boiler items that are the primary causes for these deficiencies:

- Use of coal outside of the boiler design specifications; the coal used contains excessive fine particles that are not burned in the combustion zone
- Missing particle recirculation fan at the end of the boiler; the fan was part of the original boiler design
- Low air flow from the combustion air fan
- No controls or dampers for adjusting air volume for different coal load rates; the boiler operator adjusts boiler power by simply increasing or decreasing coal feed rate

In addition, excessive heat was often sent to the residential units due to the lack of control over the water temperatures; most of the excess heat sent to the residential units was wasted by over heating and higher distribution heat losses.

Because on the observations and analyses of the operations at the boiler house, the Audit Team developed a series of recommendations and the recommendations are summarized in the following Table.

Short Term Energy Conservation Opportunities

ECO	Energy Savings/Yr	Value Cost of Savings $ (3)	Cost of ECO	Payback Years
1. Repair boiler to original design conditions	3% of Coal or 2183 t	37,584	10,000(4)	1(1)
2. Repair/replace pipe insulation	5% of coal or 3639 t			1(1)
3. Adjust air and water flows in boiler house	5% of elect or 139800kwh	1,622		1(1)
4. Automatic control system on one boiler	5800 t coal	100,000	50,000	0.5(2)

(1) Based on experience with similar boiler systems in the CIS
(2) Savings are for one boiler, see Appendix F
(3) Coal @ $17,20/tonne, electricity @ $0.0116/kwh
(4) Portable tests equipment at $10,000 with EPT funds. Funds for repair and maintenance to be provided by plant

The ECO 1, 2, 3 & 4 will be 11,622 t/year of coal (11,622/72,700 = 16% of coal used in 1994) and 139.8 mwh/year of electricity (139 t/2796 = 5% of the electricity used in 1995).

Funding Recommendations

EPT shall provide a total of $65,000 to help fund ECO's 1, 2, 3 & 4. Additional funds to complete the ECO's shall be provided by the owner.

Section 2

Plant Description

Key Plant Data

NAME OF FACILITY: Ziryanovskaya District Heating Boiler, owned and operated by Ziryanovskaya Mine, Kuznetskugol Company

KEY CONTACTS: Chief of BoilerHouse:Tarasenko Igor Alexandrovitch
Tel. 38-82-40
General Mechanician: Vladimir V. Ryssatov
Tel. 31-29-72

HEAD OFFICE LOCATION: Novokuznetsk
654025
Skorostnaya, 1

DATE OF PLANT COMMISSIONING:

NUMBER OF EMPLOYEES: 92

General

The boiler plant supplies hot water for space heating and domestic hot water for the residential community of employees of the Ugolnaya Company coal mines in the Ziryanovskaya District. The residential community currently has a population of 40,000 people living in 12,000 apartments; the apartments are the typical high rise apartment blocks common throughout Russia. Additional apartment units are under construction to provide additional and upgraded living space. It is anticipated a 30 percent increase in boiler capacity will be needed to service the new apartment space if the existing boilers continue to operate at their current low capacity levels. If the existing boilers can be made to operate at their rated capacities, no new boiler facilities would be required.

The coal mine company currently owns and operates the boiler plant, but it is anticipated that the plant will be turned over to the City Administration the foreseeable future. The distribution pipes from the boiler plant to the apartment units are owned by the residential administration. The apartments are about one half to one kilometer from the boiler house.

The supply of hot water for space heating and domestic hot water for the residential complex is the only purpose of the boiler facility.

The boiler plant has six coal fired KBTC-20 boilers rated at 20 Gcal per hour each. However, due to various operational difficulties, the actual capacities of each boiler is limited to about 12 Gcal per hour. Theboilers are operated 24 hours per day, 350 days per year (there is an annual 2-

week shutdown for maintenance). Because of the low operating capacities of the boilers all boiler capacity is needed to meet demand during winter months. In summer months, space heating is turned off and the boilers are used only to provide domestic hot water.

The coal boiler fuel is supplied by the Novokuznetskaya mines. The identified coal grade is "gas coal" having he following specification:

-	Carbon	59.5 percent
-	Hydrogen	4.0 percent
-	Nitrogen	1.06 percent
-	Sulfur	0.5 percent
-	Water	14 percent
-	Oxygen	11.4 percent
-	Ash	9.5 percent
-	Volatiles	40 percent
-	Heat value	5700 Kcal/Kg
-	Size grade	40mm with 60 percent fines (fine powder)

However in practice, the coal does not meet the above specification primarily in the ash content and consequently, in heat value. Typically, the coal has ash contents of 15-30 percent and the nominal heat value 5660 Kcal/kg is used for calculation of boiler efficiency. As of May, 1995, the price of the gas coal was 86,000 R/tonne. The boilers were designed to burn a coal without fines (graded -40 to +5 mm), that sells for about 172,000 R/tonne, a price considered uneconomical for heat production. However, reduction in emissions may be a reason to use this coal.

Four boilers have individual cyclone stack gas clean-up systems and two have wet scrubber systems. Notwithstanding the existing attempts to clean the stack gases, the stacks continuously emit dense black smoke. Visual estimates of the smoke quality rated the smoke as having full opacity or a Ringleman Number of 5, a rating for maximum opacity.

Hot water is supplied to the apartment complex via two pipe loops consisting of a supply and return lines without intermediate heat exchangers. Water that passes through the boilers goes directly to the apartments and a portion is used for domestic hot water. Consequently, the boiler feed water is taken from the municipal water system and chemical water treatment of the boiler water is limited to filtration through an activated coal bed.

Operational Status

Boilers

The boilers operate at a maximum of approximately 60 percent of the design capacities and less than design combustion efficiency (estimated 50-60 percent combustion efficiency) and

release excessive particles to the atmosphere. The audit team identified the following boiler items that are the primary causes for these deficiencies:

- Use of coal outside of the boiler design specifications; the coal used contains excessive fine particles that are not burned in the combustion zone
- Missing particle recirculation fan at the end of the boiler; the fan was part of the original boiler design
- Low air flow from the combustion air fan
- No controls or dampers for adjusting air volume for different coal load rates; the boiler operator adjusts boiler power by simply increasing or decreasing coal feed rate

In addition, excessive heat was often sent to the residential units due to the lack of control over the water temperatures; most of the excess heat sent to the residential units was wasted by over heating and higher distribution heat losses.

Stack gas Cleaning

Cyclone stack gas cleaning devices are in service on four of the boilers; the cyclones have a design efficiency of 85 percent. However, due to the use of a lower quality of coal (high fine particle and ash contents) and the resulting changes in boiler operation, it is estimated that the cyclones are operating at no more than 65 percent efficiency.

Two boilers have wet scrubbers installed having a design efficiency of 97 percent. However, due to problems with the operation of the waste water clean-up system, insufficient water is used in the scrubbers which renders them ineffective. The waste water system is currently under reconstruction and should be in operation this Summer. When the wet scrubbers are again operational, the respective boilers will be the primary boilers which should result in a significant reduction of stack emissions.

Water Distribution

Water distribution pumps and piping are in reasonably good operating condition. The chief of the boiler house estimated a water loss of about 10 percent due to leaks in the boiler house and the distribution piping. Attempts to repair the leaks are made during the annual maintenance shut down during the summer. The thermal insulation on the distribution lines appeared adequate and in good physical condition.

Residential End Use

Visual inspection of the residential apartment units indicated the potential for substantial reduction in energy demand by application of such measures as weather stripping of windows and doors, insulation of attics and sidewalls and use of thermostatic controls within the living

Section 3

Plant Energy/Environment Profile

Plant Thermal Diagram

See Appendix C for floor plans and the mass flow diagrams.

Energy Consumption Profile

Coal

"Gas Coal" grade coal is used to fire the six 20 Gcal/hour (design)boilers. Annual coal consumption for 1994 is given in Table 1 and Figure 1 (attached) for coal; the values provide a nominal base line for measurement of the effectiveness of energy conservation measures that may be implemented in the following years

Electricity

Electrical consumption at the boiler plant is not metered, but rather aggregated with other facilities of the parent coal company. Annual electrical energy and demand values were estimated. Electrical power usage is dominated by the large water pumps (for distribution and make-up water) and the fans to supply combustion air and stack draft.

Supply air fans, 6 units	75 KW/unit
Induced air fans, 6 units	200KW/unit
Water pumps, distribution, 4 units	400 KW/unit
Water pumps, distribution, 4 units	200 KW/unit
Water pump, make-up, 1 unit	200 KW/unit
Estimated annual energy consumption,1994	2796 MWH
Estimated maximum demand, 1994	1094 KW
Estimated connected demand, 1994	1628 KW

Energy Costs For 1994:

Gas Coal:	72,780 tonnes @ 86,000 R/tonne =	6259 million R
Electricity:	2796 MWH @ 58 R/KWH =	162 million R

Environmental Emissions and Penalties.

Section 4

Audit Approach and Data Summary

Energy Audit

Audit of portions of the boiler house at Ziyanovskaya were made the week of 1 May, 1995. The audit team members were B. Anderson, B Dries, L. Kayakova, and T. Lylchuk.

Combustion tests were made on boilers 3, 4, and 6. The combustion analyzer was a Bachrach set to heavy oil fuel as a coal setting was not available. The readings for efficiency, CO2, and excess air are not valid, other readings are valid. (see Appendix A)

Stack gas analyses. Typical readings of the stack gases from the boilers are listed below..

Boiler No.	CO	Oxygen	NOX	SO2	Stack Temp
3	.34%	12%	100ppm	500ppm	308C
4	.14%	14.5%	112ppm	425ppm	182C
6	.125%	12.7%	190ppm	151ppm	243C

Based on the stack gas analyses, it was determined that:

- There was incomplete combustion of the fuel (high CO content) inspite of excessive amounts of oxygen,
- The coal feed rate was variable, in terms of 10-15 minutes, as indicated by wide variations in CO concentrations and stack gas temperatures,
- The NOx and SOx concentrations are well within acceptable levels.

Calculation of combustion efficiency for boiler no. 4 (see Appendix E) was made and showed a combustion efficiency of about 75 - 80 percent.

Tests were also run on boiler no. 4 to measure air flows, air pressure and temperature. The boiler has a forced draft fan an induced draft fan. The over fire fan and fine ash return fans shown on the drawing (see Appendix B dwg. no. 1171-1/1-A-004) were not installed.

Summary Results (see Appendix C)

Fan No.	Service	Flow M3/hr.		Pressure Kg/M2	
		Design	Measured	Design	Measured
1	Combustion Air	41000	18900 (-64%)(2)	150	10 (-94%)

2	Induced Draft	84000 @ 182C,inlet	49500 (-41%)(2) drop 397, ? 193.5 150(-23%) 77520 @ 146C (-9%) (1)

(1). Measured by S. Chestnut pitot tube.

(2). Measured by W. Dries hot wire anemometer value low as maximum temp. of instrument is 55C, readings at 182C

(3). Air ducts to underside of stoker, five ducts (measured press. 7,6,4,3,3) 152, 4.6avg.(-97%)

Site Observations

The boilers are controlled manually by noting water exit temperature and pressures. All other pressure and temperature indicators and controls are missing. The operator increases or decreases the fuel supply but the air flows are not changed, all duct dampers and air flow vanes in the fans are set fully open. Boiler control is an intuitive art-form, relying on the experience and attentiveness of the individual operator.

Because of the lack of adequate control of the boilers, supply water temperatures vary on an hourly basis from the boiler regime schedule (the schedule is based on outside air temperature) and in many cases results in overheating of the residential units (see Figure 2). Review of boiler house logs, overheating for 24-hour periods ranged to 35-95 percent during moderate heating months, and somewhat less during cold winter months; during cold periods, it was common to have both over and under heating during a 24-hour period. Energy from over heated supply water is dissipated in residential units by opening windows and by increased distribution losses. Overheating also contributes to the generation of unnecessary particulate emissions from the boiler stacks.

- The air leaks in the duct work are extensive. Heat leaks due to no or damaged insulation are also present.
- Water leaks in the system also are wasting energy.
- Fan operation at less than design conditions results in low efficiencies and excessive electricity use.
- It is impossible to operate the boilers with proper efficiency and particle emission with the present conditions.
- Based on measured fuel and heat output boiler no. 4 has an estimated thermal efficiency of 47 percent. (see Appendix D)

Section 5

Energy Efficiency/Enviornmental Recommendations

General Conclusions:

- The boiler plant is not operating at design conditions due to poor coal quality, lack of maintenance, and missing and broken equipment and controls.
- The boiler plant lacks necessary instruments and controls to efficiently manage the hot water supply to the residential units.
- The plant does not have an adequate budget, technical staff or management to correct the conditions.

Energy Efficiency Recommendations

1. Repair or replace air systems to achieve design conditions.
2. Add ash return fan as in original design outlet pressure 630kg/m2.
3. Add over fire fan as in original design outlet pressure 50kg/m2
4. Repair air and water leaks.
5. Install insulation to reduce heat loss.
6. Add a automatic control system to the boilers.
7. Clean heat transfer surfaces on a regular basis.
8. Clean up the boiler house.
9. Provide outside air to the boiler house to give people clean air.
10. Check pump flows and heads and adjust for maximum efficiency.
11. Recover heat from the stack gas to preheat water and/or air.
12. Install recording temperature, pressure and flow sensors on each boiler to assist the boiler operators in boiler control.

Short Term Energy Conservation Opportunities

- Items numbers 1,2,3,4,5,7,8,9,10 and 11 should be done by the local boilerhouse management. Portable test equipment will be furnished by EPT (see appendix G). The payback will be less than one year. Necessary recording sensors should be furnished as part of item 6.
- Items 6 and 12 should be done only after items 1,2,3,4,5,7,8,and10 are completed.

The payback for the controls will be less than one year. (See appendix F for details)

Long Term ECO

- Item 12 recover heat from stack gas. This can only be done after the particles in the gas are reduced to provide clean stack gases.

Appendix A
Combustion Tests

APPENDIX A

Ziryanovskaya 3 May 96 SH-3
WEO

Boiler No 3
Stack 305 - 310C
CO 3800 - 3800 ppm
O_2 11.6 - 12.4%
NO_2 100 ppm
SO_2 500 "
Inlet 31 out 71C

Boiler No 4 2 May 95
Temp 181 - 185C
O_2 14.5%
CO 1000 - 2000 ppm
NO 110 - 115 ppm
SO_2 350 - 500 ppm
Inlet water 41 out 65C

3500/2 = 1750 = .2%
115 ppm
425 ppm

Boiler No 6 1/2 hr
Temp 215 - 270
O_2 12.1 - 13.3%) avg 12.7
CO 500 - 2000 ppm) avg 1250 ppm
NO 190 - 200 ppm
SO_2 88 - 214 ppm
Inlet water 36 outlet 70F

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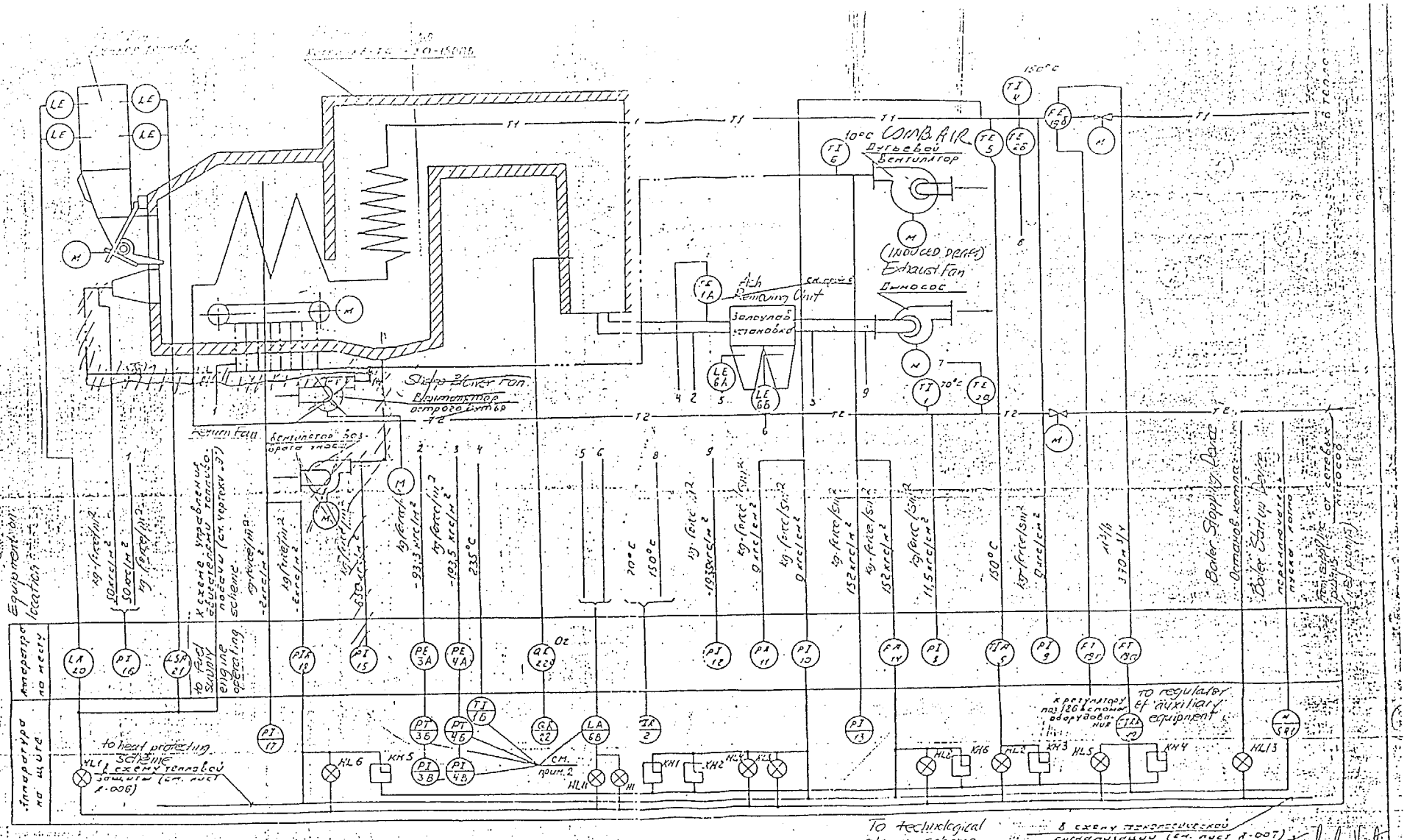
Appendix B
Boiler Control Drawing, No. 1171-1/1-A-004



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Appendix C
Air and Gas Tests

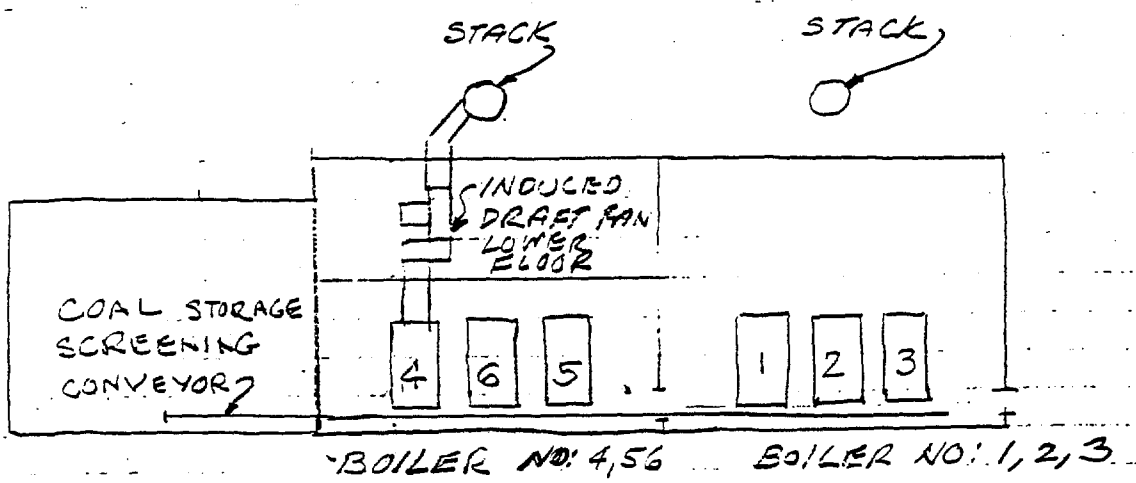

FIG. No. 1 ZIRYANOVSKAYA BOILER HOUSE UPPER FLOOR PLAN SCALE: APPROX: 1CM = 1000CM, 1" ≡ 100FT

Eiryanovskaya

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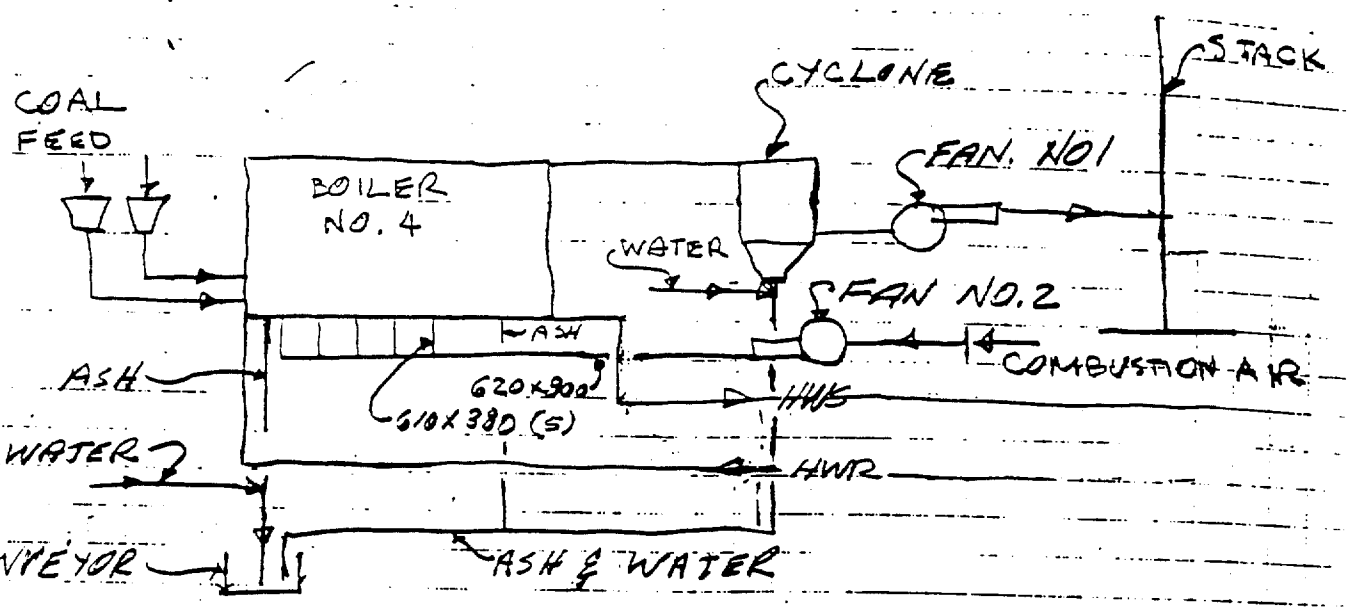


EIRYANOVSKAYA BOILER NO. 4 SCHEMATIC DIAGRAM
NO SCALE

MODEL NO.	FAN NO.	CFM m³/s	PRESSURE (H₂O) INLET	OUTLET	WATT	outlet Dimensions	RPM	Ti
BΔH 15	1	5.26	0	98Pa 2.8mm	75KW		1000	10
		18,936/h	0	10 Kg/m²		550×900 (79%)		
Design	1	41,000/h		ΔP = 150 Kg/m²		690×878		
BΔH 19	2	9.04		130mm			1000	
MIM		9.46		1274Pa	130Kg/m² (-5.12in H₂O)	922×1040 (80%)		
Design		84,000		ΔP = 3970 Kg/m²		740×1040		

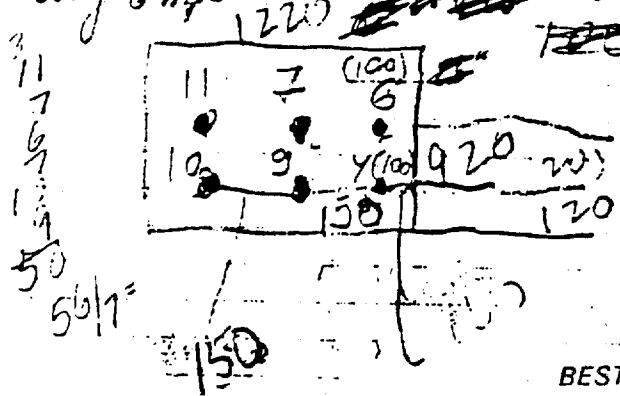
MODEL NO.	PUMP NO.	GPM	HEAD INLET	OUTLET	HP KW	VOLTS	AMPS	EFF	RPM	P
1250-125	MOTOR C-3	125 m³/h	2.65 Kg	11.5 Kg	500KW	6000V, 3φ	58	94.7	1500	0.9
"	125 67	440KW		2.5 Kg/m²	12.5 Kg/m²					
"	125	630KW								
UH 400-105		400 m³/h	105m		200KW				1500	

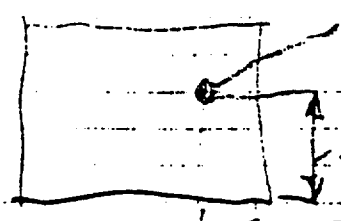
1 @ 760 m³/h
1 @ 980 "
Circulating (250-125a) 2 @ 1250 m³/h
(UH 400-105) 2 total makeup

Induced draft fan No. 2

avg 8 m/s

m² = 1.22 × .92 = 1.13





V/s = 9.04 m³/sec at 80F
at 360F, 182°C
Vol = .0737 / .0485 = 1.52
× 9.04 m³/sec =

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Appendix D
Calculation of Thermal Efficiency

Flow to housing Boiler House section 1

Pump model 1250-125a (impeller dia 570 mm)

head on pump 10 kg/m² design, 11.50 + 2.65 = 8.85 = 88.5 meter

Curve flow 1420 m³/h

Boiler No. 4 flow 250 m³/hr @ 2.5 atm design

Estimated flow at 5 atm drop

$$\left(\frac{Q_1}{Q_2}\right)^2 = \frac{P_1}{P_2} \qquad Q_2 = Q_1\sqrt{\frac{P_2}{P_1}} = 250\sqrt{2}$$

$$Q_2 = 352.5 \cong 353 \text{ m}^3/\text{hr}$$

Flow thru pump 3 x 353 = 1059 m³/h, head 100m, efficiency 77%, 420KW. pump, motor (94.7 eff) 443 KW.

Design capacity 250 m³/h x ΔT(150-70) = 20 Gcal/h

Heat out at 1430 2 May 95 Boiler No. 4 flow at 353 m³/h

Heat = 353 m³/h x (64-36) = 9.884 Gcal/h

~~= 473 x 264.2 x 9.35 x 1 x (28 x 1.8) x 10⁵ = 5246 x 10⁶ Btu/h~~

~~1.249.666~~

~~Heat cal/hr = 252 x 5246 x 10⁶ = 13.22 Gcal/hr~~

If flow is 354 m³/h then 354/473 x 13.22 = 9.89 M "

3.33 T/h x 1000 Kg/T x 5450 Kcal/Kg = 21.146 Gcal/hr

Thermal efficiency = 9.89/21.146 = 46.7%

Thermal efficiency on lower heat value of 4724 Kcal/Kg 53.5%

Above calculations disregard heat loss to stack, radiation, convection, unburned in ash and up the stack

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Appendix E
Calculation of Combustion Efficiency

Combustion Calculations: MSL Pacis Boiler 4 2 May 95

Conditions Given:

Fuel: F3 Coal volatile 40% a 45% 14mm, 65% 0-5mm

Fuel Analysis % Mol/100 b

C	57.50	C = 59.5/12 = 4.96
H_2	4.0	C ash 2.38/12 = .20
S	.5	C (CO_2+CO) = 4.76
O_2	11.0	
N_2	1.6	
H_2O	14.0	
ash	9.5	

CO_2= , O_2=14.5, CO=.140 N_2= c

% excess air (1) TA = 315% d

NO = 112.5 ppm, SO_2 = 425 ppm e

	Fuel	lb	Mol	O_2	CO_2 + SO_2	O_2	N_2	H_2O	CO
1	C to CO_2	57.8	4.91	4.81	4.81	–	–	–	–
2	C to CO	.14	.012	.006	–	–	–	–	.012
3	CO to CO_2	–	–	–	–	–	–	–	–
4	ash C	2.38	.20	–	–	–	–	–	–
5	H_2	4	2.0	1.0	–	–	–	2.0	
6	S	.5	.016	.016	–	–	–	–	–
7	O_2 deduct	11	.34	-.34	–	–	–	–	–
8	N_2	1.6	.057	0	–	–	.057	–	–
9	H_2O	–	–	–	–				–
10	H_2O	14	.78	–	–	–	–	.78	
11	Ash	9.5	–	–	–	–	–	–	–
12	SUM	100.9	5.22	5.49				2.78	.012

13		5.49		
14	O_2 Ex = 315·10 / 100 (2.5)	11.80	11.8	
15.	O_2 total	16.29		
16	N_2 3.76 x O_2 =	61.25	61.25	
17	dry air	77.54		
18		1.64		1.64
19	Air wet	78.18	4.81	11.8	61.25	4.42	.012
20	Flue gas		4.81,	11.8,	61.3	4.42,	.012

(1) calculated based on O_2 & CO

Fuel heat: 5450 kcal/kg, 7551 kcal/kg f

7550 000/252 x 2.2 = 13,618 Btu/lb g

9.5 x .20/90 = 2.38% h

Flue gas temp 182C i

Ambient 30C j

Mol of Fuel Gas Wet 82.3, Dry 77.9 k

		CO_2+SO_2	O_2	N_2	H_2O	CO	Total
22	ΔT = 273F						
23		9.–9.5	10.0	7.0	8.12	7	
24	Heat in flue gas dry	11,818	32214,	117,048,	97,98,	23	170901
25	1.04 x 3.02 x 273					3635	
26	2 + 1.4 x 3 x 273					7537	
27	2 + 1.4 x 1040 x 1.64					57420	
						68592	68,420
28	Wet flue gas						249321
29	2.38 x 13,618						32410
30	.012 x 12 x 10,200						1468
31	Total flue gas + unburned (not including unburned in stack)						283199
32	100 x 13618						1,361,800

Stack loss 20.7%

Unburned up stack

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Appendix F
Calculation of Payback and Energy Saved with Controls for Boiler No. 4

Appendix F
Calculation of Payback and Energy Saved with Controls for Boiler No. 4

Installation of automatic controls and repair of the air side equipment on Boiler No. 4 will result in an estimated improvement of the thermal efficiency from 47% to 67%. The savings in fuel at rated capacity of 20 Gcal/hr will be 3.88t/h- (47%/67% x3.88 t/h) = 1.16t/hr

Cost savings would be 1.16 tonnes x 86,000 R/tonne x 5000hr/yr = 500,000,000 R, or about $100,000.

Energy saved = 1.16t/h x 5000h x 5.6Gcal/kg = 3248Gcal/yr.

The cost of the control system is estimated to be $50,000. The cost of the control system will be paid back in less than one year by energy savings and the atmospheric emissions will be reduced by 30% because of reduced fuel consumption and by 20% due to improved combustion efficiency.

Coal used in 1994 was 72780t. Costs @ $17.20/t = $1251816.

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Appendix G
Equipment Specifications

Appendix G
Equipment Specifications

Infrared Thermometer. Infrared digital thermometer shall be equal to Model RAYPM30L2U as manufactured by EPD Technology Corp., 14 Hayes Street, Elmsford, NY, 10523, USA. Unit range: -10 to 540 C with digital read out, 9 volt battery and 220 volt, 50 cycle adaptor.

Combustion Analyzer:

A combustion analyzer that meets the following specifications and manufactured by Enerac, CEA Instruments, Land Combustion, Teledyne Analytical Instruments or equal is suitable for this application.

The instrument shall be capable of input settings for preheated combustion air temperature. Selectable fuels shall include natural gas, light and heavy oils and coal; available adjustable parameters for coal shall include heat content, ash content and % volatiles.

Measured Parameters:

- Flue gas concentrations for oxygen, carbon monoxide, and temperature

Calculated Parameters:

- Flue gas, excess air, carbon dioxide and combustion efficiency.

Analyzer Performance:

- Oxygen; 0 to 25% volume
- +/- 0.1% volume resolution
- +/- 0.2% volume accuracy

- Carbon Dioxide; 0 to 20% volume
- +/- 0.1% volume resolution
- +/- 0.2% volume accuracy

- Carbon Monoxide; 0 to 2000 parts per million volume (ppmv)
- +/- 2 ppmv resolution
- +/- 5% of reading accuracy

- Flue Gas Temperature; 0 to 1100°Centigrade
- +/- 1 °C resolution
- +/- 2 °C accuracy

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- Flue Gas Excess Air; 0 to 1000%
- +/- 1% resolution
- +/- 10% accuracy

Analyzer Features:

- Portable, battery powered, capable of operating a minimum of 6 hours on a single charge.

- Battery Charger for 220 volt, 50 Hz power and power cord.

- Condensation trap with re-usable desiccant. Desiccant to be reactivated by drying in an conventional oven or microwave oven.

- Disposable particulate matter filter capable of removing one micron particles.

- Auto "zero" upon turning on the analyzer. "Zero"; ambient air 20.9% O2, 0% CO2, 0% CO

- Inconel probe, 24 inch length minimum and 10 feet of connecting hose to the analyzer.

Span Calibration Kit:

- Certified calibration gases, range 10% O2, 6% CO2, and 1000 ppmv CO Pressurized cylinder container(s) minimum 10 cubic feet.

- Calibration gas manifold and connection to the probe.

Spare Parts:

- Desiccant, 2 quarts minimum
- Disposable Filters, 24 minimum

Velocity and Pressure Meter: pressure range from -250 to +250 mm water, velocity from 0 to 30 meters/sec., and temperature range from 0 to 300C. Unit shall have digital or analog readout, pitot tube probe and thermocouple sensor, power options - battery and 220 volt, 50 cycle, battery recharger and instruction book.

Digital Thermometer. No. 52 as manufactured by Fluke Corp. PO Box 9090, Everett, WA 98206, USA complete with 80PK-3A surface probe (temp range 0C to 260C) and 80PK-2A immersion probe (temp range -196 to 1090C.)

Multimeter: Multimeter Model 85 as manufactured by Fluke Corp. PO Box 9090 Everett, WA 98206, USA

Wattmeter: Instrument to measure volts, amps, ohms AC and DC. Wattmeter equal to 2000A Wattprobe as manufactured by TIF Instruments, Inc. 9101 NW 7th Ave, Miami Fl. 33150 USA Range 280/560 volt 20KW and 200KW ranges, 9volt battery

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Appendix H
Control Specification for Boiler No. 4

Appendix H
Technical Specifications
By Dries Associates

Company: Ziryanovskaya Mine, Kuznetskugal Company

Location of the Work: Ziryanovskaya District Heating Boiler House
Skorostnaya 1
654025 Novokuznetsk, Russia

People to Contact: Chief of Boiler House
Tarasenko Igor Alexandrovitch
Telephone: 31-29-72

General Mechanician: Vladimir V. Ryssatov
Telephone: 31-29-72

Description of Work

Boiler No. 4 has an inoperative control system and is controlled manually. A new control system will provide automatic operation.

Note: The contractor shall verify conditions and dimensions at the site of the work prior to submitting a bid.

Control System Specificaiton for Boiler No. 4

A complete automatic control system including installation, startup and a one year service contract to control the boiler. The existing boiler is a KB-TC 20 giga cal/hr coal fired water boiler. Design capacity is 20 giga cal/hr burning 4-6 tonne of 5500 kcal/kg coal. The water is supplied To a district heating system. A drawing 1171-/1-A004 (attachment B) showing the existing control system is included to provide information about the boiler. Complete drawings and specifications are available from Santech Project (L. Kazakova).

Sequence of Control Operation

All control functions shall have manual override switches. The start-up and shut down of the boiler shall be done manually. Automatic operation after start-up shall control the firing rate by

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sensing the water temperature out of the boiler. The flow of water through the boiler is constant. On a drop in water temperature the coal feed rate shall be increased. Air pressure sensors in the furnace, forced draft fan outlet, induced draft fan inlet, stoker under fire air ducts shall measure the air pressures, the oxygen sensor shall measure the oxygen content and adjust dampers to maintain the air fuel ratio to obtain maximum combustion efficiency and minimum soot emission. Water flow rate and inlet and outlet temperatures shall be measured and used to determine heat produced. A computer controller shall be programmed for the coal type and boiler no. 4 to achieve the above described control sequence. All measured and calculated parameters shall be visually displayed and recorded on the computer hard disk. Historical data shall be stored for 30 days.

High limit controls shall operate audio and visual alarms and the operator using manual controls shall shut down the boiler and correct the problem.

Control equipment and components shall include necessary wiring for a 220 volt, 50 cycle one phase electrical system.

Equipment and Material List

Sensors

1-Hot water supply temperature	30 to 250C (150)
1-Hot water return temperature	30 to 150C (70)
1-Forced draft fan outlet pressure	+0 to 400kg/m2 (152)
1-Induced draft fan inlet pressure (Locate in top center of furnace)	-0 to -400kg/m2 (-193)
1-Oxygen sensor at gas outlet of furnace	0 to 20% (6 to 8)
1-Furnace gas temperature outlet gas cleaner	0 to 300C (220)
1-Air Temperature at inlet to forced draft fan	0 to 150C (30)
1-Water flow sensor at water supply out of boiler alarm to operate If less than 250m3/hr	(350m3/hr)
5-Force draft pressure sensors one in each under air duct at grate	0 to 300kg/m2 (50kg/m2)

Note: (********) indicates design values!

Dampers and Motor Operations

1-Operator for forced draft fan inlet vanes
1-Operator for induced draft fan inlet vanes
5-Dampers and operators for under fire ducts at grate
2-Coal feed motor operators to control feed rate of spreaders and grate speed

6f

Flow Meter

1-Water flow meter for 300m pipe 13.5kg/cm2 max pressure range 100 to 600 m3/h, design conditions 354m3/h.

Computer Controller

1-Computer controller with software program and visual display to show alarms, coal feed rate, oxygen, temperatures, pressures as measured and design values. Computer to be housed in industrial type housing and mounted in existing panel adjacent to boiler no. 4. Unit to have a floppy and 200MB hard drive.

Documentation

5-Sets operator training and operating instructions
5-Sets installation and maintenance manuals

Five sets of shop drawings including wiring diagrams of the system are to be furnished for review to the purchaser for approval. No work may be done without approved shop drawings.

Service Contract

1-One year service and maintenance contract.

Miscellaneous

All necessary labor, supervision, wiring, piping and accessory items to complete the system are to be part of the contract for the control system.

Owners Requirements

The boiler house owner will install dampers and operators in ductwork and fans as well as temperature, flow, pressure and oxygen sensors and the installation will be as directed by the control contractor.

The boiler house owner will be required to repair and/or replace as necessary the air system to achieve design conditions and run tests to verify conditions are achieved before the control contractor starts the control work. Water and heat leaks in the boiler shall also be repaired.

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FIGURES

Figure 1. Coal Use for Space Heating and Domestic Hot Water, 1994

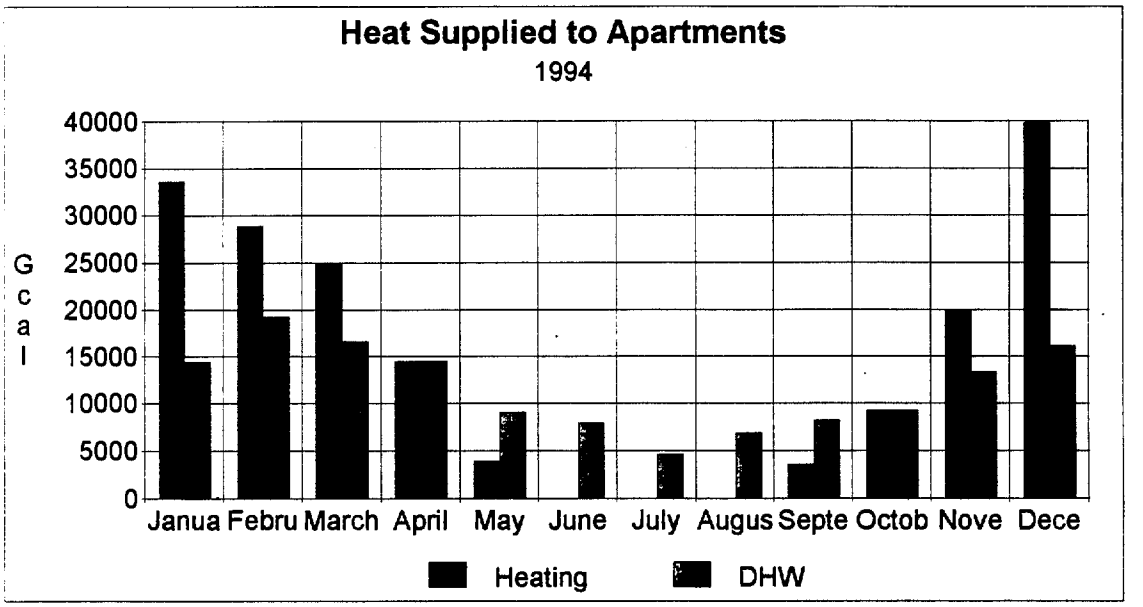
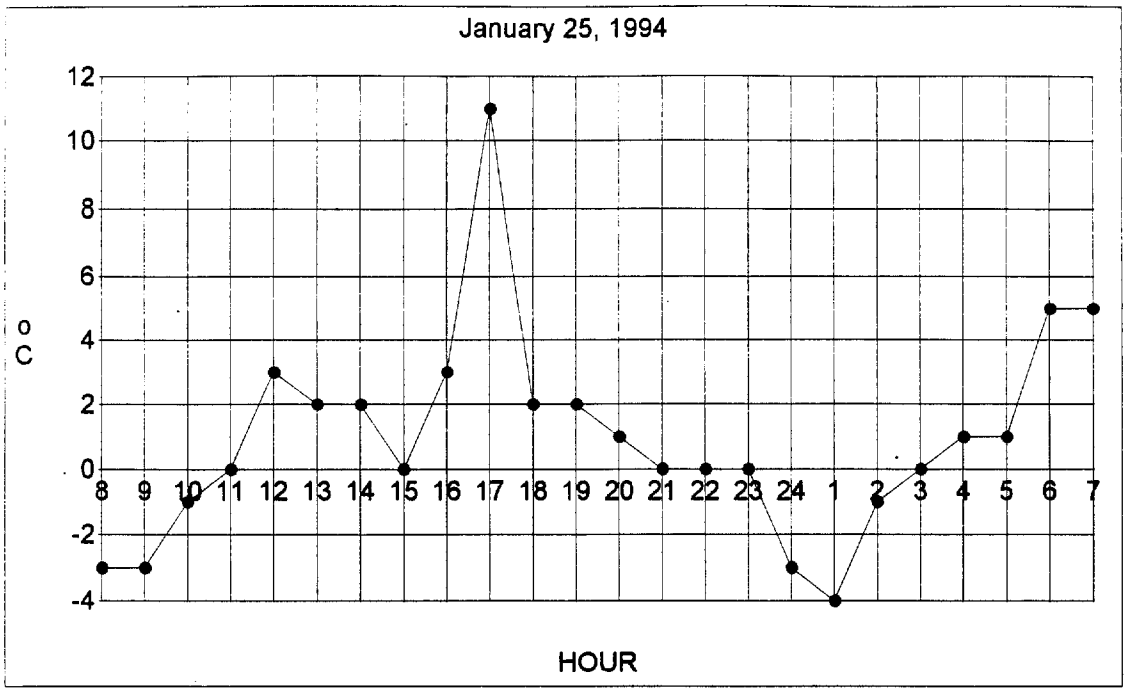
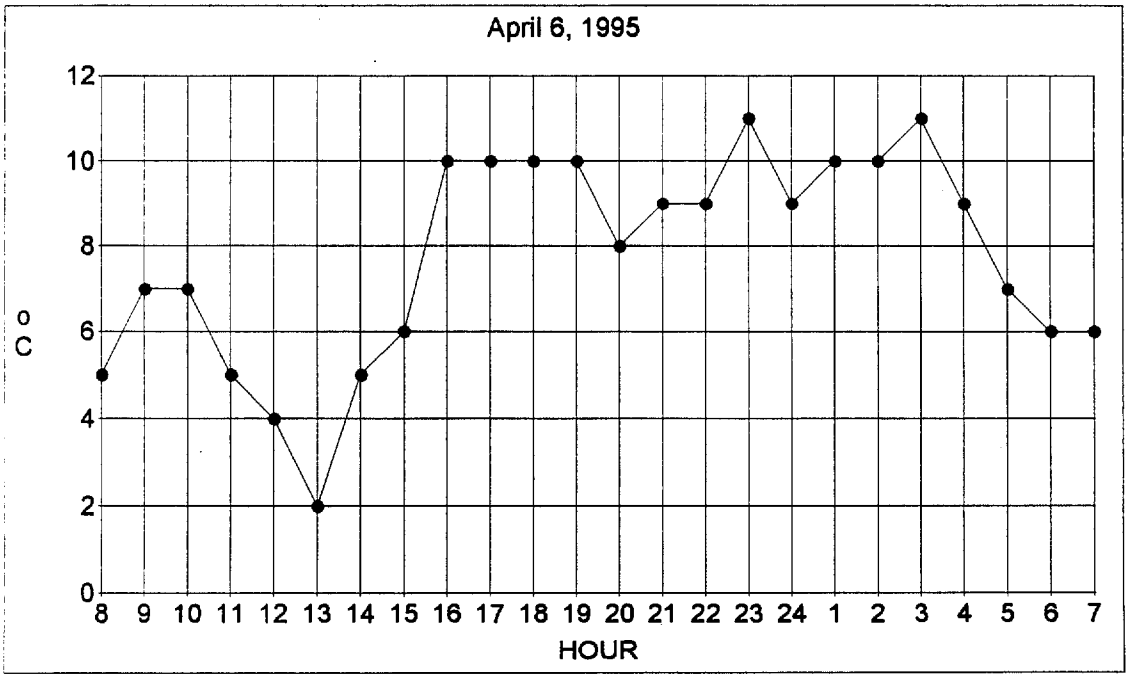


Figure 2. Deviation in hourly supply water temperature from Temperature Regiem Schedule, based on outside temperature.





TABLE

Table 1. Annual Coal Consumption, 1994

MONTH	COAL,Tonnes
January	10,955
February	10,992
March	9,468
April	6,595
May	2,940
June	1,790
July	1,050
August	1,560
September	2,676
October	4,193
November	7,570
December	12,991
Total	72,780

PREFACE
Audit Report
Abashevskaya Communal District Heating Boiler

This report is the result of an Industrial Environmental Audit carried out April 25 - May 26, 1994 at Abashevskaya District. The audit was made by a joint US - Russian team with the support of the United States Agency for International Development USAID) Environmental Policy and Technology (EPT) Project. There were 6 Americans consultants and 17 Russian specialists from the scientific research and design institutes, enterprises and environmental regulatory agencies on the team.

This audit was performed as a part of a training program for the Russian team members on conducting industrial environmental audits.

Factual information provided by Abashevskaya District formed the basis for evaluating environmental, energy efficiency and worker health and safety conditions at the facility. Opinions formed from this information are the authors and do not necessarily reflect the views of USAID or EPT.....

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AUDIT REPORT
ABASHEVSKAYA COMMUNAL DISTRICT HEATING BOILER

Description of the overall Industrial Audit Program

There is an immediate need for rapid improvement in industrial energy efficiency due to a variety of poor energy utilization practices and lack of proper maintenance of energy systems. Related to the low energy efficiency of facilities is a higher emission of particulate to the atmosphere from the coal-fired boilers. Higher than design coal burning rates subsequently overload the flue gas clean-up equipment which worsens the emission problem. Emission penalties do not alone provide sufficient economic incentive to proceed with projects to reduce emissions. Energy efficiency improvements are cost-effective within the current energy economy and can provide economic incentives that support the concern to clean-up the environment. These energy efficiency improvements will also result in a improvement in air quality by reducing emissions at the source.

Increases in energy prices to equivalent world prices have put additional pressures on industrial firms to conserve energy. Changes within the economic system (energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Along with the industrial audit program to demonstrate the effectiveness of energy efficiency improvements, the overall EPT program provided training on energy efficiency audit practices, use of energy performance measurement equipment and evaluation of energy conservation opportunities.

The Industrial Audit Project is comprised on four distinct tasks:

1. Industrial plant screening
2. Industrial plant energy audit
3. Purchase, ship, and receive equipment to implement audit recommendations
4. Implementation and monitoring

Screening of fifteen industrial plants and communal boilers, the cement plant and the ZapSib Combined Heat and Power Plant was accomplished to provide a basis for selecting the plants to be audited. Criteria used in this selection included;

1) Opportunity for energy savings (with a focus on emission reduction),

2) Reasonable payback period in the Ruble energy economy (also calculated in world prices),

3) Potential replicability of energy saving options in similar plants or systems,

4) Future viability of the plant in the changing economy and operation of the district heating system,

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5) Size of the plant,

6) Ownership,

7) Location and impact on local ambient air quality and

8) Other activities such as joint ventures or other bi-lateral aid projects.

The cement plant audit is given due to it's significant impact on the local environment of Novokuznetsk. The additional plants selected for the audit phase are:

1) Abashevkaya Communal Boiler,
2) Ziryanovskaya Communal Boiler,
3) Selected boilers at the ZapSib Combine Heat and Power Plant,
4) The ice cream and cold storage plant, and
5) The poultry processing plant.

An energy audit report has been prepared for each of the six facilities audited and a seventh report summarizing the results of the stack particulate sampling accomplished at each of the five facilities other than the cement plant. The seven reports represent the complete reporting of the energy/environmental audit activities conducted in Novokuznetsk, Russia during the period of April 25 - May 26, 1995.

The energy audit activity, described in detail in each facility report, consisted of a determination of the overall energy efficiency of the plant to identify no/low cost equipment opportunities with short term payback. An assessment was made of the technical and management capabilities and capital investment decision-making process regarding energy conservation applications. At the completion of the energy audit, equipment specifications and other documents required for procurement of U.S. and NIS manufactured equipment or materials will be prepared. Particulate sampling of the stack gasses of the five facilities with coal-fired boiler systems was conducted to determine the current stack gas loading of particulates and particulate emission rates.

Equipment specified in the energy audit will be procured, cleared through customs, and delivered to the plant. Purchased authorization requests will be prepared for approval by USAID/Washington and USAID/Moscow. Requests for Quotes or Tenders as well as purchase orders when suppliers are selected will be issued from the EPT/Moscow office to support the interest in identifying the maximum ability for these demonstration projects to be replicated by other facilities in Novokuznetsk. Equipment will be shipped to the audited sites in Novokuznetsk and technical support will be provided by the Russian team members working on these audits.

In the implementation phase, requirements for installation of the material will be identified. Where possible, this will be done by the personnel of each facility, or alternatively, by Novokuznetsk contractors. Following completion of the installation, an assessment will be made of the effectiveness of the energy conservation application and the effect on emission reduction.

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Results of the audit conducted in the Abashevskaya Communal Boiler House are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit.

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Section 1

EXECUTIVE SUMMARY

The industrial sector in Novokuznetsk is very well developed, with many large and heavy industries. In addition, there are 160 boiler houses at medium size industries and district,000

Estimated increase in efficiency 4 percent for a savings of $50,000 for a pay back period of 2.4 to the particulate emissions within the residential districts of the city. The facilities chosen for the EPT Industrial Audit project are representative of many companies or similar facilities within the city, making them ideal targets for the industrial energy audit work since potential replication is very high. Many of these medium size plants are very viable, but have not yet implemented energy conservation activities. Changes within the system (increased energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Parallel emission reductions can be expected with increases in energy efficiency

Results of the audit conducted in the Abashevskaya Communal Boiler House are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit. Equipment to implement the recommendations from the audit fall in the categories of portable and fixed equipment and are summarized in the following paragraphs.

Portable Test Equipment

Infrared Thermometer. Infrared digital thermometer shall be equal to Model RAYPM30L2U as manufactured by EPD Technology Corp., 14 Hayes Street, Elmsford, NY, 10523, USA. Unit range: -10 to 540 C with digital read out, 9 volt battery and 220 volt, 50 cycle adaptor.

Combustion Analyzer:

A combustion analyzer that meets the following specifications and manufactured by Enerac, Bacharach, CEA Instruments, Land Combustion, Teledyne Analytical Instruments or equal is suitable for this application. Measured Parameters: flue gas concentrations for oxygen, carbon monoxide, and temperature

Calculated Parameters: flue gas, excess air, carbon dioxide and combustion efficiency.

Velocity and Pressure Meter: pressure range from -250 to +250 mm water, velocity from 0 to 30 meters/sec., and temperature range from 0 to 300C. Unit shall have digital or analog readout, pitot tube probe and thermocouple sensor, power options - battery and 220 volt, 50 cycle, battery recharger and instruction book.

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Digital Thermometer. No. 52 as manufactured by Fluke Corp. PO Box 9090, Everett, WA 98206, USA complete with 80PK-3A surface probe (temp range 0 °C to 260 °C) and 80PK-2A immersion probe (temp range -196 to 1090C.)

Multimeter: Multimeter Model 85 as manufactured by Fluke Corp. PO Box 9090 Everett, WA 98206, USA Wattmeter: Instrument to measure volts, amps, ohms AC and DC.

Estimated cost of portable equipment: $10,000

Estimated increase in efficiency 4 percent for a savings of $50,000 for a pay back period of 2.4 months

Fixed Equipment

Automatic Oxygen Control:

A Complete automatic control system including installation, start up and a one year service contract to control the fuel and air flows as required by the temperature of the supply water leaving the boiler to the heating system. The existing boiler is a KB-TC 20 giga cal/hr. coal fired water boiler. Design capacity is 20 giga cal/hr. burning 4 tonne of 5500 kcal/kg coal. Complete drawings and specifications are available from Santech Project (L. Kazakova).

Calculation of Payback and Energy Saved with Controls for Boiler No. 2 Installation of automatic controls and repair of the air side equipment on Boiler No. 4 will result in an estimated improvement of the thermal efficiency from 60 - 75 percent. The savings in fuel at rated capacity of 20 Gcal/hr will be 3.88 t/h- ((1-60 percent/75 percent) x3.88 t/h) = 0.78 t/hr

Cost savings would be 0.78 tonnes x 100,000 R/tonne x 5000hr/yr = 390,000,000 R, or about $78,000.

Energy saved=0.78 t/h x 5000 h x 5.6 Gcal/kg= 2184 Gcal/yr.

The cost of the control system is estimated to be $50,000. The cost of the control system will be paid back in less than one year by energy savings and the atmospheric emissions will be reduced by 30 percent because of reduced fuel consumption and by 20 percent due to improved combustion efficiency.

The payback period is 8 months

Overfire Air Combustion System

Provide over fire air ports located above the ignition arch and directed at the primary combustion zone. Over fire air shall be from 10-15 percent of total combustion air. Use 2 of the existing "sharp blowing fans" if possible.

Injection ports shall be of the minimum size possible consistent with available pressure from existing fans and space for ports. Ports shall be sized to create the maximum velocity and turbulence possible.

All material and design for this ECO shall be in accordance with SANTEC Project specifications.

Estimated cost: $10,000 Estimated coal savings 610 tons at $20.00/ton = $12,200 for a pay back period of 10 months.

Section 2

PLANT DESCRIPTION

Key Plant Data

Name of Facility:	Abashevskaya District Heating Boiler, owned and operated by Abashevskaya Mine, Kuznetskugol Company
Key Contacts:	Chief of Boiler House: Vladimir Ziryakov General Mechanician: Valary ?? Supervisor of Central Heating Point: Jakob Zhukov
Head Office Location:	Novokuznetsk 654025 Skorostnaya, 1

Operating Data

Table 1 presents a summary of the operating data for the Abashevskaya Communal Boiler House during the year 1994. Energy production at the plant was limited by the availability of primary energy. However, the supply of energy has been a problem for several years and 1994 was taken to be a typical operating year representative of what's is expected in the coming years. During 1994 the boiler house produced 110750 Gcal of thermal energy in the from of thermal water for heating and hot water. The plant burns coal from the mine in three boilers with ratings of 20 Gcal/h each constructed in 1986. The coal burning configuration was modified last year to improve combustion efficiency. Figure 1 presents the thermal water for heating output of the plant by month for 1994. Figure 2 presents the hot water for domestic use output of the plant by month for 1994. Figure 3 presents the coal use of the plant by month for 1994.

Abashevskaya Communal Heating Plant is located at the Abashevskaya Mine on the outskirts of Novokutznesk, Russia. It provides heating and domestic hot water for approximately 30,000 residents in some 6000 dwelling units. The boiler plant consists of 3 20 Giga Calorie/Hr (Gcal/hr) nominal output capacity coal fired boilers with reciprocating grate stokers and gate feeders. The boilers provide hot water at from 65 °C to 128 °C for heating to the district heating point (approximately 2 kilometers from the boiler plant) where flat plate heat exchangers are used to isolate the boiler water from the district heating water and to heat domestic hot water.

Section 3

Plant Description

Abashevskaya Communal Heating Plant is located at the Abashevskaya Mine on the outskirts of Novokutznesk, Russia. It provides heating and domestic hot water for approximately 30,000 residents in some 6000 dwelling units. The boiler plant consists of 3 20 Giga Calorie/Hr (GC/Hr) nominal output capacity coal fired boilers with reciprocating grate stokers and gate feeders. The boilers provide hot water at from 65 °C to 128 °C for heating to the district heating point (approximately 2 kilometers from the boiler plant) where flat plate heat exchangers are used to isolate the boiler water from the district heating water and to heat domestic hot water.

3.1 Boiler Description

The three boilers at Abashevskaya communal boiler house are Russian model KT-20 water wall boilers with a nominal capacity of 20 Giga Calories/Hr (GC/H). Originally they were fired by chain grate stokers with rotary overthrow coal distributors. Due to the large portion of fines in the available coal (up to 70 percent less than 6 mm) the chain grate stokers had considerable problem with coal distribution on the fire bed. Fines were either entrained in the overfire air and frequently carried through unburned into the fly ash or would fall short on the grate and were dumped off the near end of the grate into the ash pit before they are fully burned.

3.2 Modified Coal Firing System

The three boilers at Abashevskaya communal boiler house were modified last year by a Chinese contractor with a reciprocating grate stoker which is more tolerant of fines in the coal than the original chain grate design. This modification reversed the flow of coal on the grate and uses a manually adjusted vertically rising spreader gate to regulate the flow of coal onto the grate according to a "regime" card (Table 1, Abashevskya Regime Card) which specifies the positions of various controls at three firing rates: 10 Giga Calories/hour (GC/Hr), 17 and 20 GC/H (see Table 1). The gate regulates the depth of the coal bed from 90 mm at 10 GC/Hr to 125 mm at 20 GC/Hr. Varying the length and frequency of stroke of the hydraulically driven grate provides finer control of the firing rate. The regime card also specifies the settings of various combustion air controls. At the same time as the grate modification, the Russians also added curtain walls to isolate various burning areas and provide additional furnace residence time for suspended fines. This modification eliminated the recirculation of fly ash from the convection pass back to the boiler and the use of overfire air, although the latter was apparently a matter of running out of funds.

Section 4

Energy Conservation Opportunities

4.1 Oxygen Control for Boilers

Combustion tests using a Bacharach Portable Combustion Analyzer (CA) of boilers 1 and 2 show that the flue gas oxygen content at the entrance to the battery cyclones is from 8 to 12 percent. Design conditions call for 6 to 8 percent. Maintaining the combustion air in the design range will improve combustion efficiency by 3 to 4 percent. Based on reported coal use in 1994 of 24,960 metric tons, this will result in a reduction in coal use of 874 tons and a savings of 87,360,000 Roubles ($17,472). Although an oxygen sensor is installed with a display in the control room adjustments are made manually by adjusting the forced draft fan inlet vanes (from the remote position in the control room) and the O_2 level tends to drift, up to an observed 12 percent in one period. An automatic control system will maintain O2 levels in the 6-8 percent range more reliably. There would also be a savings in fan energy consumption due to lower flows although this is neglected in energy savings calculations.

Estimated Annual Coal Savings (metric tons)	874
Coal Cost per Ton (Roubles)	100,000
Annual Savings (Roubles)	87,360,000
Estimated Cost (Roubles)	50,000,000
Estimated Payback (months)	7

Digital Display of Distribution Water Temperature

Although the Distribution Water Temperature is displayed on a chart recorder and Temperature is manually adjusted it is difficult to read and is often as much as 5 °C above the schedule temperature. A digital display of the temperature to the nearest degree will provide the operator with a more precise indication of the water temperature and enable her to maintain the supply temperature closer to the scheduled temperature. It is estimated that this will reduce the over temperature of the supply water by 1 --3 °C , or an average of 2 °C . With an average differential between the supply water and ambient temperatures of 100 °C this will reduce distribution losses by 2 percent. Since distribution losses are estimated to be 40 percent of the supply this results in a 0.8 percent savings.

Annual Coal Use	24,960
Estimated Reduction %	0.8%
Estimated Reduction - metric tons	199.7
Estimated Savings - kR/y	19,968
Estimated Cost - kR	12,500
Payback - Months	8

Modify Combustion Air Supply Ducts and Dampers

The present combustion air supply duct to zone 2 is under sized for the amount of air required in this zone. Velocities in this branch exceed 35 m/sec (6,893 ft/min). In order to provide sufficient air to this section the ventilation fan pressure must be kept very high (1500 - 2400 Pa). The other branch duct dampers are fully closed, or nearly so, yet because of the high pressure necessary to supply air to port 2, leakage past the dampers is excessive and too much air is supplied to the ignition zone and burnout zones. This causes excessive carryout of ash particles and of unburned coal. Enlarging the duct to port 2 to reduce velocities will reduce the required pressure from the ventilation fan and reduce the leakage past the dampers to the other zones. The dampers should also be fitted with low leakage seals or replaced with low leakage type dampers.

This modification will save fan energy and will reduce unburned carbon in the fly ash and bottom ash. Estimated savings are:

Electrical Savings	
Ventilation Fan Flow (average)	763 m^3/h
Present Fan Pressure (average)	2000 Pa
Present Fan kW (average)	64
Estimated Fan Pressure after	1500 Pa
New Fan kW (average)	41.5
Estimated annual Hours or Operation	4380
Annual kWh Savings	202,858
Cost per kWh (Roubles)	225
Annual Savings (kR)	45,630
Coal Savings	
Present Average Flue Gas O_2 %	9.5
Estimated Reduction to	8.5
Present Unburned Carbon in Fly Ash and Bottom Ash	30.9
Estimated UBC after Modification	15.5
Fuel Burn at 12.5 GCh Present*	3.10
Fuel Burn at 12.5 GCh Future	2.86
Savings per hour - tons	0.24
Annual hours of operation	4,380
Annual Fuel Savings - tons	1,056
Annual Cost Savings kR	105,578

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Total Cost Savings - kR	151,207
Estimated Cost - kR	50,000
Payback - months	4

* See TAS computer calculations in Appendix zz

4.2 Install Overfire Air System

Lack of over fire air results in incomplete combustion in the furnace, increases production of carbon monoxide emissions and increases un burned carbon in the fly ash. Installation of an over fire system utilizing the existing "sharp blowing fans" with approximately 12-15 percent of the total combustion air will reduce UBC and CO emissions. It should also enable smokeless operation at a lower level of excess air. Calculations below assume the previous ECO - Modify Combustion Air Supply Ducts and Dampers is previously accomplished

Coal Savings

Present Average Flue Gas O_2 %	8.5
Estimated Reduction to	7.5
Present Unburned Carbon in Fly Ash and Bottom Ash	15.5
Estimated UBC after Modification	7.5
Fuel Burn at 12.5 GCh Present*	2.86
Fuel Burn at 12.5 GCh Future	2.74
Savings per hour - tons	0.14
Annual hours of operation	4,380
Annual Fuel Savings - tons	613.2
Annual Cost Savings kR	61,320
Estimated Cost - kR	50,000
Payback - months	10

* See TAS computer calculations in Appendix zz

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Section 5

Specifications

5.1 Oxygen Control Specification

Provide an automatic control system capable of continually sensing the excess oxygen (0-20 percent) in coal fired boiler flue gases up to 750oC and resetting the position of the inlet guide vanes (inlet damper) of the forced draft fan (FDF) to maintain a flue gas oxygen content of 4+- 0.2- percent (adjustable from 3 to 8 percent). The output of controller shall be a 0-5 milli-amp signal compatible with Russian standard practice to a Russian manufactured motorized controller (Mechanized Electrical single rotation model 250/63, 0.25 rpm, 120 Ohms with 220 vac-24vdc, 10VA power supply).(model 100/25 for city refrigerator).

The system shall also sense boiler static pressure and flue gas temperature at the probe location and display same.

The system shall be PC based with capability for future expansion. Processer shall be a minimum of an Intel 486DX2-66 with a minimum of 8 megabytes of memory. Processer bus shall be ISA/PCI. Provide a hard disk with a minimum of 340 MB and a 3.5 inch floppy disk. Display shall be a minimum of a 14 inch VGA color monitor. Operating system shall be MSDOS with Windows 3.11 or later.

Mounting of Sensor

Oxygen sensor shall be mounted in the crossover duct between the boiler and the battery cyclone, as close as possible to the boiler outlet. Sensor leads shall be in a flexible metal heat shield conduit for a distance of 2 meters then in heat shielded rigid conduit to the site of the controller.

Type of Sensor

Temperature Rating - Must withstand continuous exposure to 500oC flue gases.

Particulates - sensor shall be suitable for operation in a highly concentrated hot particle environment. Particulate loadings of up to 25 grams/standard cubic meter may be encountered.

Other Flue gas contents - Sulphur oxides content of flue gas may range up to 2000 parts per million by volume.

Controller Mounting

Provide a gas and dust tight enclosure for mounting of controller and display. Display and standard adjustments shall be accessible without breaking the integrity of the enclosure.

Displays

Provide digital display (separate from monitor) of flue gas oxygen content in percent, flue gas temperature in degrees C, and static pressure in mm of water at sensor location. Provide visible error indications whenever any are out of range.

Software

Provide software that will calculate and display combustion efficiency based on a user input fuel analysis.

Data Storage

Provide non-volatile (hard disk or equivalent) storage capability for up to 30 days of data for 10 points at 15 minute intervals. Provide 3.5 inch removable (floppy disk) storage for transfer of data for off site analysis.

Manual Control

Provide a manual failure mode for control of combustion air in case of controller failure by means of a manually adjustable control rheostat. The system shall shift to manual control and sound an audible alarm whenever output of oxygen sensor is out of range.

Power Supply

Provide an uninterruptible power supply and power conditioning system to operate the system for a minimum of 30 minutes without line power. Power system shall tolerate frequencies from 40-60 HZ, voltages of 220 volts plus or minus 25 percent and voltage spikes of up to 1000 volts of up to 20 microseconds. Provide audible and visual alarms of power failure and software to automatically shut down system if unattended and power failure exceeds 30 minutes.

Other

The entire system shall be suitable for operation in a dusty environment and shall be protected as necessary.

5.2 Digital Display of Distribution Water Temperature

Provide a PC based sensor and a digital display for distribution water temperature. The system shall be PC based with capability for future expansion. Processer shall be a minimum of an Intel 486DX2-66 with a minimum of 8 megabytes of memory. Processer bus shall be ISA/PCI. Provide a hard disk with a minimum of 340 MB and a 3.5 inch floppy disk. Display shall be a minimum of a 14 inch VGA color monitor. Operating system shall be MSDOS with Windows 3.11 or later.

Digital Display shall be a 4 digit Light Emitting Diode (LED) of at least 25 mm height. Digital display shall be mounted in control panel adjacent to existing chart recorder.

Modify Combustion Air Supply Ducts and Dampers

Increase size of branch duct to primary combustion area (Port 2) or provide second branch duct to reduce velocities and consequent pressure required from the ventilation fan. Duct shall be constructed similarly to existing ducts. Duct size shall be sufficient to reduce required fan pressure at full load to less than 2000 Pa.

Install low leakage dampers in all branch ducts. Leakage shall be less than 1 percent at a differential pressure of 2000 Pa.

Install Overfire Air System

Provide over fire air ports located above the ignition arch and directed at the primary combustion zone. Over fire air shall be from 10-15 percent of total combustion air. Use 2 of the existing "sharp blowing fans" if possible.

Injection ports shall be of the minimum size possible consistent with available pressure from existing fans and space for ports. Ports shall be sized to create the maximum velocity and turbulence possible.

All material and design for this ECO shall be in accordance with SANTEC Project specifications.

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TABLES

TABLE 1 - 1994 ENERGY PROFILES

Abashevskaya Communal Boiler House - Hot Water Production		
Month	**Energy Gcal**	**Average Demand Gcal/Hour**
January	3200	4
February	3100	5
March	2800	4
April	2500	3
May	3800	5
June	3300	5
July	2900	4
August	1650	2
September	2700	4
October	2700	4
November	3700	5
December	3700	5
Annual Total	**36050**	

Abashevskaya Communal Boiler House - Heating Water Production		
Month	**Energy Gcal**	**Average Demand Gcal/Hour**
January	12800	17
February	11700	17
March	11900	16
April	9200	13
May	4000	5
June	0	0
July	0	0
August	0	0
September	2500	3
October	5400	7
November	7200	10
December	10000	13
Annual Total	**74700**	

Abashevskaya Communal Boiler House - Coal Requirements		
Month	**Coal Tons**	**Average Demand Tons/Hour**
January	3600	5
February	3330	5
March	3310	4
April	2640	4
May	1760	2
June	750	1
July	650	1
August	370	0.5
September	1170	2
October	1830	2
November	2460	3
December	3090	4
Annual Total	**24960**	

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Table 2 - Boiler 2 Regime Card			
Abashevskaya Communal Boiler House - Boiler Operating Regimes Boiler #2			
Boiler Outputs (GC/Hr)	10	17	20
For Coal of Following Analysis			
kC/kG (LHV)		6570	
Ash and Noncombustible %		19.5%	
Moisture		8.0%	
Volatiles		40.1%	
Fnes (0-6MM) %		70-75%	
Boiler Parameters			
Fuel Bed Depth (mm)	90	105	125
Grate Stroke (mm)	90	160	160
Stroke Period	30	24	22
Fuel Use (kG/Hr)	2200	3500	4300
Sp. Fule Cons. kG/GC	222	205.9	225
Water Data			
Flow Rate (CM/Hr)	300	300	300
Temperature IN	35	55	65
Temperature OUT	68.3	111.7	131.7
Pressure IN (atm)	7.5	7.5	7.5
Pressure Loss (atm)	4.5	4.5	4.5
Ventilation (Combustion Air) Data			
FD Fan OUT (Pa)	1500	2000	2400
Static Pr. Under Grates (Pa)			
Region I	100	250	250
Region II	300-400	300-400	400-500
Region III	300-400	400-450	450-500
Region IV	0	~10	~10
Supply Air Temperature C	15	15	15

Stack Conditions			
Boiler Vacuum (Pa)	100-150	150-200	150-200
After Boiler	700-800	800-900	800-900
After Cyclone	1400-1500	1600-1700	1900-2000
Flue Temp before BC	240	250	265
Combustion EFF	70-0%	80.0%	67.0%
Percent 0_2		6-8%	

Table 3 - Regime Card Check Figures			
Check Numbers			
Flue Gas Volume Factor	1	1.0195	1.0487
Cyclone DP (Pa)	700	800	1100
Relative Volume Flow Based on Cyclone Loss	1	1.0690	1.2536
Relative Mass Flow	1.0	1.0486	1.1953
Expected Mass Flow (Based on Fuel	1.0	1.5909	1.9545

Table 4 - Combustion Air Flow Measurements						
Duct size is 300 by 600 mm	**Velocity Measurements (meters/sec)**					
Port >>.	1	2	3	4	5	6
Position	(starting from bottom of duct every 3 cm)					
1	5	>30	14	2.2	5	3.5
2	7.5	>30	12	3	5	3
3	10	>30	13	3	4.5	4
4	1	>30	11	3	5	5
5	12	>30	10	3	6	5.5
6	8	>30	8	3	6.5	6
7	13	>30	7	3.5	8	5.5
8	14.5	>30	5	4	9	7
9	17	>30	4	9	7.5	
10	20	>30	4		8	
Sum	118.0	0.0	88.0	24.7	58.0	55.0
Average	11.8	35.0	8.8	3.1	6.4	5.5
Cubic Meter/Min	127.4	378.0	95.0	33.3	69.6	59.4
Percent of Total	5.98	49.5	12.5	4.4	9.1	7.8
Total m^3/Min	762.8					
Inlet deg C	30.0					
Air Density Ratio	0.8875					
St. Air kG/m^3	1.2577					
Mass Flow - kG/min	851.5			(from air flow measurements)		
Mass Flow - kG/min	1150.0			(from particle sampling)		

f \Abashavaskya Table 4

Table 5 - Back Calculation Of Coal Use		
	Stack Sampling	**CA Measurement**
FLUE GAS FLOW RATE M^3/MIN (Actual)	2,063.00	1,610.90
Conversion Factor (Ft^3/M^3)	35.31	35.31
(Ft^3/MIN)	72,853.76	56,887.99
Flue Gas Temp Deg C	388	388
Deg. F	730.4	730.4
Density Factor	0.4452	0.4452
Flue Gas Density Lb/Ft3	0.03473	0.03473
Wet Mass Flue Gas (Lb/Hr)	151,803.	118,535
Flue Gas 02	8.2%	8.2%
Lb Wet Flue Gas/Lb Coal (from Combustion Chart)	13.2	13.2
Coal Burn (Lb/Hr)	11,500.	8,980
Coal Burn (mt/Hr)	5.23	4.08
Coal Heat Vlue (Btu/Lb)	9,900	9,900
Boiler Input (mmbtu/HR)	113.85	88.90
(mmbtu/GC)	3.97	3.97
Boiler Input (Gc/Hr)	28.69	22.40
Fuel Efficiency		
Eff from Chart	71.3%	71.3%
Less Ash Loss (%ASH*%UC)/(%ULT C)	10.0%	10.0%
Less Fly Ash Loss	9.0%	9.0%
Net Efficiency	**52.3%**	**52.3%**

TABLE 6 - COMBUSTION TEST RESULTS

- Abashavaskya Boiler #1 - Before Cyclone								
2 May 1995 - Instrument - Bacharach Model 300 NSX SN 2C0502								
Time	deg C	% O2	% CO2	% EA	% Eff.	NOX	ppm SOX	ppm CO
1422	322	9.9%	8.7%	84.0%	80.0%	145	490	
1424	323	9.7%	8.4%	84.0%	80.0%	149	544	
1426	327	9.8%	8.5%	79.0%	80.0%	143	548	
1428	307	9.2%	8.9%	74.0%	81.8%	152	544	
1431	331	9.2%	8.8%	79.0%	80.1%	159	518	
After Cyclone								
1500	275	12.1%	6.7%			120	322	
1505	272	12.3%	6.5%			119	320	
6 May 1995 - Boiler #2								
1025	252	12.9%	6.3%	146.0%	80.3%	145	177	97
1027	254	12.0%	6.4%	143.0%	80.5%	159	218	96
1029	256	12.0%	6.5%	140.0%	80.4%	164	245	88
1031	254	12.5%	6.5%	140.0%	80.4%	159	245	81
4 May 1995 - Boiler #1								
1029	300	12.1%	6.8%	129.0%	78.9%	153	301	1988
1031	297	11.8%	7.0%	131.0%	79.1%	149	342	2736
1033	294	11.9%	6.8%	126.0%	78.1%	151	347	1728
1035	288	11.3%	7.1%	126.0%	79.7%	153	362	2158
1037	292	10.9%	7.2%	179.0%	79.9%	160	385	1813
CA flow was adjusted for following tests								
1045	330	8.9%	9.1%	70.0%	81.5%	204	674	3162
1047	334	8.5%	9.0%	74.0%	81.9%	201	682	3158
1049	339	8.6%	9.1%	73.0%	80.6%	205	684	3148
1055	349	9.2%	9.0%	73.0%	80.2%	204	663	3147
Flow of ventilation air fan was adjusted								
1101	332	9.1%	8.9%	76.0%	80.8%	185	567	2991
1103	343	8.4%	9.3%	65.0%	80.8%	201	682	3152
1107	336	8.9%	8.7%	79.0%	80.9%	200	632	3259
1109	317	10.6%	7.5%			197	564	473
Adjusted ports 1,2 &3								
1128	334	9.2%	9.0%	73.0%	81.0%	201	619	3123
1130	338	9.4%	8.9%	70.0%	80.3%	201	619	2855
Adjusted fan settings								
1135	343	8.9%	9.2%	70.0%	80.8%	211	628	2960
1139	351	7.7%	9.7%	60.0%	81.1%	205	664	2826
1145	352	7.9%	9.6%	64.0%	80.3%	203	669	3120
Note: after adjusting the ventilation (FD) fan static pressure dropped from 3350 Pa to 2800 indicating a 25% reduction in power								

FIGURES

Figure 1
HOT WATER SUPPLIED TO DISTRICT FROM ABASHEVSKAYA COMMUNAL BOILER

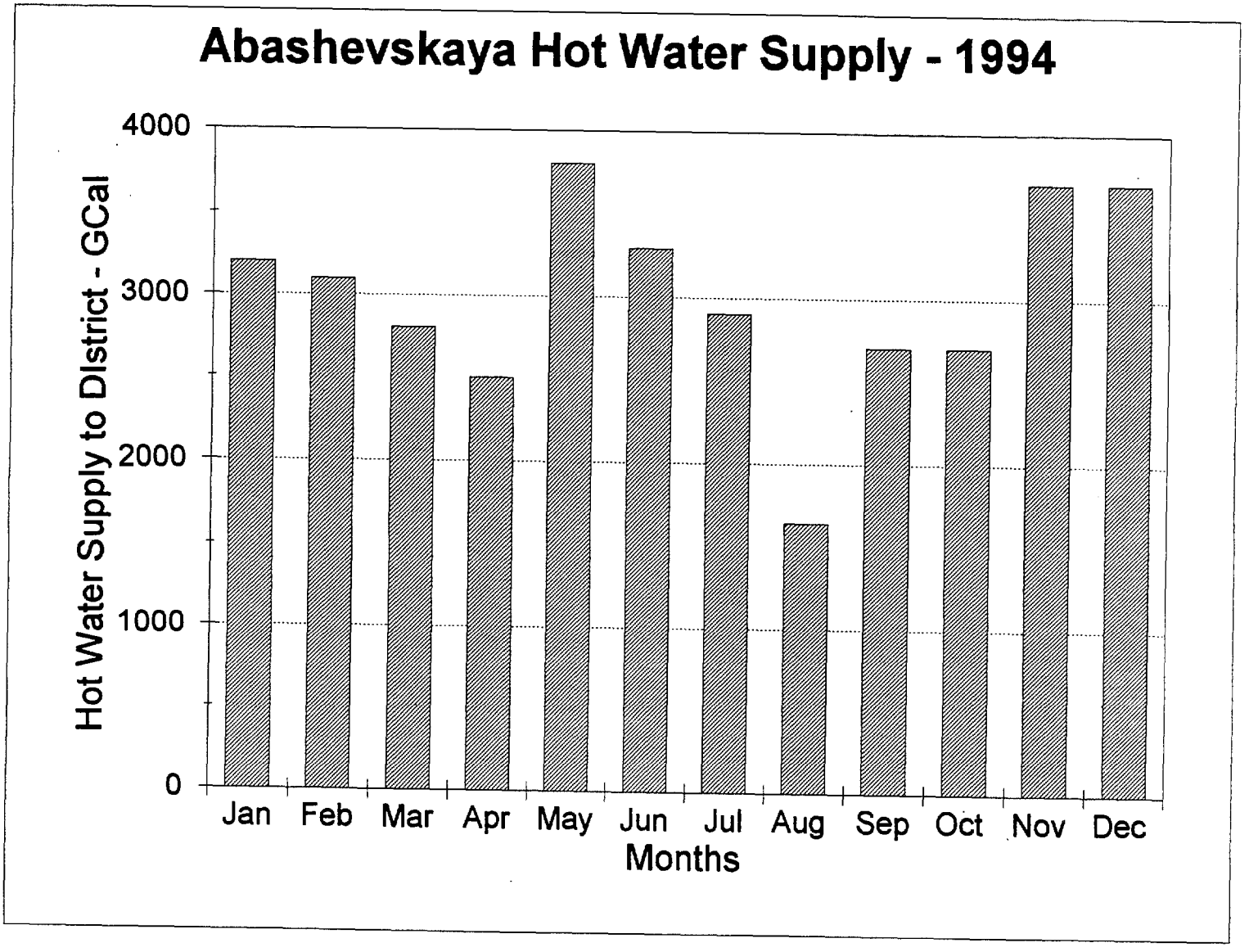


Figure 2
HEATING ENERGY SUPPLIED TO DISTRICT BY ABASHEVSKAYA COMMUNAL BOILER HOUSE

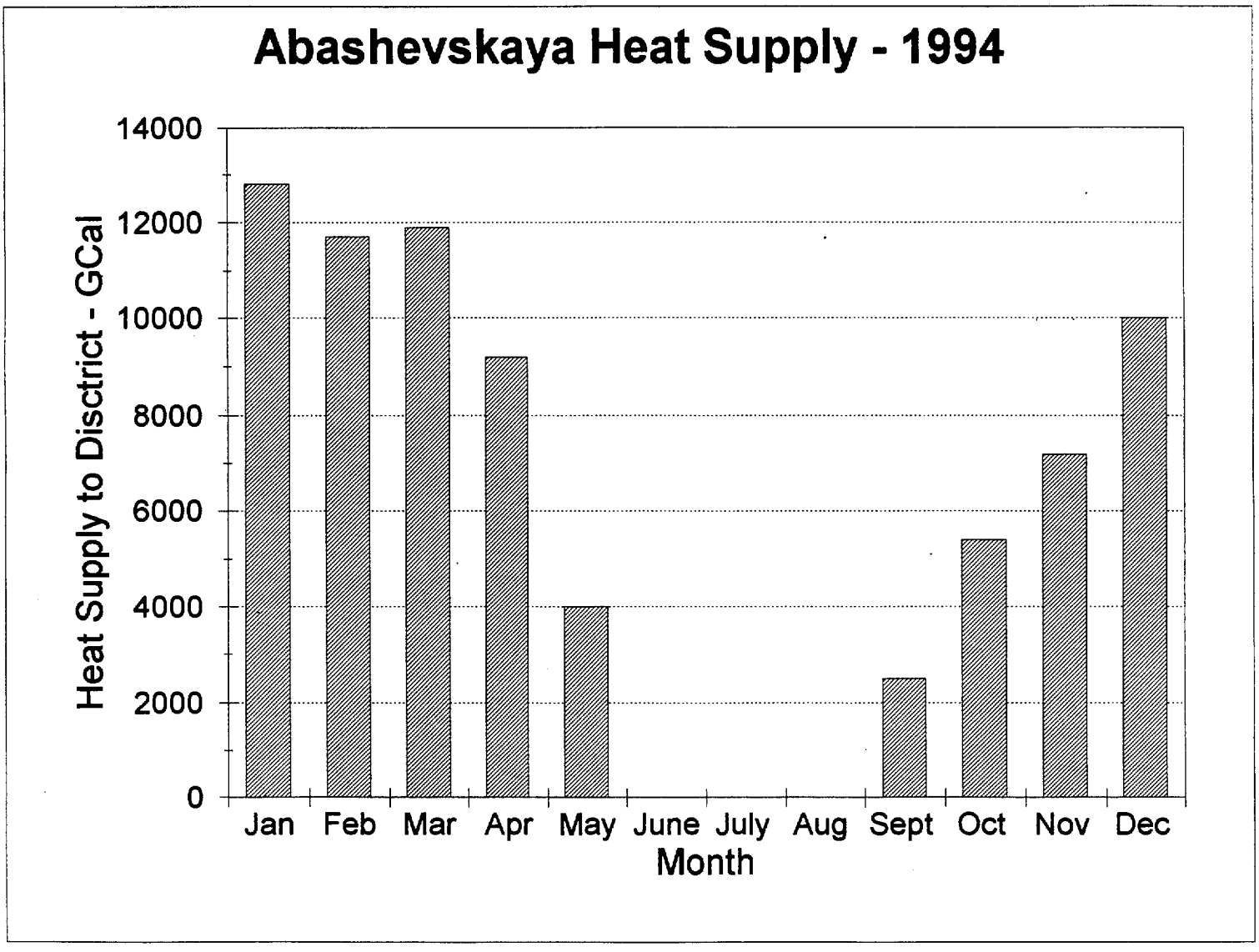
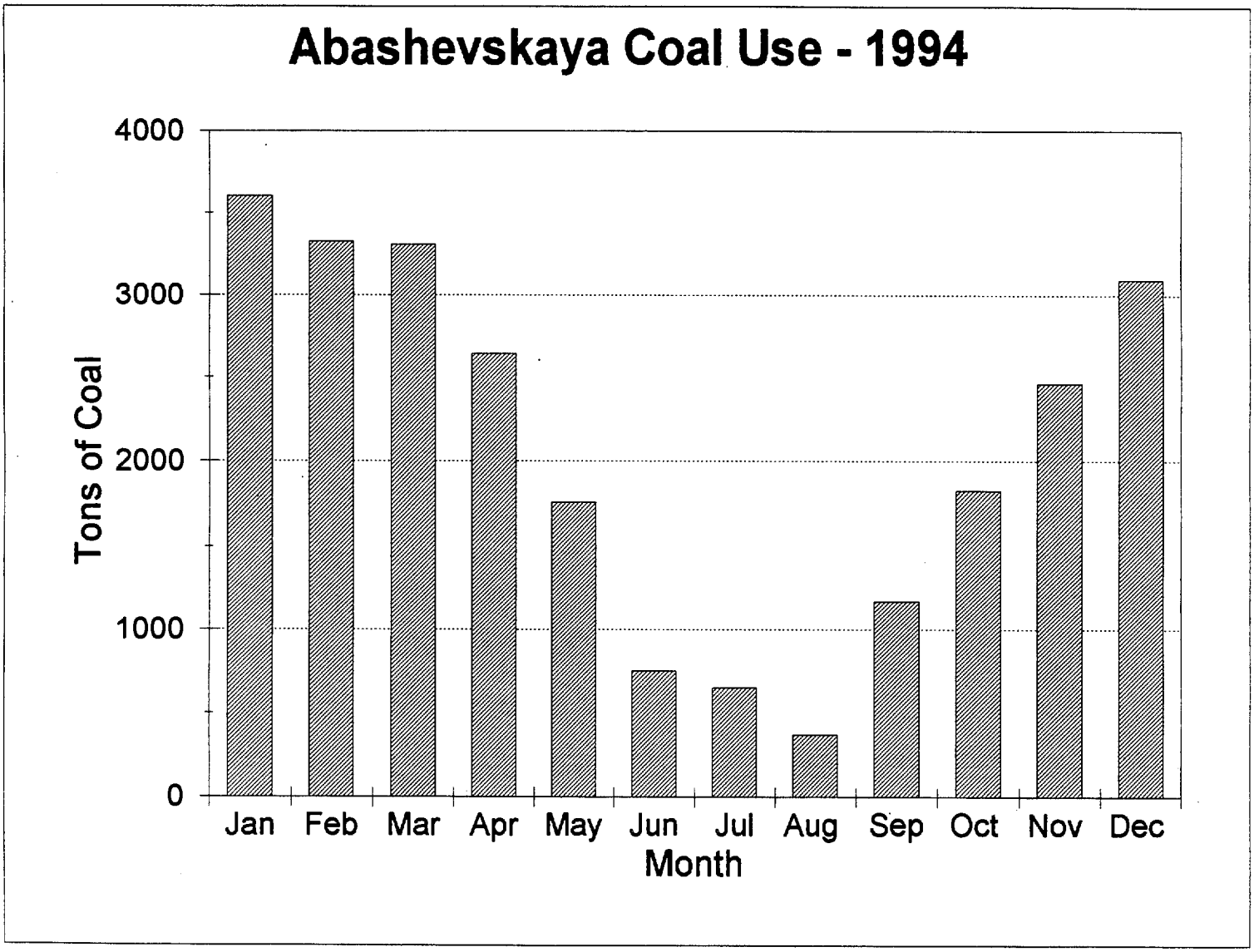


Figure 3
COAL USE FOR 1994 BY THE ABASHEVSKAYA COMMUNAL BOILER HOUSE



APPENDIX I

APPENDIX I

.....COMBUSTION CALCULATIONS 06-06-1995 14:54:04

==========

PRESENT CONDITION

*** RUN IDENTIFICATION ***

PROJECT NAME: 9.4509

*** ULTIMATE ANALYSIS, % BY WEIGHT ***

1.	CARBON %	47.4
2.	HYDROGEN %	4
3.	SULFUR %	.3
4.	OXYGEN %	16.8
5.	NITROGEN %	4
6.	WATER %	8
7.	ASH %	19.5
8.	H. HEATING VALUE, BTU/LB	10260
9.	% OF ASH THAT IS FLY ASH	30
10.	TEMPERATURE OF FUEL, F	80
11.	FUEL SP HT, BTU/LB-F COAL=.3,OIL=.53	.3

*** OTHER DATA INPUTS ***

1.	LEAKAGE IN AIR HEATER (0?) %	0
2.	EXCESS AIR, (20?) %	20
3.	UNDIL EXIT GAS TEMP, (300?) F	617
4.	AMBIENT AIR TEMP, (80?) F	80
5.	CARBON IN REFUSE, (0?) %	30.9
6.	BAROMETRIC PRESS,(29.92?)INHG	29.92
7.	PRECIPITATOR EFFICENCY,(99?)%	99
8.	RADIATION LOSS, (1.5?) %	1.5
9.	MANUFACTURERS MARGIN, (1?) %	1
10.	HEAT ABSORBED, MMBTU/HR	49.5
11.	RELATIVE HUMIDITY, (60?) %	60
12.	EMISS,NOx, lb/mmBtu HHV (.1?)	.1
13.	EMISS,CO, lb/mmBtu HHV (.2?)	.2
14.	EMISS,UBHC, lb/mmBtu HHV(.09?)	.09
15.	EMISS,Part, lb/mmBtu HHV(.01?)	.01
16.	EMISS Base Dry Excess O2%(3?)	3

*** ORSAT ANALYSIS ***

1.	% VOL O2 :	9.5
2.	% VOL CO2 :	11.5
3.	% VOL CO :	.3

==========

RESULTS

*** PERCENTAGE LOSSES ***

LOSS DUE TO CO2 IN GAS	%	1.6718
LOSS DUE TO CO IN GAS	%	2839E-5
LOSS DUE TO SO2 IN GAS	%	522E-5
LOSS DUE TO O2 IN GAS	%	28122E-5
LOSS DUE TO N2 IN GAS	%	6.2437
LOSS DUE TO STEAM IN GAS	%	1.2606
LOSS OF STEAM LAT HEAT	%	4.4600
LOSS DUE TO CARB IN ASH	%	11.983
LOSS DUE TO UNBURNED CO	%	86194E-5
LOSS DUE TO RAD & MFG MRG	%	2.5
TOTAL LOSS	%	29.296
FUEL TEMP CREDIT,	BTU/LBF	0

*** GAS & AIR FLOWS ***

BOILER EFFICIENCY,	%	70.703
TOTAL FUEL HEAT ,	MMBTU/HR	70.010
FUEL BURN RATE,	KLB/HR	6.8236
AIR INTO BURNERS,	KLB/HR	41.830
GAS LVING FURN,	KLB/HR	46.728
AIR HTR LKG,	KLB/HR	0
FLY ASH LVG FURN,	KLB/HR	39918E-5
FLY ASH LVG PRECIP,	KLB/HR	399E-5
BOTTOM ASH PRODUCED,	KLB/HR	93143E-5
MOISTURE IN AIR,	LB/LBDAIR	1313E-5

*** FLUE GAS CHARACTERISTICS....WET ***

VOLUME	CO2	%	13.353
VOLUME	CO	%	32049E-5
VOLUME	N2	%	70.928
VOLUME	O2	%	3.1138
VOLUME	SO2	%	3977E-5
VOLUME	H20	%	12.243
TOTAL OF ABOVE			100
MOL WT OF GAS LVG HTR			29.051
DENS @ 60F/30INHG		LB/CUFT	7655E-5
DILUT TEMP LVG AIR HTR		F	617
CORR DENS @ FLOW CONDITIONS			3686E-5

*** GAS ANALYSIS BY WEIGHT, and EPA EMISSIONS ***

CO2	Klb/hr	9.4509
CO	Klb/hr	14434E-5
SO2	Klb/hr	4094E-5
O2	Klb/hr	1.6027
H20	Klb/hr	3.5448
N2	Klb/hr	31.944
TOTAL	Klb/hr	46.728
EMISS,NOX (NO2)	lb/hr	7.0010
EMISS,NOX (NO2)	ppmvd 3% O2	111.21
EMISS,CO	lb/hr	14.002
EMISS,CO	ppmvd 3% O2	365.40
EMISS,UBHC (CH4)	lb/hr	6.3009
EMISS,UBHC (CH4)	ppmvd 3% O2	287.75
EMISS,PARTICULTe,	lb/hr	70010E-5

.....COMBUSTION CALCULATIONS 06-06-1995 14:57:44

02 CONTROL AND CA MOD

*** RUN IDENTIFICATION ***

PROJECT NAME: 9.8754

*** ULTIMATE ANALYSIS, % BY WEIGHT ***

1.	CARBON %	47.4
2.	HYDROGEN %	4
3.	SULFUR %	.3
4.	OXYGEN %	16.8
5.	NITROGEN %	4
6.	WATER %	8
7.	ASH %	19.5
8.	H. HEATING VALUE, BTU/LB	10260
9.	% OF ASH THAT IS FLY ASH	30
10.	TEMPERATURE OF FUEL, F	80
11.	FUEL SP HT, BTU/LB-F COAL=.3,OIL=.53	.3

*** OTHER DATA INPUTS ***

1.	LEAKAGE IN AIR HEATER (0?) %	0
2.	EXCESS AIR, (20?) %	20
3.	UNDIL EXIT GAS TEMP, (300?) F	617
4.	AMBIENT AIR TEMP, (80?) F	80
5.	CARBON IN REFUSE, (0?) %	15.5
6.	BAROMETRIC PRESS,(29.92?)INHG	29.92
7.	PRECIPITATOR EFFICENCY,(99?)%	99
8.	RADIATION LOSS, (1.5?) %	1.5
9.	MANUFACTURERS MARGIN, (1?) %	1
10.	HEAT ABSORBED, MMBTU/HR	49.5
11.	RELATIVE HUMIDITY, (60?) %	60
12.	EMISS,NOx, lb/mmBtu HHV (.1?)	.1
13.	EMISS,CO, lb/mmBtu HHV (.2?)	.2
14.	EMISS,UBHC, lb/mmBtu HHV(.09?)	.09
15.	EMISS,Part, lb/mmBtu HHV(.01?)	.01
16.	EMISS Base Dry Excess O2%(3?)	3

*** ORSAT ANALYSIS ***

1.	% VOL O2 :	8.5
2.	% VOL CO2 :	12.5
3.	% VOL CO :	.3

==========

RESULTS

*** PERCENTAGE LOSSES ***

LOSS DUE TO CO2 IN GAS	%	1.8941
LOSS DUE TO CO IN GAS	%	3217E-5
LOSS DUE TO SO2 IN GAS	%	522E-5
LOSS DUE TO O2 IN GAS	%	31368E-5
LOSS DUE TO N2 IN GAS	%	6.9582
LOSS DUE TO STEAM IN GAS	%	1.2828
LOSS OF STEAM LAT HEAT	%	4.4600
LOSS DUE TO CARB IN ASH	%	4.9156
LOSS DUE TO UNBURNED CO	%	97655E-5
LOSS DUE TO RAD & MFG MRG	%	2.5
TOTAL LOSS	%	23.338
FUEL TEMP CREDIT,	BTU/LBF	0

*** GAS & AIR FLOWS ***

BOILER EFFICIENCY,	%	76.661
TOTAL FUEL HEAT ,	MMBTU/HR	64.569
FUEL BURN RATE,	KLB/HR	6.2933
AIR INTO BURNERS,	KLB/HR	43.032
GAS LVING FURN,	KLB/HR	47.872
AIR HTR LKG,	KLB/HR	0
FLY ASH LVG FURN,	KLB/HR	36816E-5
FLY ASH LVG PRECIP,	KLB/HR	368E-5
BOTTOM ASH PRODUCED,	KLB/HR	85904E-5
MOISTURE IN AIR,	LB/LBDAIR	1313E-5

*** FLUE GAS CHARACTERISTICS....WET ***

VOLUME	CO2	%	13.690
VOLUME	CO	%	32857E-5
VOLUME	N2	%	71.526
VOLUME	O2	%	3.1428
VOLUME	SO2	%	3598E-5
VOLUME	H20	%	11.275
TOTAL OF ABOVE			100
MOL WT OF GAS LVG HTR			29.201
DENS @ 60F/30INHG		LB/CUFT	7694E-5
DILUT TEMP LVG AIR HTR		F	617
CORR DENS @ FLOW CONDITIONS			3705E-5

*** GAS ANALYSIS BY WEIGHT, and EPA EMISSIONS ***

CO2	Klb/hr	9.8754
CO	Klb/hr	15082E-5
SO2	Klb/hr	3776E-5
O2	Klb/hr	1.6487
H20	Klb/hr	3.3271
N2	Klb/hr	32.832
TOTAL	Klb/hr	47.872
EMISS,NOX (NO2)	lb/hr	6.4569
EMISS,NOX (NO2)	ppmvd 3% O2	99.501
EMISS,CO	lb/hr	12.913
EMISS,CO	ppmvd 3% O2	326.93
EMISS,UBHC (CH4)	lb/hr	5.8112
EMISS,UBHC (CH4)	ppmvd 3% O2	257.45
EMISS,PARTICULTe,	lb/hr	64569E-5

OVERFIRE AIR

*** RUN IDENTIFICATION ***

PROJECT NAME: ABASH0002

*** ULTIMATE ANALYSIS, % BY WEIGHT ***

1. CARBON %	47.4
2. HYDROGEN %	4
3. SULFUR %	.3
4. OXYGEN %	16.8
5. NITROGEN %	4
6. WATER %	8
7. ASH %	19.5
8. H. HEATING VALUE, BTU/LB	10260
9. % OF ASH THAT IS FLY ASH	30
10. TEMPERATURE OF FUEL, F	80
11. FUEL SP HT, BTU/LB-F COAL=.3,OIL=.53	.3

*** OTHER DATA INPUTS ***

1. LEAKAGE IN AIR HEATER (0?) %	0
2. EXCESS AIR, (20?) %	20
3. UNDIL EXIT GAS TEMP, (300?) F	617
4. AMBIENT AIR TEMP, (80?) F	80
5. CARBON IN REFUSE, (0?) %	7.5
6. BAROMETRIC PRESS,(29.92?)INHG	29.92
7. PRECIPITATOR EFFICENCY,(99?)%	99
8. RADIATION LOSS, (1.5?) %	1.5
9. MANUFACTURERS MARGIN, (1?) %	1
10. HEAT ABSORBED, MMBTU/HR	49.5
11. RELATIVE HUMIDITY, (60?) %	60
12.EMISS,NOx, lb/mmBtu HHV (.1?)	.1
13.EMISS,CO, lb/mmBtu HHV (.2?)	.2
14.EMISS,UBHC, lb/mmBtu HHV(.09?)	.09
15.EMISS,Part, lb/mmBtu HHV(.01?)	.01
16.EMISS Base Dry Excess O2%(3?)	3

*** ORSAT ANALYSIS ***

1. % VOL O2 :	7.5
2. % VOL CO2 :	13.5
3. % VOL CO :	.03

RESULTS

*** PERCENTAGE LOSSES ***

LOSS DUE TO CO2 IN GAS	%	2.0234
LOSS DUE TO CO IN GAS	%	318E-5
LOSS DUE TO SO2 IN GAS	%	522E-5
LOSS DUE TO O2 IN GAS	%	32938E-5
LOSS DUE TO N2 IN GAS	%	7.3038
LOSS DUE TO STEAM IN GAS	%	1.2936
LOSS OF STEAM LAT HEAT	%	4.4600
LOSS DUE TO CARB IN ASH	%	2.1728
LOSS DUE TO UNBURNED CO	%	9659E-5
LOSS DUE TO RAD & MFG MRG	%	2.5
TOTAL LOSS	%	20.188
FUEL TEMP CREDIT,	BTU/LBF	0

*** GAS & AIR FLOWS ***

BOILER EFFICIENCY,	%	79.811
TOTAL FUEL HEAT ,	MMBTU/HR	62.020
FUEL BURN RATE,	KLB/HR	6.0449
AIR INTO BURNERS,	KLB/HR	43.402
GAS LVING FURN,	KLB/HR	48.172
AIR HTR LKG,	KLB/HR	0
FLY ASH LVG FURN,	KLB/HR	35362E-5
FLY ASH LVG PRECIP,	KLB/HR	353E-5
BOTTOM ASH PRODUCED,	KLB/HR	82513E-5
MOISTURE IN AIR,	LB/LBDAIR	1313E-5

*** FLUE GAS CHARACTERISTICS....WET ***

VOLUME	CO2	%	14.003
VOLUME	CO	%	3111E-5
VOLUME	N2	%	71.885
VOLUME	O2	%	3.1597
VOLUME	SO2	%	3445E-5
VOLUME	H20	%	10.886
TOTAL OF ABOVE			100.00
MOL WT OF GAS LVG HTR			29.290
DENS @ 60F/30INHG		LB/CUFT	7718E-5
DILUT TEMP LVG AIR HTR		F	617
CORR DENS @ FLOW CONDITIONS			3716E-5

*** GAS ANALYSIS BY WEIGHT, and EPA EMISSIONS ***

CO2	Klb/hr		10.133
CO	Klb/hr		1432E-5
SO2	Klb/hr		3626E-5
O2	Klb/hr		1.6629
H20	Klb/hr		3.2226
N2	Klb/hr		33.103
TOTAL	Klb/hr		48.172
EMISS,NOX (NO2)		lb/hr	6.2020
EMISS,NOX (NO2)	ppmvd 3% O2		94.871
EMISS,CO		lb/hr	12.404
EMISS,CO	ppmvd 3% O2		311.72
EMISS,UBHC (CH4)		lb/hr	5.5818
EMISS,UBHC (CH4)	ppmvd 3% O2		245.48
EMISS,PARTICULTe,		lb/hr	62020E-5

PREFACE
Audit Report
Novokuznetsk Cement Plant

This report is the result of an Industrial Environmental Audit carried out April 25 - May 26, 1995 at the Novokuznetsk Cement Plant. The audit was made by a joint US - Russian team with the support of the United States Agency for International Development USAID) Environmental Policy and Technology (EPT) Project. There were 6 Americans consultants and 17 Russian specialists from the scientific research and design institutes, enterprises and environmental regulatory agencies on the team.

This audit was performed as a part of a training program for the Russian team members on conducting industrial environmental audits.

Factual information provided by Novokuznetsk Cement Plant formed the basis for evaluating environmental, energy efficiency and worker health and safety conditions at the facility. Opinions formed from this information are the authors and do not necessarily reflect the views of USAID or EPT.....

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AUDIT REPORT
Novokuznetsk Cement Plant

Description of the overall Industrial Audit Program

There is an immediate need for rapid improvement in industrial energy efficiency due to a variety of poor energy utilization practices and lack of proper maintenance of energy systems. Related to the low energy efficiency of facilities is a higher emission of particulate to the atmosphere from the coal-fired boilers. Higher than design coal burning rates subsequently overload the flue gas clean-up equipment which worsens the emission problem. Emission penalties do not alone provide sufficient economic incentive to proceed with projects to reduce emissions. Energy efficiency improvements are cost-effective within the current energy economy and can provide economic incentives that support the concern to clean-up the environment. These energy efficiency improvements will also result in a improvement in air quality by reducing emissions at the source.

Increases in energy prices to equivalent world prices have put additional pressures on industrial firms to conserve energy. Changes within the economic system (energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Along with the industrial audit program to demonstrate the effectiveness of energy efficiency improvements, the overall EPT program provided training on energy efficiency audit practices, use of energy performance measurement equipment and evaluation of energy conservation opportunities.

The Industrial Audit Project is comprised on four distinct tasks:

1. Industrial plant screening
2. Industrial plant energy audit
3. Purchase, ship, and receive equipment to implement audit recommendations
4. Implementation and monitoring

Screening of fifteen industrial plants and communal boilers, the cement plant and the ZapSib Combined Heat and Power Plant was accomplished to provide a basis for selecting the plants to be audited. Criteria used in this selection included;

1. Opportunity for energy savings (with a focus on emission reduction),

2. Reasonable payback period in Ruble energy economy (also calculated in world prices),

3. Potential replicability of energy saving options in similar plants or systems,

4. Future viability of the plant in the changing economy and operation of the district heating system,

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5. Size of the plant,

6. Ownership,

7. Location and impact on local ambient air quality and

8. Other activities such as joint ventures or other bi-lateral aid projects.

The cement plant audit is given due to it's significant impact on the local environment of Novokuznetsk. The additional plants selected for the audit phase are:

1. Abashevkaya Communal Boiler,
2. Ziryanovskaya Communal Boiler,
3. Selected boilers at the ZapSib Combine Heat and Power Plant,
4. The ice cream and cold storage plant, and
5. The poultry processing plant.

An energy audit report has been prepared for each of the six facilities audited and a seventh report summarizing the results of the stack particulate sampling accomplished at each of the five facilities other than the cement plant. The seven reports represent the complete reporting of the energy/environmental audit activities conducted in Novokuznetsk, Russia during the period of April 25 - May 26, 1995.

The energy audit activity, described in detail in each facility report, consisted of a determination of the overall energy efficiency of the plant to identify no/low cost equipment opportunities with short term payback. An assessment was made of the technical and management capabilities and capital investment decision-making process regarding energy conservation applications. At the completion of the energy audit, equipment specifications and other documents required for procurement of U.S. and NIS manufactured equipment or materials will be prepared. Particulate sampling of the stack gasses of the five facilities with coal-fired boiler systems was conducted to determine the current stack gas loading of particulates and particulate emission rates.

Equipment specified in the energy audit will be procured, cleared through customs, and delivered to the plant. Purchased authorization requests will be prepared for approval by USAID/Washington and USAID/Moscow. Requests for Quotes or Tenders as well as purchase orders when suppliers are selected will be issued from the EPT/Moscow office to support the interest in identifying the maximum ability for these demonstration projects to be replicated by other facilities in Novokuznetsk. Equipment will be shipped to the audited sites in Novokuznetsk and technical support will be provided by the Russian team members working on these audits.

In the implementation phase, requirements for installation of the material will be identified. Where possible, this will be done by the personnel of each facility, or alternatively, by Novokuznetsk contractors. Following completion of the installation, an assessment will be made of the effectiveness of the energy conservation application and the effect on emission reduction.

Results of the audit conducted in the Novokuznetsk Cement Plant are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit.

Section 1

Executive Summary

The industrial sector in Novokuznetsk is very well developed, with many large and heavy industries. In addition, there are 160 boiler houses at medium size industries and district heating systems that consume a large percentage of the regional energy use and are major contributors to the particulate emissions within the residential districts of the city. The facilities chosen for the EPT Industrial Audit project are representative of many companies or similar facilities within the city, making them ideal targets for the industrial energy audit work since potential replication is very high. Many of these medium size plants are very viable, but have not yet implemented energy conservation activities. Changes within the system (increased energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Parallel emission reductions can be expected with increases in energy efficiency

Results of the audit conducted in the Novokuznetsk Cement Plant are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit.

This is a large plant having a design production capacity of 100 tonnes of clinker cement per hour; the four 70 meter long kilns each have a 25 tonne per hour capacity. The "dry process" is used through out the plant, during which the raw materials are mixed and ground to a fine state without water in preparation for calcining in the kilns. The dry process is more energy economical than the older "wet process" (that grinds the raw materials in a wet slurry) but has the potential for greater dust emissions. In this plant the dust potential was fully realized in the form of excessive air emissions and oppressive working conditions throughout the plant. The reduction of the dust emissions was the particular focus of the audit team's efforts.

The major process steps are:

- Mix and grind the raw materials to a fine powder; the plant uses three ball mills for raw material grinding.
- Pre-calcine the mix in suspension preheaters to 800 oC, using exhaust gases from the kiln.
- Calcine the mix in the kiln at high temperatures to form "clinker", the raw form of cement. The clinker is cooled and the extracted heat is used to pre-heat combustion air to 800 C.

- Grind the clinker into fine powder (cement) in ball mills; the plant has three ball mills for final grinding. Additional slag (up to 40%) is ground with the clinker depending on the cement grade.

Electrostatic precipitators are installed to control particulate emissions as part of each of the above processing steps. However, due to lack of proper maintenance and outdated design, the ESP units do not operate efficiently and in 1994, 12,000 tonnes of particulates were released to the atmosphere. In 1994, the plant operated at only 40 percent of design capacity due to poor market demand for cement.

The plant appears to be able to operate at near full rated capacity at such time sales demand for cement may increase providing relatively minor maintenance work is completed. However, the current operational condition of the equipment is poor and is in dire need of major overhaul and in some cases rebuilding with modern technology. Due to operational problems, the kilns are operated at capacities down to 16 tonnes per hour; about 65 percent of the rated capacity. The major renovation needs were beyond the financial limits of the project

A discussion with the management to determine their needs showed that they had prepared a project to improve the mixing of the raw materials by installing a system to control the mixing and produce better control over the process. Implementation of the proposed project will reduce energy and emissions and increase the production and quality of the cement. The audit team agreed with plant management that the proposed automatic weighing project was of high priority and consequently directed it efforts to detailed evaluation of the proposal, including inspection of actual sites for proposed instrument installation, review of records of raw material and clinker chemical analyses, and discussions concerning the technologies to be utilized in the control systems.

Based on the audit team's evaluation of the automatic weighing of raw materials project, this project is recommend for EPT funding. The total cost of the project is $98,000 of which $76,102 is be provided by EPT and the remainder from the cement company as a cost sharing. The project has an estimated energy payback of 1.2 years (see Appendix B). It is estimated that the project could be completed in about nine months after signing of contract (see Appendix C). Electrical energy to be saved is 540,000 kwh/yr or 0.5 percent of all electricity used in 1994 and 10586 Gcal of gas fuel or 2.8 percent used in 1994.

Section 2

Plant Description

Key Plant Data

Name of Facility:	Novokuznetsk Cement Plant, a joint stock company.
Address:	654006 Joint Stock Company Cement Plant Novokuznetsk, Kemerovo Region
Key Contacts:	Karnaukhov Viktor Nikolaevitch, Director, Head of Plant Telephone: 46-06-31 Batrshin Rinnat Raffikovitch, Senior Engineer Telephone: 46-07-22
Head Office Location:	As above
Date of Plant Commissioning:	1943
Number of Employees:	700

General

This is a large plant having a design production capacity of 100 tonnes of clinker cement per hour; the four 70 meter long kilns each have a 25 tonne per hour capacity. The "dry process" is used through out the plant, during which the raw materials are mixed and ground to a fine state without water in preparation for calcining in the kilns. The dry process is more energy economical than the older "wet process" (that grinds the raw materials in a wet slurry) but has the potential for greater dust emissions. In this plant the dust potential was fully realized in the form of excessive air emissions and oppressive working conditions throughout the plant. The reduction of the dust emissions was the particular focus of the audit team's efforts.

The primary product of the plant is portland cement manufactured in four grades, 200, 300 and 400 kg/cm2 strength levels and a sulfur resistant cement. The plant has recently experimented with the production of dolomite refractory for application at the neighboring steel mill (KMK), but at this time it is unclear if dolomite will materialize as a product line.

The raw materials for the portland cement are limestone (source of CaO), quartzite (source of SiO2), blast furnace dust (source of Fe) and blast furnace slag (source of CaO and SiO2).

Additional slag is blended with the final cement in amounts varying to 40 percent depending on the required grade of cement (ground slag has pozzolonic properties).

The major process steps are:

- Mix and grind the raw materials to a fine powder; the plant uses three ball mills for raw material grinding.
- Pre-calcine the mix in suspension preheaters to 800 oC, using exhaust gases from the kiln.
- Calcine the mix in the kiln at high temperatures to form "clinker", the raw form of cement. The clinker is cooled and the extracted heat is used to pre-heat combustion air to 800 C.
- Grind the clinker into fine powder (cement) in ball mills; the plant has three ball mills for final grinding. Additional slag (up to 40 percent) is ground with the clinker depending on the cement grade.

In an effort to control air emissions, exhaust gases from each of the above ball mills and kilns pass through cyclones and finally through electrostatic precipitators. However, for reasons discussed in following sections, the emission control systems are relatively ineffective (estimated efficiency of 75 percent) and at full operating capacity, the plant releases 12,000 tonnes of particulates per year into the atmosphere. Table 1 (attached) lists the particulate air emissions for 1994 for the different manufacturing processes. During 1994, the plant operated at only 40 percent of design capacity due to low market demand.

Operational Status

The plant appears to be able to operate at near full rated capacity at such time sales demand for cement may increase providing relatively minor maintenance work is completed. However, the current operational condition of the equipment is poor and is in dire need of major overhaul and in some cases rebuilding with modern technology. Due to operational problems, the kilns are operated at capacities down to 16 tonnes per hour; about 65 percent of the rated capacity. The major renovation needs were beyond the financial limits of the project but are listed below for reference.

1. Renovation of the suspension preheaters. The preheaters for each kiln are a vertical stack of four units rising about 20 meters in height. They are old and are afflicted with numerous air leaks throughout the system; this results in an estimated doubling of exhaust air volume and is a major source of dust in the plant area. The increased exhaust air volume overloads the electrostatic precipitators (EPS) and large dust emissions result.

2. Completion of EPS system for the kilns. Construction had been initiated several years ago for a central EPS to handle the exhaust gases from all four kilns. The project was halted two years ago, with about 80 percent completion, due to lack of funds for completion. The new EPS was to operate at 99percent efficiency and reduce air emissions from the kilns to 200 tonnes per year at full production rate. Currently, it is estimated by plant management that at least $2 million would be required to complete the project. At this time they have no source of funding.

Plant management believes that "piecemeal" funding of the above projects would be a waste of resources.

A third renovation project area was proposed by plant management that matched the scope and resources of the EPT project, The Automatic Weighing of Kiln Raw Materials. Currently, the ratioing of the four raw material feed materials is controlled manually and the accuracy of the ratios is dependent largely on the experience and visual observations of the feed operators. Chemical analyses of the feed blend is not performed and only after chemical analyses of the clinker, and 1-2 days delay, can the composition be verified and necessary adjustments to the feed ratio be made. The raw material feed ratio effects not only product quality but kiln productivity, specific energy consumption, released emissions and kiln refractory life. This project area was recommended for funding by the audit team and is discussed in more detail in following sections.

Current Plans for Energy Conservation/Environmental Control

Plant management is keenly aware of the economic and environmental benefits to be gained by equipment and process renovation. However, due to tight financial conditions, only relatively minor maintenance related items are funded. Consequently, no significant plans for renovation or improvement are scheduled in the foreseeable future.

Plant management Organization

The Senior Engineer has prime responsibility for energy conservation and environmental control. At this time there is no organizational group identified to direct or implement energy or environmental programs.

Section 3

Plant Energy/Environment Profile

Plant Process Diagram - See Appendix A

Energy Consumption and Costs

Natural Gas. Natural gas is used to fire the kilns, however, the kilns are designed to burn both natural gas and coal. Table 2 (attached) lists the monthly consumption and costs for natural gas for 1994. Based on the total production during 1994 of 400,000 tonnes of cement, the specific consumption and cost of natural gas per tonne were 1,450 m3/tonne and 5033 ruble/tonne, respectively. During 1994, the price of natural gas increased from 25.1 to 73.8 R/m3, and as of May, 1995, the price has increased to 179.5 R/m3.

Electricity. Electricity is used primarily for large drive motors for ball mills, air fans and material conveying systems. Monthly electrical consumption and costs are listed in Table 3 (attached) for 1994. During 1994, the cost of electrical energy increased from 7.08 to 17 rubles /kwh. and as of May, 1995, the cost has increased to 93 rubles /kwh. The specific consumption and cost of electricity were 246.7 kwh/tonne and 2417 ruble/tonne.

It should be noted that the specific costs of energy per tonne for 1994 do not represent current energy costs; in terms of current energy costs, the energy costs have increased by a factor of about 4. The Cement plant management estimates their total energy costs per tonne of cement as of May, 1995 is about 35,000 rubles/tonne or about 18 percent of the selling price of the cement. It should also be noted that the specific energy costs are lowered significantly by the practice of blending up to 40 percent slag into the final cement product. Since the slag is not processed through the kilns, it requires only minimal energy investment for final grinding. Consequently the specific energy cost for pure cement is in the 40,000 to 50,000 rubles/tonne range. If/when the plant operates at full capacity, the specific energy costs will decrease by about 40 percent.

Environmental Emissions and Penalties

Although it is clearly realized by plant management and city administration that air emissions far exceed any rational environmental limits, the plant is officially operating within air emission limits. Current emission limits were set equivalent to actual emissions at full production activity, and since the plant is operating at less than full capacity, they are well within the emission standards and are not subject to any environmental penalties. It seems that the plant and the city administration had come to some practical understanding that allows the plant to operate during difficult economic times.

In recognition of the hazardous working conditions in the plant, primarily due to air borne dust, the age for retirement pensions have been reduced from the normal age of 60 to 45 for women and 50 for men.

Section 4

Audit Approach and Data Summary

Energy Audit

During the week of May 8-13, 1995, the audit team reviewed and inspected all aspects of the cement manufacturing process, including environmental controls. Activity regarding the boiler house was not possible since both boilers were dismantled for renovation (steam and hot water were being purchased from the adjacent KMK steel plant).

A discussion with the management to determine their needs showed that they had prepared a project to improve the mixing of the raw materials by installing a system to control the mixing and produce better control over the process. Implementation of the proposed project will reduce energy and emissions and increase the production and quality of the cement. The audit team agreed with plant management that the proposed automatic weighing project was of high priority and consequently directed it efforts to detailed evaluation of the proposal, including inspection of actual sites for proposed instrument installation, review of records of raw material and clinker chemical analyses, and discussions concerning the technologies to be utilized in the control systems.

Specific areas of energy use are the raw material preparation, kilns for clinker production and final grinding and mixing of the cement.

Large amounts of electricity and natural gas are used in the plant.

A plot plan (A-1) and schematic mass flow diagrams (A-2,3,4,5) of the production process are shown in appendix A.

Site Observations

Air and heat leaks are evident and the air required by the material handling system exceeds the design capacities.

Fans and pumps operate at more or less than design conditions. This results in low efficiencies and excessive electricity use.

Heat recovery at the raw material inlet to the kiln and at the combustion air inlet should be checked to see if they are at peak efficiency.

Section 5

Energy Efficiency Recommendations

Short Term Recommendations:

1. Repair air, heat and water leaks
2. Install raw material mixing system
3. Check fans and pumps and adjust to use minimum electricity

Short Term Energy Conservation Opportunities:

Raw Material Mixing System

A system to mix the raw materials will use automatic scales to weigh the material and control the mixture by a computer with a software program custom written for the types of raw material. The product quality will be improved and electrical and heat energy will be saved.

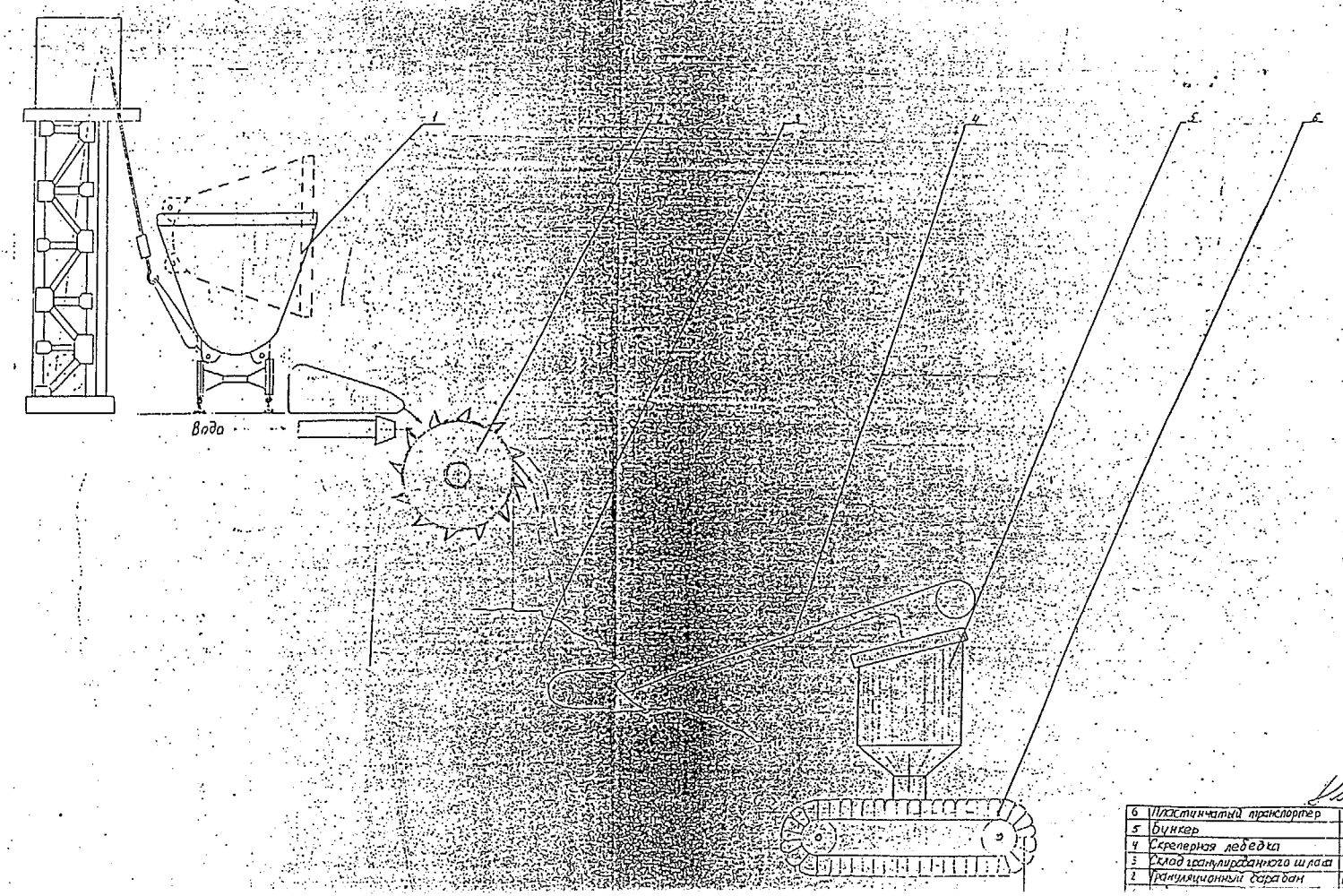
A payback of about 1.2 years will occur with production at 257000t/yr. The production can be increased to 680000t/yr if the market demand increase. The payback will be then about 4 months. See Appendix B

Long Term Recommendations:

1. Improve heat recovery from clinker to preheat combustion air.
2. Repair and operate electrostatic filters at design conditions.
3. Repair cyclone system to improve heat transfer to incoming raw material

APPENDIX A

ТЕХНОЛОГИЧЕСКАЯ СХЕМА ГРАНУЛЯЦИИ ШЛАК



6	Пластинчатый транспортер	1/	B=1200 L=30
5	Бункер	3	
4	Скреперная лебедка	5	СЗА-7-4
3	Склад гранулированного шлака		
2	Грануляционный барабан	10	ф1100мм l=1500мм

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ТЕХНОЛОГИЧЕСКАЯ СХЕМА ПОМОЛА ЦЕМ

№ п/п	Наименование	кол.	Примечание
13	Шнек	1	N-22 кВт
12	Фуллер-насос	2	
11	Дымосос	1	N-150 кВт
10	Электрофильтр	1	
9	Вентилятор аспирационный	1	N-160 кВт
8	Батарейные циклоны	1	
7	Циклоны	1	
6	Шнек	1	N-220 кВт
5	Транспортер ленточный	2	для шлака и
4	Сепаратор	1	
3	Весоизмерители	2	N-1,5 кВт
2	Шнек	1	N-17 кВт
1	Мельница Ш-50	1	

А-3

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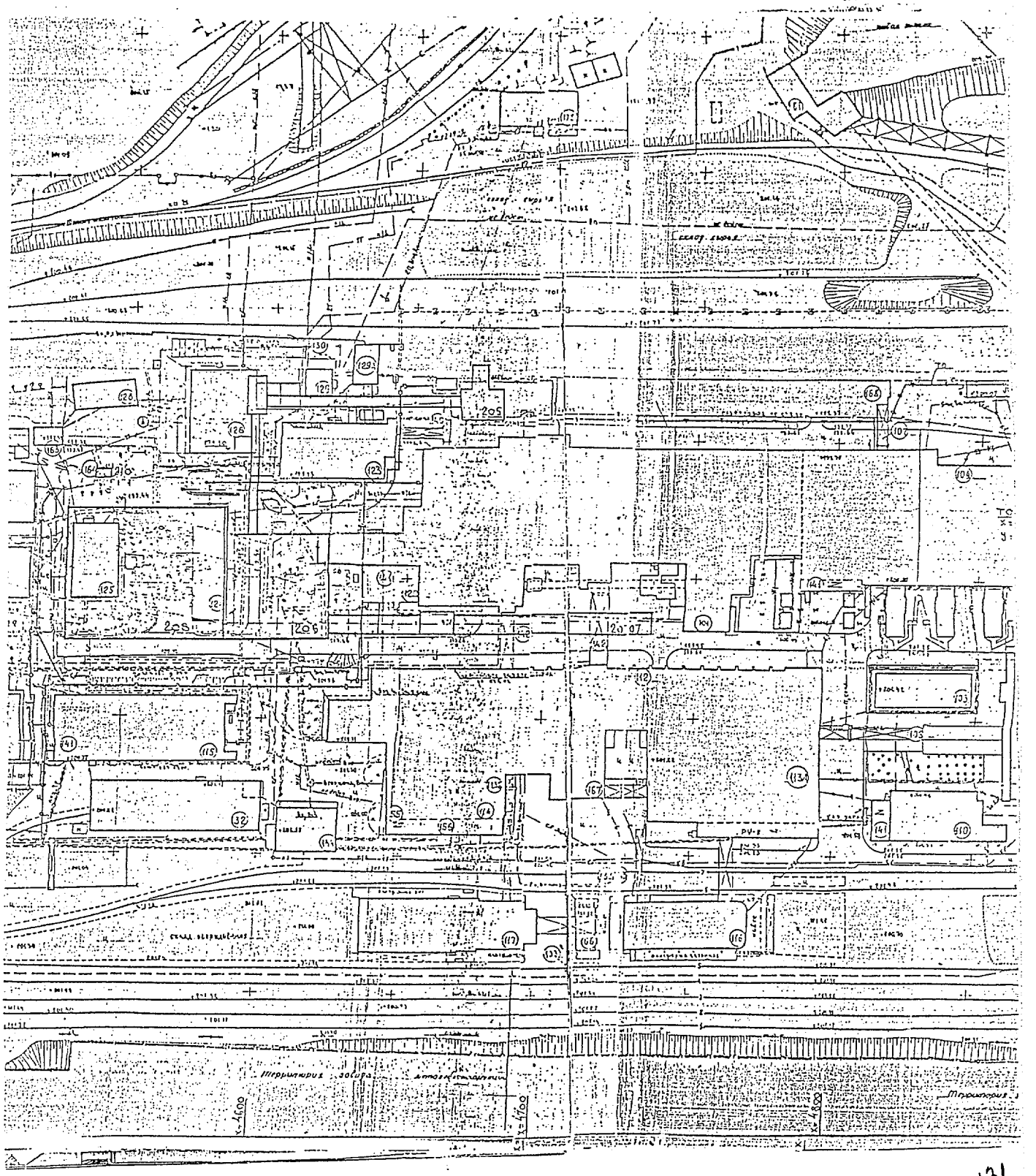

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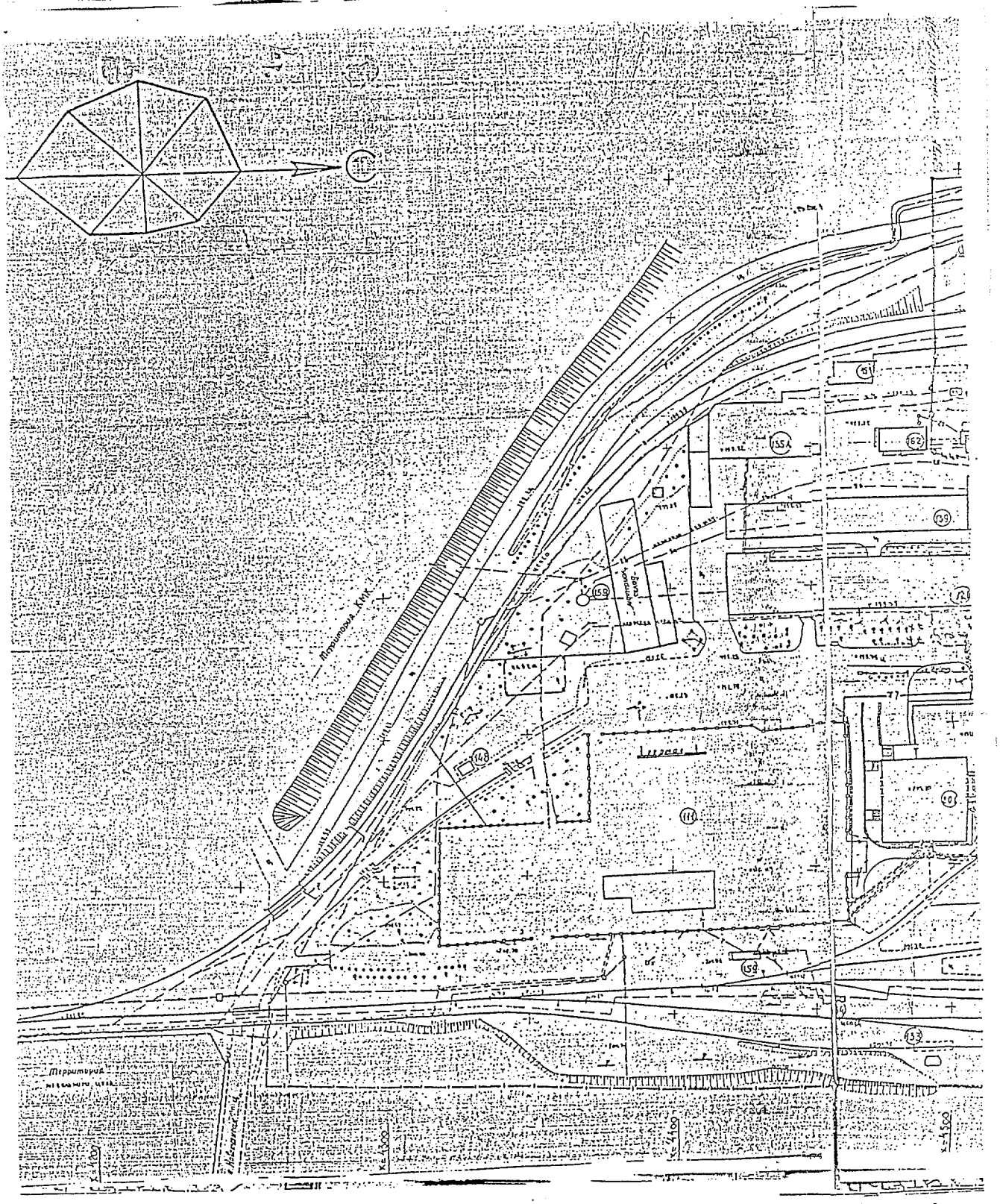

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Ч	Помещение	Строящ. планируемое
	Газоходы, дымососы	
	Установка электрофильтров за печами	— " —
	Дымовая труба	— " —
	Сети газоснабжения	— " —
	Газоходы, дымососы	— " —
	Отделение дробления гипса с галереями	— " —
	Скиповый склад клинкера с бункерами	— " —
	Доставок	— " —
	Клинкерная галерея	— " —
	Отделение цементных мельниц	— " —
	Резервуар теплой воды	— " —

Условные обозначения

- Существующие здания и сооружения
- Реконструируемые здания и сооружения
- Проектируемые здания и сооружения
- Существующие автодороги и проезды
- Проектируемые автодороги и площадки
- Существующие железнодорожные пути
- Реконструируемые железнодорожные пути
- Проектируемые железнодорожные пути
- Существующие откосы
- Ограда железобетонная
- Ограда металлическая
- Стенка подпорная
- Граница земельного отвода
- Отдельно стоящие инженерных коммуникаций
- Существующие сети
- Электрокабель низкого напряжения
- Электрокабель высокого напряжения (в траншее)
- То же (в коллекторе)
- ЛЭП низкого напряжения на опорах
- ЛЭП высокого напряжения на опорах
- Воздушная проводная линия связи
- Паропровод, конденсатопровод, горячее водоснабжение
- Теплотрасса
- Водопровод производственный
- Водопровод питьевой воды
- Водопровод на опорах
- Водопровод обратного водоснабжения (обратный)
- Водопровод обратного водоснабжения (прямой)
- Канализация бытовая
- Канализация дождевая
- Канализация напорная
- Канализация производственная
- Цементопровод, газопровод на опорах
- Паропровод на опорах
- Существующее благоустройство
- Отдельно стоящее дерево
- Кустарник групповой посадки
- Кустарник рядовой посадки
- Рядовая посадка деревьев
- Газон
- Точка выделений с координатами

Примечания:
1. Настоящий лист разработан на генеральном плане по состоянию на 01.01.90 ГП-1 с использованием чертежей технологического отдела.
2. Система высот Балтийская.
3. Система координат условная кузнецкого металлургического комбината (от оси мартеновской печи).
4. На данном чертеже источники выделения вредных веществ существующего положения (точки 1...14) не несены.

Разработка 1.01.91				126-0-ГП	
Гл. спец.				Кузнецкий цементный завод	
Нач. отд.				Ген. план. Экспликация помещений	Стадия / Лист / Листов
					Р / 1 / 1

А-1

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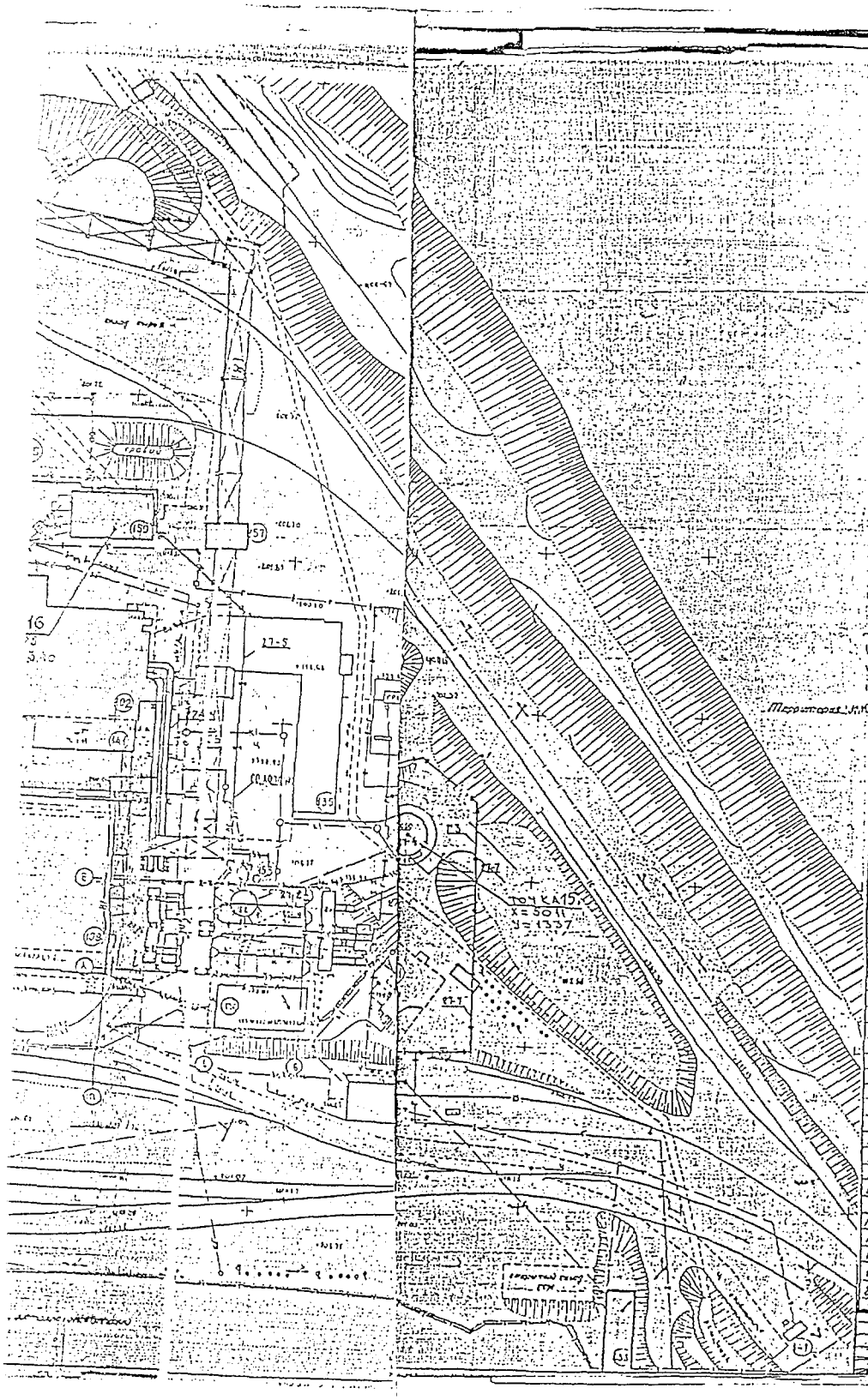

Экспликация зданий и сооруж

Атр. номер	Наименование зданий и сооружен
101	Главный производственный корпус
102	Сырьевое отделение
103	Электроподстанция при сырьевом от[illegible]
	[illegible]
104	Бытовые помещения сырьевого отделе[illegible]
105	Одноэтажный склад угля и известняка
106	Установка сырого шлака
107	Галерея в отделение сырьевых мельниц
108	Сушильное отделение шлака
109	Галерея от сушильного отделения в [illegible]
	ниц цементных
110	Электрообогревательная мастерская
111	Главная понизительная подстанция
112	Склад клинкера
113.5	Отделение цементных мельниц (пасп[illegible]
113.6	Отделение цементных мельниц (пасп[illegible]
114	Электрофильтры отделения цемент[illegible]
115	Железобетонная
116	Дымовая металлическая
117	Цеховая железобетонная
120	Электроподстанция печного отделения
121	Механическая мастерская
123	Котельная
124	Водоуправление, лаборатория
125	Бытовой корпус
126	Столовая
128	Медпункт
129	Насосная питьевой воды
129.5	Насосная технической воды
130	Резервуары хоз. питьевой воды
132	Склад смазочных мат
133	Заводские весы
134	Пост ЭЦ
135	Автотаро[illegible]
135.1	Автотаро[illegible] цементного
135	Помещение КИП
137	Локомотивное депо
138	Склад масел
139	Ремонтно-строительный цех
140	Галерея от склада в весовое отделе[illegible]
141	Транспортерная подстанция
142	Галерея от печного отделения в [illegible]
	клинкера
144	Склад ОКСа
147	Насосная станция под охлажденной [illegible]
	питьевой воды
148	Проходная [illegible]ожная
149	Проходная [illegible]ерная
150	Силосы сыр[illegible]вой муки
151	Ремонтный [illegible]ел
152	Насосная станция перекачки компо[illegible]
	сита
153	Резервуары [illegible]ита
	[illegible]
155	Моторное отделение
156	Электроподстанция
157	Трансформаторная станция
158	Скважина №[illegible] хоз. питьевой воды
159	Помещение [illegible]ля обогащения питьевой во[illegible]
161	Скреперная
162	Проходная
163	Насосная станция оборотного водо[illegible]
	[illegible]жения
164	Резервуар [illegible]ротной воды
165	Ремонтная [illegible] цех мастерская
166	Контора [illegible]монтажного цеха
167	Установка эл[illegible]ктрофильтров к мельн[illegible]
	№ 1–8
168	Сушильное [illegible] отделение известняка
[illegible]	[illegible]
171	Склад метал[illegible]ла и отдела элект[illegible]
172	Контора це[illegible]го грануляции
201	Центральный [illegible] бытовой корпус

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Схема газоочистной установки вращающейся печи №2 цеха „Обжиг"

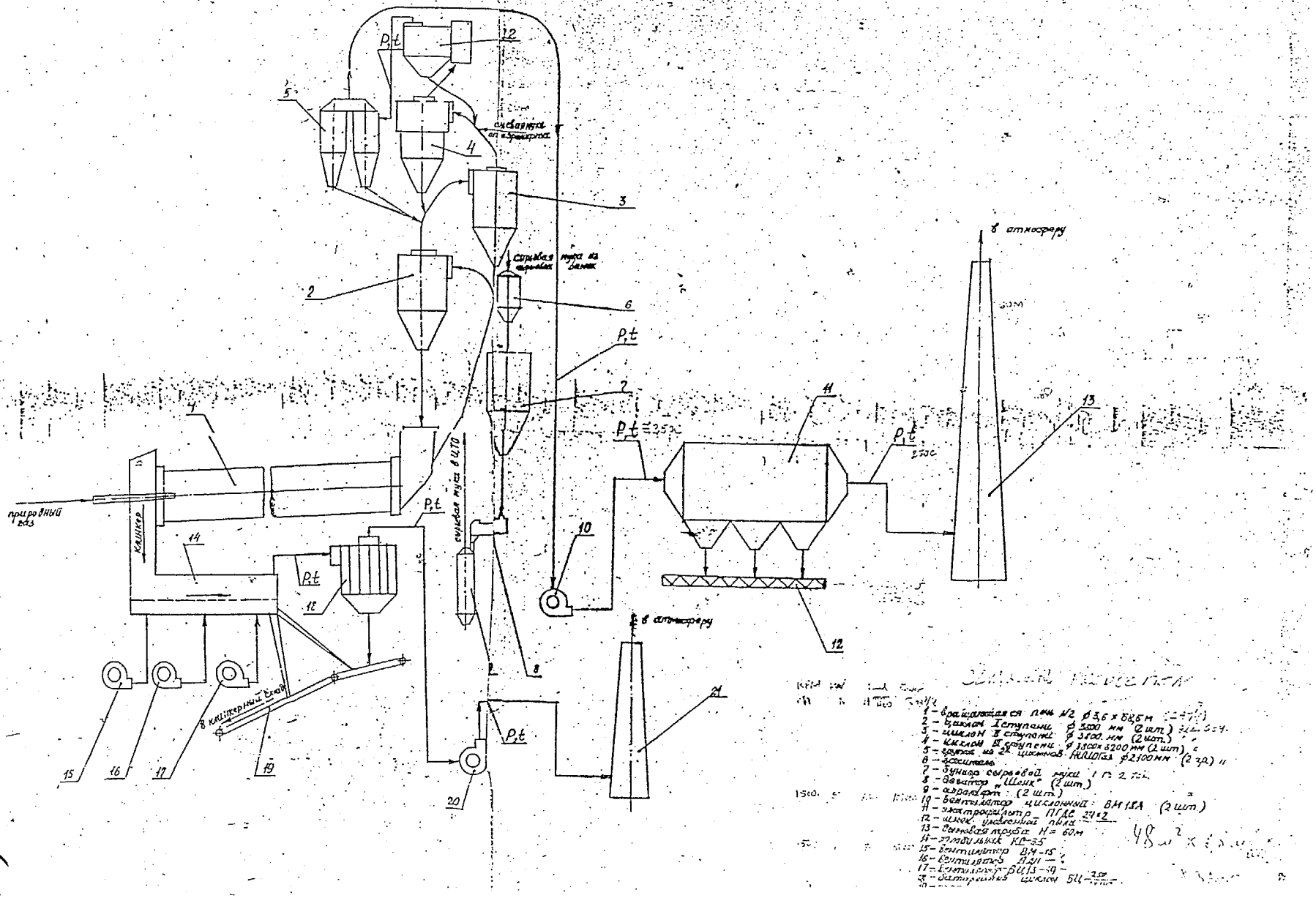

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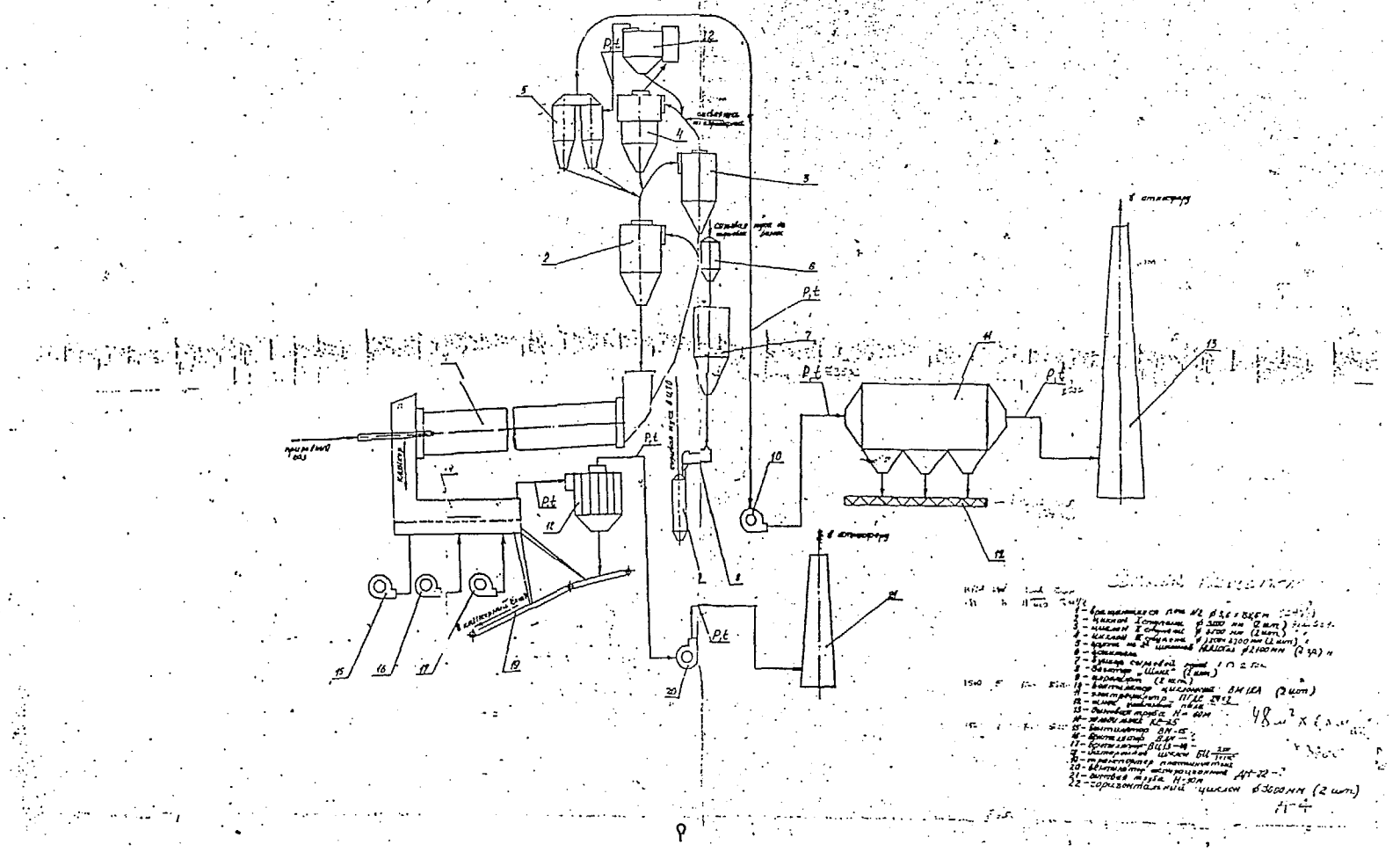
Схема газоочистной установки вращающейся печи №2 цеха „Обжиг"



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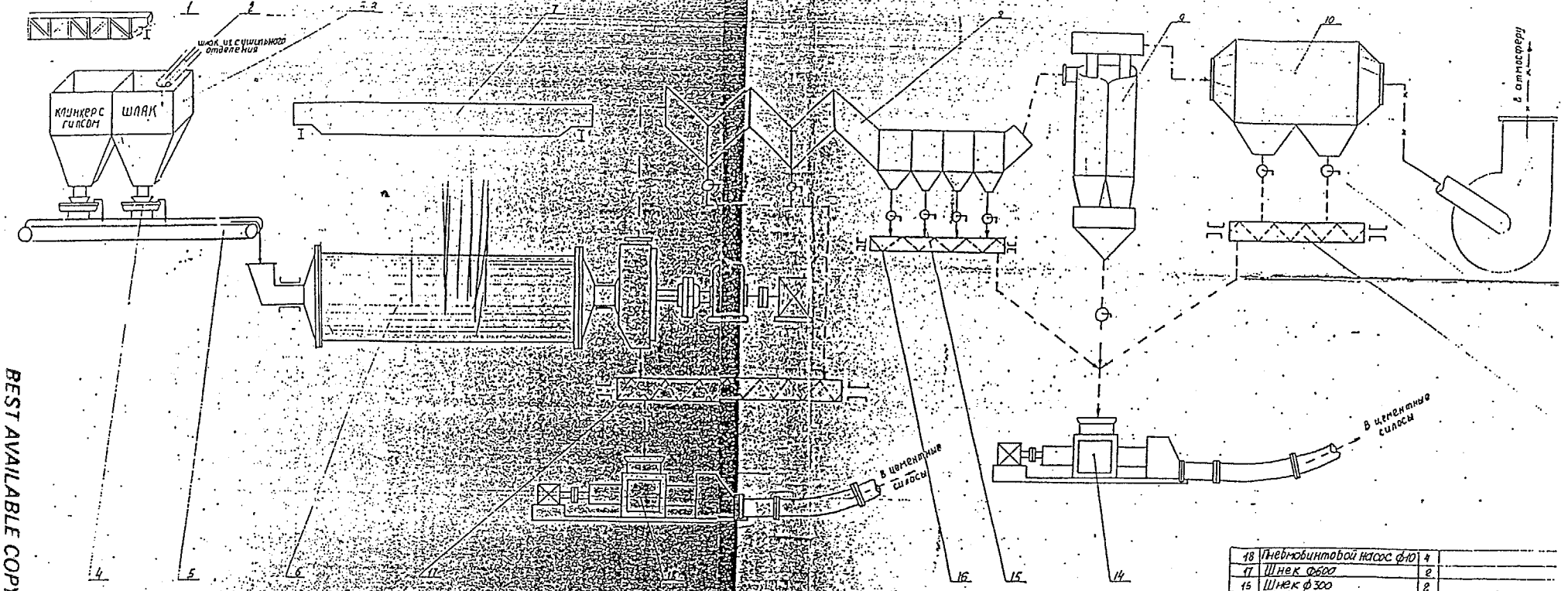
ТЕХНОЛОГИЧЕСКАЯ СХЕМА ПОМОЛА ЦЕМЕНТА



18	Пневмовинтовой насос ф10	4	
17	Шнек ф600	2	
15	Шнек ф300	8	
15	Мигалка		
14	Пневмовинтовой насос ф6	2	
13	Шнек ф300	5	
12	Мигалка	8	
11	Вентилятор ВД-10	6	
10	Электрофильтр ЦВСК	4	
9	Циклон РИНОЛАЗ ф400	2	
8	Питающие дозаторы	4	[illegible]
7	Крюковой кран Р-5т	2	
6	Шаровая мельница	8	[illegible]
5	Ленточный транспортер	8	В-650 L-43м
4	Тарельчатый питатель	16	
3	Бункер	16	
2	Ленточный транспортер	1	В-800

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APPENDIX B

АО "Кузнецкий цементный завод"
г.Новокузнецк

Утверждаю:
Технический директор
АО КЦЗ
Батршин Р.Р.

"___"_____95 г.

Technico-economic background of the project introduction

Технико-экономическое обоснование внедрения проекта "Система автоматического управления помолом и приготовлением сырьевой смеси"

"automatic system of raw mix preparation control grinding

Разработчик проекта: НПКП "Кодер", г.Новокузнецк

1. Внедрение данного проекта позволит увеличить часовую производительность вращающихся печей, тем самым повысив объем выпускаемой продукции, снизить энергозатраты на производство клинкера.

Исходные данные для расчета:

Показатели	Базовый вариант	Новый вариант
1	2	3
Годовой объем выпуска продукции (клинкера), тыс.т.	236	257.2
Полная себестоимость продукции, руб/1т	106000	101511 / 101790
Производительность вращающихся печей, т/ч	65.6	69.9
Коэффициент использования	0.41	0.42
Расход электроэнергии на обжиг 1т. клинкера, квт/ч	70	67.9 (снижение на 3%)
Расход условного топлива:на обжиг 1т. клинкера, кгут	196 kg/fuel/t	190.12 (снижение на 3%)
Расход сжатого воздуха на 1т. клинкера, тыс.м^3	0.716	0.695 (снижение на 3%)
Стоимость электроэнергии, руб/1 квт.ч.	135	135
Стоимость условного топлива, руб/1 тут	163000	163000
Стоимость сжатого воздуха, руб/1000 м^3	25500	25500
Условно-постоянные расходы, руб/1т.	29100	21243
Дополнительные единовременные затраты на приобретение нового импортного оборудования, руб.	-	388120200 (76102 доллара)
Нормы амортизационных отчислений на приобретение импортного оборудования, % а) компьютеры; б) дозатор известняка	 - -	 13.63? 11.3

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1). Снижение затрат по электроэнергии на 1 т. клинкера
135 * (70 - 67.9) = 283.5 руб.

2). Снижение затрат по условному топливу на 1 т. клинкера
163000 * (196 - 190.12) = 958.44 руб.

3). Снижение затрат по сжатому воздуху на 1 т. клинкера
25500 * (0.716 - 0.695) = 535.5 руб.

4). Снижение условно-постоянных расходов
29100 * 0.09 = 2619 руб.

5). Дополнительные амортизационные отчисления по установке нового импортного оборудования
35102 * 5100 * 0.1363 = 24400453 руб.
41000 * 5100 * 0.113 = 23628300 руб.

Всего: 48028753 руб..

На 1 т. клинкера:
48028753 руб. / 270000 =177.88 руб.

6). В результате себестоимость 1т. клинкера после внедрения проекта составит:
106000 - 283.3 - 958.44 -535.5 - 2619 + 177.88 = 101782 руб/1т.

7). Экономический эффект равен:
Э = (106000 - 101782) * 257200 = 1.084.869.600 руб.

8). Срок окупаемости проекта:

$$\frac{98102 * 5100}{1.084.869.600} = 0.46 \text{ года,}$$

где (98102 $ * 5100) - стоимость проекта (руб.)

2. За счет улучшения аэродинамического режима печей (снижение объема отходящих газов), повышения качества выпускаемой продукции прогнозируется уменьшение выбросов в атмосферу на 3-5%.

3. Снижение энергозатрат в производстве от внедрения проекта составит - 3%.

Расчет составил:

Инженер-технолог Кузнецова А.И.

Инженер-экономист Осташова Л.И.

АО "Кузнецкий цементный завод"
Россия, г.Новокузнецк

Estimated budget for the "automatic system of grinding + raw mix preparation control" project introduction

Потребность финансирования проекта системы автоматического управления помолом и приготовлением сырьевой смеси.

Stage?. System for raw mix weighing

Этап 1. Подсистема взвешивания и дозирования сырьевой смеси.

Проект выполняет:
научно-производственное коммерческое предприятие "Кодер". г.Новокузнецк

Компьютерно-контроллерная аппаратура управления, стандартное программное обеспечение. OCTAGON SYSTEMS, ICONICS (США).	**35102$**
Дозатор известняка. SCHENK.	**41000 $**
Проектирование, монтаж, пуско-наладочные работы. KODER.Ltd г.Новокузнецк.	**22000 $**
ИТОГО:	**98102 $**

Технический директор
Батршин Р.Р.

"___" _____ 1995 г.

kcz/p2.doc

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APPENDIX C

Appendix C Portable Test Equipment

Combustion Analyzer:

A Combustion analyzer that meets the following specifications and manufactured by Enerac, CEA Instruments, Land Combustion, Teledyne Analytical Instruments or equal is suitable for this application.

Measured Parameters: Flue Gas Concentrations for Oxygen, Carbon Dioxide, Carbon Monoxide, and Temperature

Calculated Parameter: Flue Gas Excess Air Combustion Efficiency

Analyzer Performance:

Oxygen; 0 to 25% volume
+/- 0.1% volume resolution
+/- 0.2% volume accuracy
Carbon Dioxide; 0 to 20% volume
+/- 0.1% volume resolution
+/- 0.2% volume accuracy

Carbon Monoxide; 0 to 2000 parts per million volume (ppmv)
+/- 2 ppmv resolution
+/- 5% of reading accuracy

Flue Gas Temperature; 0 to 1100°Centigrade
+/- 1 °C resolution
+/- 2 °C accuracy

Flue Gas Excess Air; 0 to 1000%
+/- 1% resolution
+/- 10% accuracy

Analyzer Features:

- Portable, battery powered, capable of operating a minimum of 6 hours on a single charge.

- Battery Charger for 220 volt, 50 Hz power and power cord.

- Condensation trap with re-usable desiccant. Desiccant to be reactivated by drying in an conventional oven or microwave oven.

- Disposable particulate matter filter capable of removing one micron particles.

- Auto "zero" upon turning on the analyzer. "Zero"; ambient air 20.9% O_2, 0% CO_2, 0% CO

- Inconel probe, 24 inch length minimum and 10 feet of connecting hose to the analyzer.

Span Calibration Kit:

- Certified calibration gases, range 10% O2, 6% CO2, and 1000 ppmv CO Pressurized cylinder container(s) minimum 10 cubic feet.

- Calibration gas manifold and connection to the probe.

Spare Parts: Desiccant, 2 quarts minimum
Disposable Filters, 24 minimum

Digital Thermometer:

Digital thermometer no. 52 as manufactured by Fluke Corp. PO Box 9090, Everett, WA 98206, USA complete with 80PK-3A surface probe (temp range 0C to 260C) and 80PK-2A immersion probe (temp range -196 to 1090C.)

Multimeter:

Multimeter model 85 as manufactured by Fluke Corp. PO Box 9090 Everett, WA 98206, USA. Instrument to measure volts, amps, ohms AC and DC.

Wattmeter:
Wattmeter equal to 2000A Wattprobe as manufactured by TIF Instruments, Inc. 9101 NW 7th Ave, Miami Fl. 33150 USA
Range 280/560 volt 20KW and 200KW ranges, 9volt battery

Infrared Thermometer. Infrared digital thermometer shall be equal to Model RAYPM30L2U as manufactured by EPD Technology Corp., 14 Hayes Street, Elmsford, NY, 10523, USA. Unit range: -10 to 540 C with digital read out, 9 volt battery and 220 volt, 50 cycle adaptor.

Velocity and Pressure Meter: pressure range from -250 to +250 mm water, velocity from 0 to 30 meters/sec., and temperature range from 0 to 300C. Unit shall have digital or analog readout, pitot tube probe and thermocouple sensor, power options - battery and 220 volt, 50 cycle, battery recharger and instruction book.

APPENDIX D

НАУЧНО-ПРОИЗВОДСТВЕННОЕ КОММЕРЧЕСКОЕ ПРЕДПРИЯТИЕ
"КОДЕР"
(Товарищество с ограниченной ответственностью)

Для служебного пользования

Утверждаю:
Технический директор
АО Кузнецкий цементный завод
Батршин Р.Р.

"_____ 95 г.

Appendix D
Mass Weighing System Proposal

(Original available but not translated)

Система автоматического управления помолом и приготовлением сырьевой смеси

Подсистема взвешивания и дозирования сырьевой смеси
(Эскизный проект)

Разработано:
Директор НПКП "Кодер"
Нагайцев Ю.В.
"25" 01 95 г.

Согласовано:
Главный энергетик
АО Кузнецкий цементный завод
Воробьев А.П.
"25" 01 95 г.

г.Новокузнецк, 95 г.

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Tables

Table 1 ATMOSPHERIC DUST EMMISSIONS, 1994
In Tonnes

Month	Raw Material Grinding	Kilns	Slag Drying	Clinker Grinding	Other
January	14.36	403.8	2.15	19.43	21.9
February	13.45	211.62	2.02	11.53	21
March	13.76	206.44	0.92	5.93	22
April	7.95	224.84	1.61	8.83	21.9
May	9.78	256.34	1.93	10.3	21.9
June	2.59	95.9	1.01	10.5	21.9
July	6.68	323	1.84	12.14	21.9
August	3.92	324.36	1.87	14.37	21.9
eptember	4.65	304.29	1.76	12.76	21.9
October	6.43	315	1.9	14.48	21.9
November	9.5	279.17	1.83	12.34	21.9
December	4.6	78.74	1.1	7.87	22
Total	97.67	3023.5	19.94	140.48	262.1

Table 1

Total
461.64
259.62
249.05
265.13
300.25
131.9
365.56
366.42
345.36
359.71
324.74
114.31
3543.69

Table 2

Natural Gas Consumption, 1994

	R/1000 M3	1000 M3	Cost, R
Jan.	25,110	6584	165,324,240
Feb.	27,621	4652	128,492,892
Mar.	33,145	4333	143,617,285
Apr.	38,448	3940	151,485,120
May.	42,293	3994	168,918,242
Jun.	46,945	1343	63,047,135
Jul.	50,231	3346	168,072,926
Aug.	54,752	3141	171,976,032
Sep.	59,131	3163	187,031,353
Oct.	62,679	3956	247,958,124
Nov.	67,066	4028	270,141,848
Dec.	73,773	1996	147,250,908
Total		44476	2,013,316,105

* 1/95 cost, includes 23% tax

1994 production = 400,000 tonnes
Nominal production capacity = 1,5000,000 tonnes

M3= cubic meters

Table 3 Electrical consumption and costs, 1994

Electrical Consumption, 1994

Month	KWH	R/KWH	Energy Cost, R	Demand Cost, R	Total Electric Cost, R
Jan.	12,578,000	7.08	89,052,240	10,604	89,062,844
Feb.	10,295,000	7.08	72,888,600	10,604	72,899,204
Mar.	9,681,000	7.08	68,541,480	10,604	68,552,084
Apr.	9,553,000	7.08	67,635,240	10,604	67,645,844
May.	9,250,000	7.08	65,490,000	10,604	65,500,604
Jun.	4,479,000	11.08	49,627,320	10,604	49,637,924
Jul.	7,922,000	11.08	87,775,760	16,852	87,792,612
Aug.	6,691,000	11.08	74,136,280	16,852	74,153,132
Sep.	6,785,000	11.08	75,177,800	16,852	75,194,652
Oct.	8,214,000	11.08	91,011,120	30,795	91,041,915
Nov.	8,041,000	17	136,697,000	36,280	136,733,280
Dec.	5,212,000	17	88,604,000	36,280	88,640,280
Total	98,701,000		966,636,840		966,854,375

1994 production = 400,000 tonnes
Nominal production capacity = 1,5000,000 tonnes

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PREFACE
Audit Report
Novokuznetsk Poultry Plant

This report is the result of an Industrial Environmental Audit carried out April 25 - May 26, 1995 at the Novokuznetsk Poultry Plant. The audit was made by a joint US - Russian team with the support of the United States Agency for International Development USAID) Environmental Policy and Technology (EPT) Project. There were 6 Americans consultants and 17 Russian specialists from the scientific research and design institutes, enterprises and environmental regulatory agencies on the team.

This audit was performed as a part of a training program for the Russian team members on conducting industrial environmental audits.

Factual information provided by Novokuznetsk Poultry Plant formed the basis for evaluating environmental, energy efficiency and worker health and safety conditions at the facility. Opinions formed from this information are the authors and do not necessarily reflect the views of USAID or EPT.....

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AUDIT REPORT
Poultry Plant

Description of the Overall Industrial Audit Program

There is an immediate need for rapid improvement in industrial energy efficiency due to a variety of poor energy utilization practices and lack of proper maintenance of energy systems. Related to the low energy efficiency of facilities is a higher emission of particulate to the atmosphere from the coal-fired boilers. Higher than design coal burning rates subsequently overload the flue gas clean-up equipment which worsens the emission problem. Emission penalties do not alone provide sufficient economic incentive to proceed with projects to reduce emissions. Energy efficiency improvements are cost-effective within the current energy economy and can provide economic incentives that support the concern to clean-up the environment. These energy efficiency improvements will also result in a improvement in air quality by reducing emissions at the source.

Increases in energy prices to equivalent world prices have put additional pressures on industrial firms to conserve energy. Changes within the economic system (energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Along with the industrial audit program to demonstrate the effectiveness of energy efficiency improvements, the overall EPT program provided training on energy efficiency audit practices, use of energy performance measurement equipment and evaluation of energy conservation opportunities.

The Industrial Audit Project is comprised on four distinct tasks:

1. Industrial plant screening
2. Industrial plant energy audit
3. Purchase, ship, and receive equipment to implement audit recommendations
4. Implementation and monitoring

Screening of fifteen industrial plants and communal boilers, the cement plant and the ZapSib Combined Heat and Power Plant was accomplished to provide a basis for selecting the plants to be audited. Criteria used in this selection included;

- Opportunity for energy savings (with a focus on emission reduction),
- Reasonable payback period in Ruble energy economy (also calculated in world prices),
- Potential replicability of energy saving options in similar plants or systems,
- Future viability of the plant in the changing economy and operation of the district heating system,
- Size of the plant,
- Ownership,
- Location and impact on local ambient air quality and
- Other activities such as joint ventures or other bi-lateral aid projects.

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The cement plant audit is given due to it's significant impact on the local environment of Novokuznetsk. The additional plants selected for the audit phase are:

1 Abashevkaya Communal Boiler,
2 Ziryanovskaya Communal Boiler,
3 Selected boilers at the ZapSib Combine Heat and Power Plant,
4 The ice cream and cold storage plant, and
5 The poultry processing plant.

An energy audit report has been prepared for each of the six facilities audited and a seventh report summarizing the results of the stack particulate sampling accomplished at each of the five facilities other than the cement plant. The seven reports represent the complete reporting of the energy/environmental audit activities conducted in Novokuznetsk, Russia during the period of April 25 - May 26, 1995.

The energy audit activity, described in detail in each facility report, consisted of a determination of the overall energy efficiency of the plant to identify no/low cost equipment opportunities with short term payback. An assessment was made of the technical and management capabilities and capital investment decision-making process regarding energy conservation applications. At the completion of the energy audit, equipment specifications and other documents required for procurement of U.S. and NIS manufactured equipment or materials will be prepared. Particulate sampling of the stack gasses of the five facilities with coal-fired boiler systems was conducted to determine the current stack gas loading of particulates and particulate emission rates.

Equipment specified in the energy audit will be procured, cleared through customs, and delivered to the plant. Purchased authorization requests will be prepared for approval by USAID/Washington and USAID/Moscow. Requests for Quotes or Tenders as well as purchase orders when suppliers are selected will be issued from the EPT/Moscow office to support the interest in identifying the maximum ability for these demonstration projects to be replicated by other facilities in Novokuznetsk. Equipment will be shipped to the audited sites in Novokuznetsk and technical support will be provided by the Russian team members working on these audits.

In the implementation phase, requirements for installation of the material will be identified. Where possible, this will be done by the personnel of each facility, or alternatively, by Novokuznetsk contractors. Following completion of the installation, an assessment will be made of the effectiveness of the energy conservation application and the effect on emission reduction.

Results of the audit conducted in the Poultry Plant are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit.

Section 1

Executive Summary

The industrial sector in Novokuznetsk is very well developed, with many large and heavy industries. In addition, there are 160 boiler houses at medium size industries and district heating systems that consume a large percentage of the regional energy use and are major contributors to the particulate emissions within the residential districts of the city. The facilities chosen for the EPT Industrial Audit project are representative of many companies or similar facilities within the city, making them ideal targets for the industrial energy audit work since potential replication is very high. Many of these medium size plants are very viable, but have not yet implemented energy conservation activities. Changes within the system (increased energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Parallel emission reductions can be expected with increases in energy efficiency

Results of the audit conducted in the Poultry Plant are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit.

This large poultry plant is a major supplier of both eggs and chicken meat in the area. It is integrated both vertically and horizontally to maximize utilization of their primary and secondary resources. In addition to their egg and meat production, smaller ancillilory product line include dehydrated eggs, bakery products, noodles (uses eggs), pillows (uses feathers), fertilizer (chicken manure) and a mayonnaise plant is under construction. All products are direct marketed by company owned trucks on a daily basis. Although sales are currently in balance with production levels, it is believed the fresh egg and meat market is saturated and future growth lies with the higher value added ancillary markets such as mayonnaise and possibly expansion of the marketing area.

The company owned boiler house supplies steam and hot water to the chicken processing area and hot water to the employee housing complex. In addition, the boiler house sells steam and hot water to an adjacent meat processing plant. The boiler house has three model DKVP 20-13 steam boilers rated at 20 tonnes of steam per hour or 11.2 Gcal. However, due to poor coal quality, the boilers are derated about 10 percent. The boilers make steam at 13 Kg/cm2 pressure or 180 C.

Normally, the hot water temperature is controlled to meet the heat requirements of the apartment complex in accordance with a defined schedule based on outside air temperature. However, for 4-5 days per month when young chicks are received, water temperatures are increased to supply the necessary heat for the chicks. During these periods, the apartment complex and other buildings within the chicken processing area become overheated and the excess heat is wasted by opening windows or other ventilation ports; approximately 100 percent excess heat is supplied to the apartment complex.

Based on the energy audit performed, the following short and long term energy conservation recommendations are offered:

Short Term Recommendations:

1. Repair and adjust boiler no. 3 air systems to achieve design conditions.
2. Add over fire fan as in original design outlet pressure 50kg/m2
3. Repair air and water leaks.
4. Install insulation to reduce heat loss on steam and water distribution lines. (see Appendix D and F)
5. Clean up the boiler house.
6. Check pump flows and heads and adjust for maximum efficiency.
7. Add a automatic control system to the boilers. (see Appendix E)
8. Clean heat transfer surfaces on a regular basis.
9. Provide automatic temperature control on heating water supplied to housing units. (see Appendix F)

See attached Short Term Energy Conservation Opportunities Table.

Total savings based on ECOs 1,2,3,4 and 5 will be 13237 t/yr coal, 54 percent of 1994 consumption, and 3 percent of the electricity.

Funding Recommendations:

EPT should provide $100,000 to fund ECO 1, 2, 3 and part of 5. Funding for parts of ECOs 1, 2, and 5 should be provided by the owner.

Section 2

Plant Description

Key Plant Data

Name of Facility:	Novokunetsk Poultry Processing Plant, (Joint Stock Company "Agroprom")
Address:	654944 SAGORSKI PLACE, Novokuznetsk, Russia
Key Contacts:	Vallintine Antonovitch Yfrymov, General Director Tel. 43-22-75 Vasily Eremtov, Head of Boiler House
Head Office Location:	As above.
Date of Plant Commissioning:	1972; Private stock company since 1994.
Number of Employees:	550

General

This large poultry plant is a major supplier of both eggs and chicken meat in the area. It is integrated both vertically and horizontally to maximize utilization of their primary and secondary resources. In addition to their egg and meat production, smaller ancillilory product line include dehydrated eggs, bakery products, noodles (uses eggs), pillows (uses feathers), fertilizer (chicken manure) and a mayonase plant is under construction. All products are direct marketed by company owned trucks on a daily basis. Although sales are currently in balance with production levels, it is believed the fresh egg and meat market is saturated and future growth lies with the higher value added ancillary markets such as mayonnaise and possibly expansion of the marketing area.

Chicken Processing

Both broiler and hen one day old chicks are purchased from an outside supplier and raised to maturity. Broilers are processed into meat after 55-60 days, Hens are kept for one year as layers and then processed into meat. The average bird population is about 650 thousand, with a continuing addition of chicks and processing of mature birds. Approximately 80 million eggs and 1000 tonnes of meat are produced per year.

The major use of heat is for heating the chicken houses during cold weather months; the total 48,000 m^2 for floor area in 28 buildings. The day old chicks require temperatures of 40 C and as they mature the temperatures are decreased to a minimum of 18 C. In cold weather,

supplemental electric heating is used periodically for houses having young chicks. Smaller amounts of heat are required for the chicken meat processing building and the administrative building.

Apartment Complex

The employee housing complex consists of 550 apartments (about 2000 people), a school and community center. The boiler house supplies hot water for space heating and domestic hot water. Hot water supplied to the apartment complex is not metered and residents have no control of individual apartment temperature (e,g. no thermostats). Visual inspection of the residential apartment units indicated the potential for substantial reduction in energy demand by application of such measures as weatherstripping of windows and doors, insulation of attics and sidewalls and use of thermostatic controls within the living units. Although the determination of the potential energy savings from the residential units was outside the scope of this project, it is important to note that application of energy conservation measures to the residences could reduce the heat demand on the boilers by an estimated 10-30 percent. Due to low boiler efficiencies and distribution losses, all savings in residential end use translates to at least twice the amount of savings in fuel consumption and environmental emissions.

Governmental regulations limits the payments for heat by the residents to about 15 percent of the total costs; the balance is absorbed by the company. Consequently it would be of benefit to the company to implement energy conservation measures within the apartment complex.

Boiler House

The company owned boiler house supplies steam and hot water to the chicken processing area and hot water to the employee housing complex. In addition, the boiler house sells steam and hot water to an adjacent meat processing plant.

The boiler house has three model DKVP 20-13 steam boilers rated at 20 tonnes of steam per hour or 11.2 Gcal. However, due to poor coal quality, the boilers are derated about 10 percent. The boilers make steam at 13 Kg/cm2 pressure or 180 C. Steam heat exchangers at the boiler house produce the hot water supply at the required temperatures. Control of the water temperature is manual. Normally, the hot water temperature is controlled to meet the heat requirements of the apartment complex in accordance with a defined schedule based on outside air temperature. However, for 4-5 days per month when young chicks are received, water temperatures are increased to supply the necessary heat for the chicks. During these periods, the apartment complex and other buildings within the chicken processing area become overheated and the excess heat is wasted by opening windows or other ventilation ports; approximately 100 percent excess heat is supplied to the apartment complex.

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Operational Status

Chicken Processing

The chicken processing area has a low energy intensity and appeared to be a well operated area. Relatively small amounts of steam and hot water are used for defethering and washing. Waste heat recovery from the hot water was not considered as a potential energy conservation measure.

Chicken Houses

The primary energy use in the chicken houses was for space heating using fan blown heat exchangers. The temperature control was manual. Fans are used to provide ventilation air, and again, these are controlled manually. It was apparent that basic housekeeping measures such as cleaning of heat exchanger surfaces, fan grills and motors would result immediate energy savings and improve the operating life of the equipment.

Apartment Complex

As noted above, the apartment complex is in need of conventional weatherization measures, e.g. weatherstripping of doors and windows, insulation of the building envelope and control of space heating by thermostats. In addition, central control over overheating of the supply hot water is needed.

Boiler House

The boiler are reasonably operated notwithstanding that about half of the operating controls are missing or inoperable. Through conscientious efforts of the operators, excessive air emissions are low (by Russian standards) and boiler therma lefficiencies of about 50 percent are obtained.

Heat Distribution

The thermal insulation on steam and hot water distribution pipes was either missing or in need of repair on approximately 2000m of the 4000 m of piping. Occasional water/steam leaks were observed along the distribution pipe.

Current Plans for Energy Conservation/Environmental Control Pollution Control

The plant has no plans for improvement of energy efficiency or reduction of environmental pollution control.

Section 3

Plant Energy/Environment Profile

Energy Consumption and Cost Profile

Coal

"Gas Coal" grade coal is used to fire the three 11.2 Gcal/hour (design)boilers. Annual coal consumption for 1994 is given in Figure 1 (file ENERUSE, CHART 2); the values provide a nominal base line for measurement of the effectiveness of energy conservation measures that may be implemented in the following years. The monthly profile for steam production is given in Figure 2(file ENERUSE CHART 1) and the relative end use of the steam, as either steam or hot water, is given in Figure 3(file ENERUSE, CHART 4) and Table 3.

During 1994, the cost of coal was 86,000 rubles per tonne. The total cost for the 24,332 tonnes of coal during 1994 was 2.09 billion rubles.

Electricity

The plant obtains its electrical power through transmission lines from the adjacent meat processing plant. Consequently, the plant pays the base energy cost plus a 14 ruble/kwh commission to the meat processing plant, plus a VAT of 21.5 percent. Since the plant is identified as an agricultural business, it is exempt from demand charges. Recent history of total energy costs are:

- As of 1/94 24.3 R/kwh
- As of 12/94 86.2 R/kwh
- As of 5/95 93.6 R/kwh

Electrical energy consumption and cost data for 1994 are given in Figure 4.

Environmental Emissions and Penalties

Section 4

Audit Approach and Data Summary

Energy Audit

Audit of portions of the boiler house, chicken houses and processing plant were made the week of May 15, 1995.

Combustion tests were made on boiler 3. The combustion analyzer was a Bachrach set to heavy oil fuel as a coal setting was not available. The readings for efficiency, CO2, and excess air are not valid, other readings are valid.

Typical Readings

Boiler No.	CO	Oxygen	NOX	SO2	Stack Temp
3	0.105 percent	7.8 percent	380ppm	260ppm	333C

Boiler was operating at 24 m3/hr 100 percent nominal capacity.
Calculated CO2 13 percent, efficiency 82 percent percent measured.

A schematic mass flow diagram of the boiler is shown in Appendix A.

Calculation of combustion efficiency for boiler no. 3 (see Appendix A) was made and showed a combustion efficiency of about 75 percent.

Tests were also run on to measure air flows, air pressure and temperature. The boiler has a forced draft fan and an induced draft fan and a fine ash return fan. (see Appendix B)

Summary Results (see Appendix B)

Fan no.	Service	Flow M3/hr. Design	Flow M3/hr. Measured	Pressure mm H2O Design	Pressure mm H2O Measured
1	Combustion Air	27000	31500 (+31%)(2)	-----	27
2	Induced Draft	53000	41820 @116C (1) (-21 percent)	-----	-4.8
3	Ash Fan	1800	-----	-----	-----

4(3)(2) Combustion (ducts from front to back of boiler are numbered 1,2,3,4.)

Duct No.	Flow,m3	Temp. C	Pressure mm H2O
1	----- 3402	119	----- 1
2	----- 7402	123	----- 1.5
3	----- 2520	120	----- 1.5
4	----- 18173	120	----- 3.0

Visual observations of the stack plume showed very little smog and soot. (Estimate the Ringleman no. 0 to 1)

(1) measured by B. Mayweather with pitot tube boiler no 2.
(2) measured by W. Dries hot wire anemometer
(3) Air ducts to underside of stoker, four ducts total

Site Observations

The boilers are controlled manually by noting steam exit temperature and pressures. About half of the pressure and temperature indicators and controls are missing. The operator increases the fuel supply on a drop of steam pressure. The air flows are not changed, and all duct dampers and air flow vanes in the fans are set at fixed positions.

The air leaks in the duct work are present. Heat leaks due to no or damaged insulation are also present.

Water leaks in the system also are wasting energy.

Fan and pump operation at more or less than design conditions results in low efficiencies and excessive electricity use.

It is impossible to operate the boilers with proper efficiency and particle emission with the present conditions.

Based on measured fuel and heat output boiler no. 4 has an estimated thermal efficiency of 50 percent. (see Appendix C)

About 50 percent of the insulation on the approximately 4000m of distribution piping is missing or damaged. The heat loss from bare pipes is high and much heat is wasted.

An inspection chicken growing house no. 9 showed the outside air heating system in poor operating condition and had no automatic controls. Additional heat is provide for baby chicks with four 60kw electric heaters for part of the year.

Condensate from the processing plant is not returned to the boiler and is wasted.

Section 5

Energy Efficiency Recommendations

General Conclusions

The boiler plant is not operating at design conditions due to lack of maintenance, and missing or broken equipment and controls.

The plant has not had an adequate budget, technical staff or management to correct the conditions.

Short Term Recommendations

1. Repair and adjust boiler no. 3 air systems to achieve design conditions.
2. Add over fire fan as in original design outlet pressure 50kg/m2
3. Repair air and water leaks.
4. Install insulation to reduce heat loss on steam and water distribution lines. (see appendix D and F)
5. Clean up the boiler house.
6. Check pump flows and heads and adjust for maximum efficiency.
7. Add a automatic control system to the boilers. (see Appendix E)
8. Clean heat transfer surfaces on a regular basis.
9. Provide automatic temperature control on heating water supplied to housing units. (see Appendix F)

Short Term Energy Conservation Opportunities

Items numbers 1,2,3,4,5,and 6 should be done by the company. Portable test equipment will be furnished by EPT (see Appendix G). The payback will be less than one year.

Items 7 and 9 should be done only after items 1,2,3,4,5 and 6 are completed.

The payback for the boiler controls (no. 7 above) will be less than one year.
(see Appendix E for details)

The payback for (no. 5 above) pipe insulation will be about 0.8 year.(see Appendix D and Appendix F)

Long Term Recommendations

1. Repair and replace condensate return system
2. Install meters to measure heat to housing units.

3. Repair and renovate water treatment for heating water supply.

Energy Conservation Opportunities Investigated but Not Recommended

1. Provide automatic temperature control on chicken house no. 9 (see Appendix H)

APPENDICES

Poultry Processor 15 May 95 SH

Boiler No. 3

Appendix A

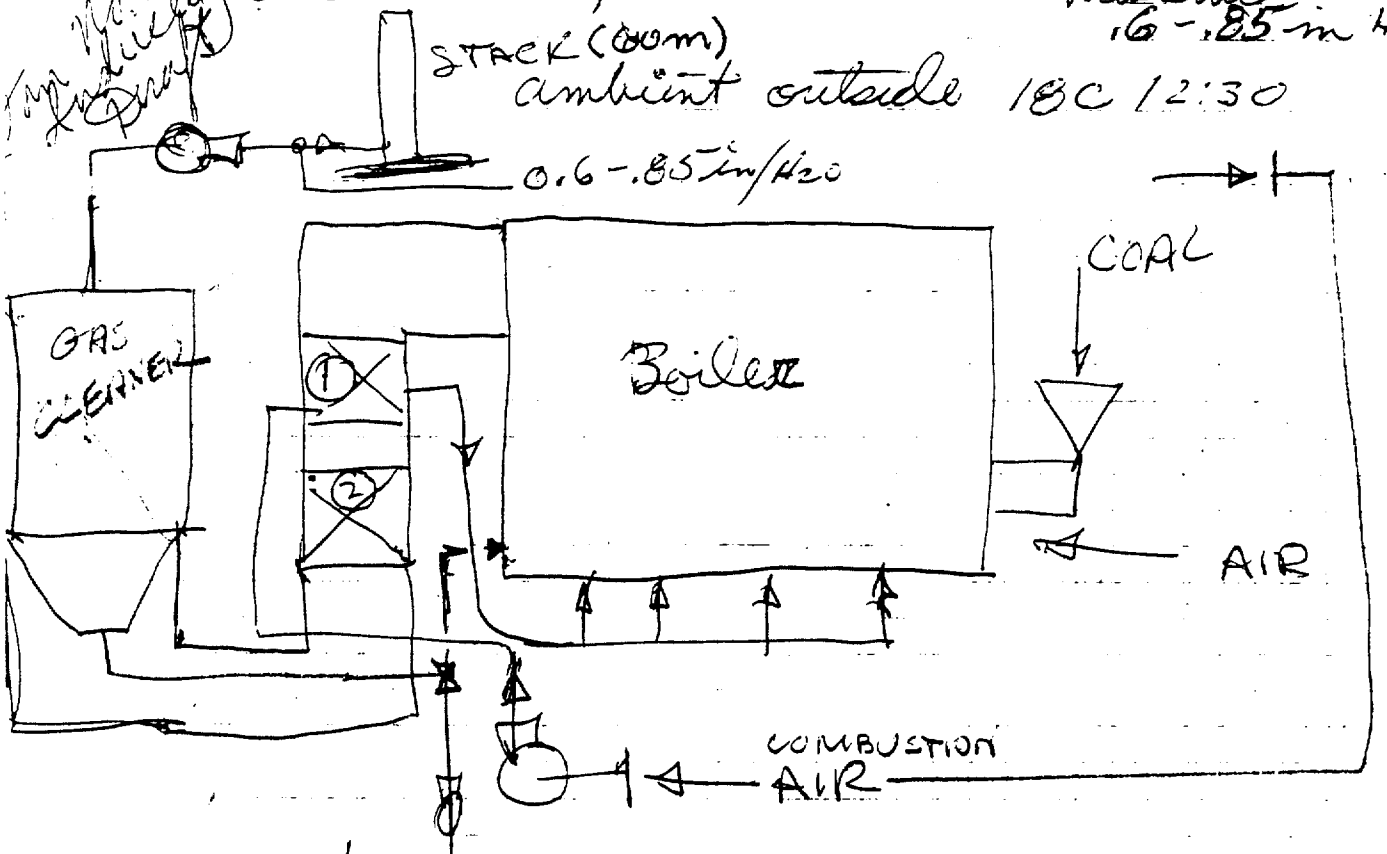
Pressure .6 - .85 in H2O

outlet 184°C

STACK (30m)

ambient outside 18C 12:30

0.6 - .85 in/H2O



① air preheater
② water preheater

Flow m³/hr	Boiler No. 3 Stack Temp	CO ppm	O2 %	Eff Heavy Oil	NOx ppm	SOx ppm	Steam Pressure
24	335	105	7.8	"82%"	380	260	10 kg/cm² (188C temp)

1130 - 1150

Comb. air Temp 116°C

CO_2 by calculation $O_2 + N_2 + CO_2 = 100\%$ $CO_2 \cong 13\%$

7.8 + 79

$\frac{7.8}{86.8}$ CO_2 = (100.00 − 86.80) = 13.20

Stack temp 550F

Total air 158% } chart B&W Chap 4
Excess is 58%

Eff: 75% Excess air 40% page 18 Fig. 6 AFM 85-12 Vol. I

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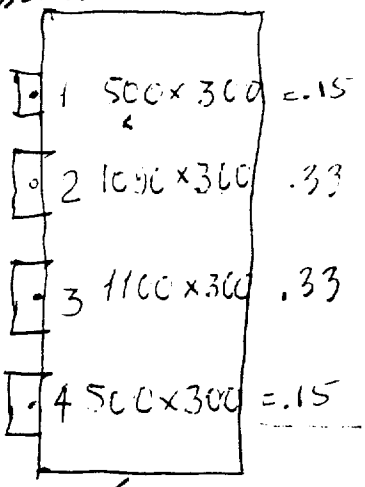
Poultry Processing 16 May 95 ACC

SH-2

11.13 Main flow 23.6 m³/h

12.06 " " 23.3 m³/h

Pressure 9.8 kg/cm²

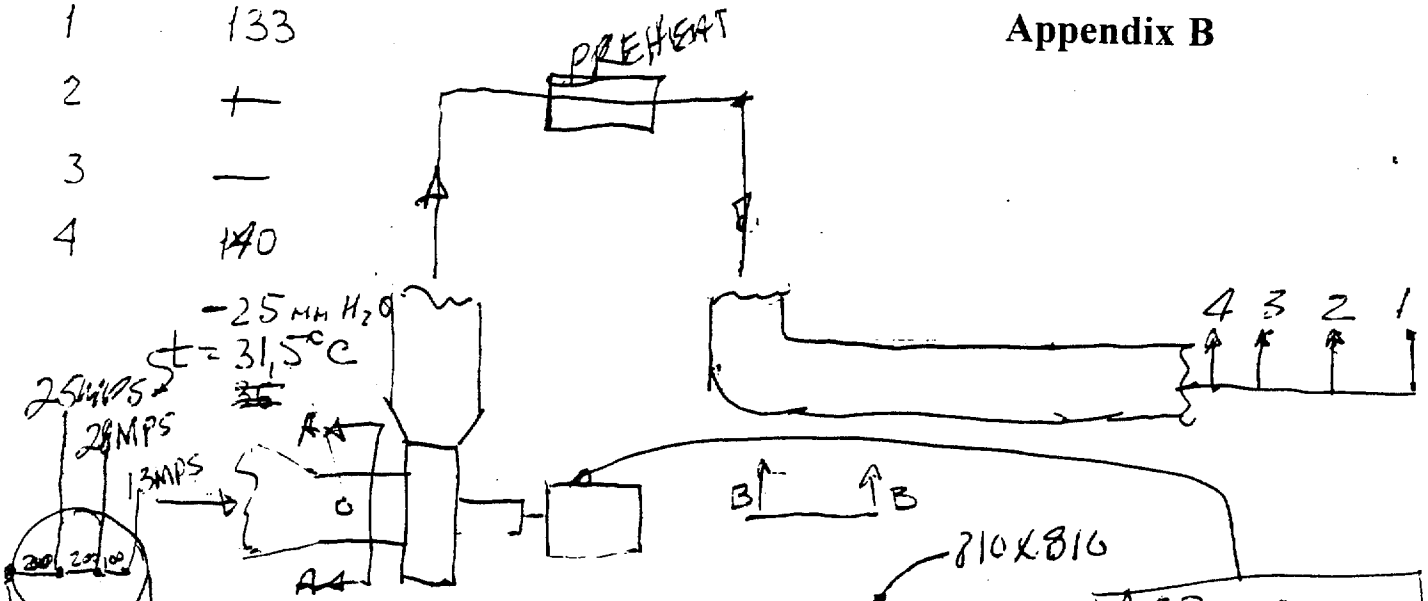


	MM H_2O	t°C	(1) 1.5 MPS	30 MPS
1	+1,0	119	34001,5	.108 .225
2	+1,5	123	74021,5	.235 .49
3	+1,5	120	25200,5	.08 .165
4	+3,0	120	18,173	.578 .0
Total				2.08

(1) Reading not accurate outside of range of Kurz unit (max temp of 55° above ambient) corrected for temp. in private based on fan flow measured at the fan.

	t°, C
1	133
2	—
3	—
4	140

Appendix B



A02-82-8
30 kW
730 dB/mm
R.H.g. 91%

Fan Not Varied

	t°, C	mm H_2O
1	142	+2,0
2		
3		

Measured 8,35 × .15 = 31,500 m³/h @ 27 mm/H₂O at 31.5C

Fan			m³/h	RPM	KW	Pressure
Fan No. 2	I-6	Induced draft	53000	1355	55	165 mm
" No. 1	I-7	Forward	24000	1355	20	115 mm
" 3	I-3	Exh Fan	1800	1440	45	

395 kg/m²

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Appendix C
Thermal Efficiency Calculations Boiler No. 3

The boiler is a model DKVR 20-13 rated at 9.5 kg/cm2 pressure, 20m3/h flow, inlet water at 70C using coal of "GAS" type.

At a steam flow of 22.5 m3/h of steam at a coal feed rate was measured at 4 t/h.

Heat output = .56 Gcal/m3 x 22.5 m3/h = 11.2 Gcal/h.

Based on 5600 kcal/kg heat in the coal the total heat in the coal burned in one hour is 22.4 Gcal.

Thermal efficiency = 11.2/22.4 = about 50 percent.

Note: Average load for the two boilers running at a total of 16,000 hours per year = 1.5 tonnes per hour coal or about 51 percent of peak normal load.

Appendix D
Insulation of Hot Water Distribution Piping

The distribution piping consists of about 4000m of pipes of sizes up to 300 mm diameter. The insulation is damaged or missing on about 2000m of pipe.

One meter of 300mm diameter pipe with new insulation will save heat:

Heat saved = .95m2 x 10m/ft2 x 23 1 btu/ft2 x 252 cal/btu = 591724 cal/m/h

A 200mm diameter pipe will have a saving of 39643 cal/m/h

Heat saved 300mm diameter=2000m x 591724 cal/m x 8000 h/year = 9467 Gcal/yr
Heat saved 200mm diameter=2000m x 396456 cal/m x 8000 h/year = 6343 Gcal/yr

The loss for 2000m of 200mm diameter and 300mm diameter pipe is 15810 Gcal/year

Fuel saved=(15810 Gcal/year)/(5.6 x .5) = 5646 t/year (based on 5600 kcal/kg coal heat content and 50 percent thermal efficiency)

Fuel cost saved = 5646 t/y x 8600R/t = 485 MR/yr (485 MR/yr/5000 R/$) = $97112/year

Cost of insulation 2000m of 200mm and 300mm diameter pipe based on USA material costs and local labor at $4/h=$132000. (based on $29/m of 200mm and $34/m of 300mm pipe).

Local material costs will be less and the total cost is estimated to be 60 percent of $132000=$79200 for local labor and material.

The payback = $79200/$97112 = about 0.8 year.

Appendix E.
No. 3 Boiler Control Energy Conservation Opportunity

The estimated increase in boiler efficiency with a new control system is about 10%. The resulting fuel saving will be 0.1 x 4t/h x 8000h/yr=3200t/yr. Fuel cost saved=86000R/t x 3200t/yr= 275.5MR/yr=(at 5000R/$=$55000/yr). Cost of control system is $50000, a payback occurs in about one year.

Similar savings can be made if boiler no. 2 is equipped with new controls. Boiler no. 1 is a standby and should not have new controls installed. It should be noted that the boilers must be repaired to restore them to operate at their original design conditions.

Note: Coal used in 1994 was 24,332 tonnes at $17.20 per tonne for a total cost of $418,510.

Control Specification for Boiler No. 3 at - Novokuznetsk Poultry Plant Boiler House

A complete automatic control system including installation, start up and a one year service contract to control the fuel and air flows as required by the temperature of the supply water leaving the boiler to the heating system. The existing boiler is a DKVR 20 giga cal/hr. coal fired steam boiler. Design capacity is 20 giga cal/hr. burning 5-6 tonne of 5600 kcal/kg coal. Complete drawings and specifications are available from Santech Project (L. Kazakova).

Sequence of Control Operation:

All control functions shall have manual override switches. The start up and shut down of the boiler shall be done manually. Automatic operation after start up shall control the firing rate by sensing the steam pressure out of the boiler. On a drop in steam pressure the coal feed rate shall be increased. Air pressure sensors in the furnace, forced draft fan outlet , induced draft fan inlet, stoker under fire air ducts shall measure the air pressures, the oxygen sensor shall measure the oxygen content and adjust dampers to maintain the air fuel ratio to obtain maximum combustion efficiency and minimum soot emission. A steam flow meter shall be installed. A computer controller shall be programmed for the coal type and boiler no. 3 to achieve the above described control sequence. The computer shall display screens of measured and calculated data. Historical data shall be stored for 30 days on the hard disk.

High limit controls and low water controls shall operate audio and visual alarms and the operator using manual controls shall shut down the boiler and correct the problem.

Control equipment and components shall include necessary wiring for a 220volt, 50 cycle one phase electrical system.

Equipment and Material List

Sensors:

1-Steam flow meter	0 to 30 m3/hour (20 m3/hr)
1-Steam pressure	0 to 15atm. (13)
1-Feed water temperature	30 to 150C (70)
1-Forced draft fan outlet press	+0 to 400kg/m2 (152)
1-Induced draft fan inlet press	-0 to -400kg/m2 (-193)
1-Furnace draft press (locate in top center of furnace)	-0 to 50kg/m2 (-2)
1-Oxygen sensor at gas outlet of furnace	0 to 20% (6 to 8)
1-Furnace gas temp at outlet before gas cleaner	0 to 300C (235
1-Air temp. at inlet to forced draft fan	0 to 150C (30)
4-Force draft pressure sensors one in each under air duct at grate	0 to 300kg/m2 (50kg/m2)

Note: (********) indicates design values!

Dampers and Motor Operators:
1-Operator for forced draft fan inlet vanes
1-Operator for induced draft fan inlet vanes
4-Dampers and operators for under fire ducts at grate
2-Coal feed motor operators to control feed rate of spreaders and grate speed

Computer Controller:
1-Computer controller with software program and visual display to show alarms, coal feed rate, oxygen, temperatures, pressures as measured and design values.

Documentation:
5-Sets operator training and operating instructions
5-Sets installation and maintenance manuals

Service Contract:
1-One year service and maintenance contact

Miscellaneous:
All necessary labor, supervision, wiring, piping and accessory items to complete the system are to be part of the contract for the control system.

Owners Requirements:
The boiler house owner will install dampers and operators in ductwork and fans as well as temperature, flow, pressure and oxygen sensors and alarms. The installation will be as directed by the control contractor.

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The boiler house owner will be required to repair and/or replace as necessary the air system to achieve design conditions and run tests to verify conditions are achieved before the control contractor starts the control work. Water and heat leaks in the boiler shall also be repaired.

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Appendix F
Automatic Control of Temperature to Water to Housing Units

The temperature of water to the housing units is higher than necessary because for part of the year the temperature needs to be high enough to provide the heat needed to heat the baby chick houses at the poultry plant. The remainder of the year water temperatures are higher than required and the excess heat is wasted.

Control of water temperature to the housing buildings or groups of buildings by a three way valve, pump and controller will provide water temperature based on the outside air temperature. Figure 5 shows a typical installation. Five locations for this control system are shown on Figure 6.

Heat loads and costs are shown in the following table:

Control Location	No. Housing Units(1)	Heat Watts/h	Cost $
1	120apt.	1320000	$13000
2	128apt + school	1708000	$16200
3	72apt	792000	$6600
4	200apt	2200000	$20000
5	20 houses	340000	$5400
Total 540 housing units + school			**$61200**

(1) 11000W/apt, 17000W/house, 300000W/school

Savings of 10% are estimated due to better control and reduction of over heating during the heating season. An additional 15% is estimated to be saved during the time the water temperature is increased to heat the baby chicks.

Total fuel saved is estimated as 25% of heat for housing including domestic hot water..

Fuel saved = 0.25X73,090 Gcal/yr = 18,270 Gcal/yr
Fuel cost saved = (18,270 Gcal/yr/5.6Gcal/t) X 86,000R/t = 280.5 mR/yr, or $56,100
Payback = $61,200/$56,100 = about 1.1 year.
Equipment Specification for Control of Water Temperature to Apartment Complex.

Schematic piping diagrams are shown in Figures 5 and 6. Schedules of buildings, equipment and material must be consulted to determine the quantity, sizes and capacity of equipment and materials for each location. All equipment and piping shall be rated for the following conditions:

Primary (District heating system)

Rated Pressure:	1.0 MPa (150 psi) system
Temperature	150 C (300F)-75C (167F)
Working Pressure:	Supply 0.8 MPa (110 psi)
Return	0.1 MPa (15 psi)

Secondary

Temperature:	95C-70C
Pressure:	1.0 MPa (150 psi) for system materials
Working Pressure:	0.3 MPa (45 psi) design
Pump Head:	1.45 MPa, 15m, 50 ft.

Pump
Equal to Grundfoss in-line centrifuge pump, 220 volt 50 cycle motor and magnetic starter with 24 volt holding coil.

Control Valve
Equal to Honeywell V5000 style two way or three way bypass with body for 1.0 MPa (150 psi) 150C motor M6421A, 24 volt AC.

Controller
Equal to Honeywell ZG-50 with TH-4 output module, SU-53-54 time clock, ZF-03 function module, AF-20 outdoor air sensor, VG-20A supply water sensor, VF-20a return water sensor, MCP-1 pump relay. Unit to operate from 220 volt 50 cycle service. Control cycle to provide outdoor air reset control.

Ball Valves
Steel body, teflon seals equal to Worcester controls series 59.

Balancing Valves
Bronze of cast iron body equal to BAL-TRON for 1.0 MPa, 150C service.

Appendix G
Portable Test Equipment Specification

A. Combustion Analyzer:

- Combustion analyzer that meets the following specifications and manufactured by Enerac, CEA Instruments, Land Combustion, Teledyne Analytical Instruments or equal is suitable for this application.

Measured Parameters:

- Flue Gas Concentrations for Oxygen, Carbon Dioxide, Carbon Monoxide, and Temperature

Calculated Parameter:

- Flue Gas Excess Air Combustion Efficiency

Analyzer Performance:

- Oxygen; 0 to 25% volume
- +/- 0.1% volume resolution
- +/- 0.2% volume accuracy
- Carbon Dioxide; 0 to 20% volume
- +/- 0.1% volume resolution
- +/- 0.2% volume accuracy

Carbon Monoxide:

- 0 to 2000 parts per million volume (ppmv) +/- 2 ppmv resolution +/- 5% of reading accuracy

Flue Gas Temperature:

- 0 to 1100°Centigrade +/- 1 °C resolution +/- 2 °C accuracy

Flue Gas Excess Air:

- 0 to 1000% /- 1% resolution +/- 10% accuracy

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Analyzer Features:

- Portable, battery powered, capable of operating a minimum of 6 hours on a single charge.

- Battery Charger for 220 volt, 50 Hz power and power cord.

- Condensation trap with re-usable desiccant. Desiccant to be reactivated by drying in an conventional oven or microwave oven.

- Disposable particulate matter filter capable of removing one micron particles.

- Auto "zero" upon turning on the analyzer. "Zero"; ambient air 20.9% O2, 0% CO2, 0% CO

- Inconel probe, 24 inch length minimum and 10 feet of connecting hose to the analyzer.

Span Calibration Kit:

- Certified calibration gases, range 10% O2, 6% CO2, and 1000 ppmv CO Pressurized cylinder container(s) minimum 10 cubic feet.

- Calibration gas manifold and connection to the probe.

Spare Parts:

- Desiccant, 2 quarts minimum Disposable Filters, 24 minimum

Digital Thermometer:

- Digital thermometer no. 52 as manufactured by Fluke Corp. PO Box 9090, Everett, WA 98206, USA complete with 80PK-3A surface probe (temp range 0C to 260C) and 80PK-2A immersion probe (temp range -196 to 1090C.)

Multimeter:

- Multimeter model 85 as manufactured by Fluke Corp. PO Box 9090 Everett, WA 98206, USA. Instrument to measure volts, amps, ohms AC and DC.

Wattmeter:

- Wattmeter equal to 2000A Wattprobe as manufactured by TIF Instruments, Inc. 9101 NW 7th Ave, Miami Fl. 33150 USA Range 280/560 volt 20KW and 200KW ranges, 9volt battery

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Infrared Digital Thermometer:

- Infrared digital thermometer shall be equal to Model RAYPM30L2U as manufactured by EPD Technology Corp., 14 Hayes Street, Elmsford, NY, 10523, USA. Unit range: -10 to 540 C with digital read out, 9 volt battery and 220 volt, 50 cycle adaptor.

Velocity and Pressure Meter:

- Instrument to measure velocity 0 to 50mps, pressure -10 to +10 inch water (2500mm), temperature range 0 to 400C, digital or analog readout, battery and 220v, 50 cycle voltage operated. Complete with instruction book and case and spare rechargable battery.

Temperature Recorder for Poultry House:

- Two wall monted temperature recorders with paper strip charts shall record ambient temperature inside the house.

- Two recorders equal to model A542-001 9Russian Specification) wall mounted with TSP098754Z.882.024 temperature sensors, twn rolls of paper and two bottles of ink for each recorder. Units shall operate on 220 volts, 50 cycle power.

Appendix H
Chicken House No. 9 Temperature Control of Outside Air System

The house is ventilated with exhaust fans, outside air intakes and four air handling units that heat the air in winter. The units are 100% outside air and each unit handles 28000m3/h of air. The coils are controlled manually A new system of three way valves and pump with a controller will save an estimated 10% of the heat.

The estimated annual heat saving for house is based on heating 138000m3/h of air 3000h/yr from 0 to 18C.

Heat required for air =138000m3/h x (18--37C) x Const.=2.187Gcal/h
Heat saved=.10 x 2.187Gcal/h x (18/55) x 3000h/yr=214.5Gcal/yr
Fuel saved=214.5gcal/(.5 x 5.6Gcal/t)=76.6t/yr
Fuel cost saved=76.6t x $17.20/t=$1317

Cost of four control systems 4 @ $6600=$26400
Payback=26400/1317=20 yrs.
Payback is too long, do not install this system.

FIGURES

Figure 1

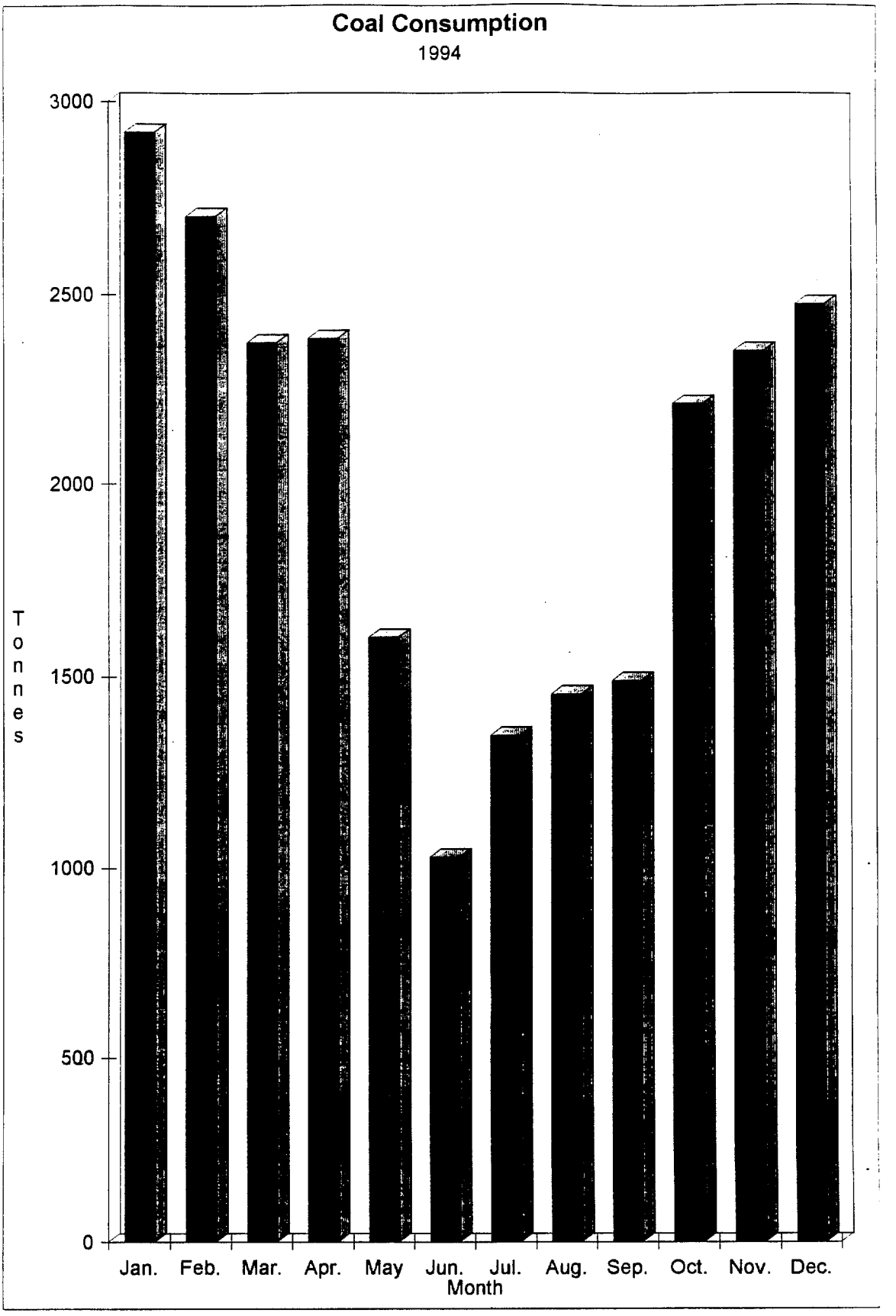
Coal Consumption
1994
3000
2500
2000
1500
1000
500
0
Tonnes
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Month

Figure 2

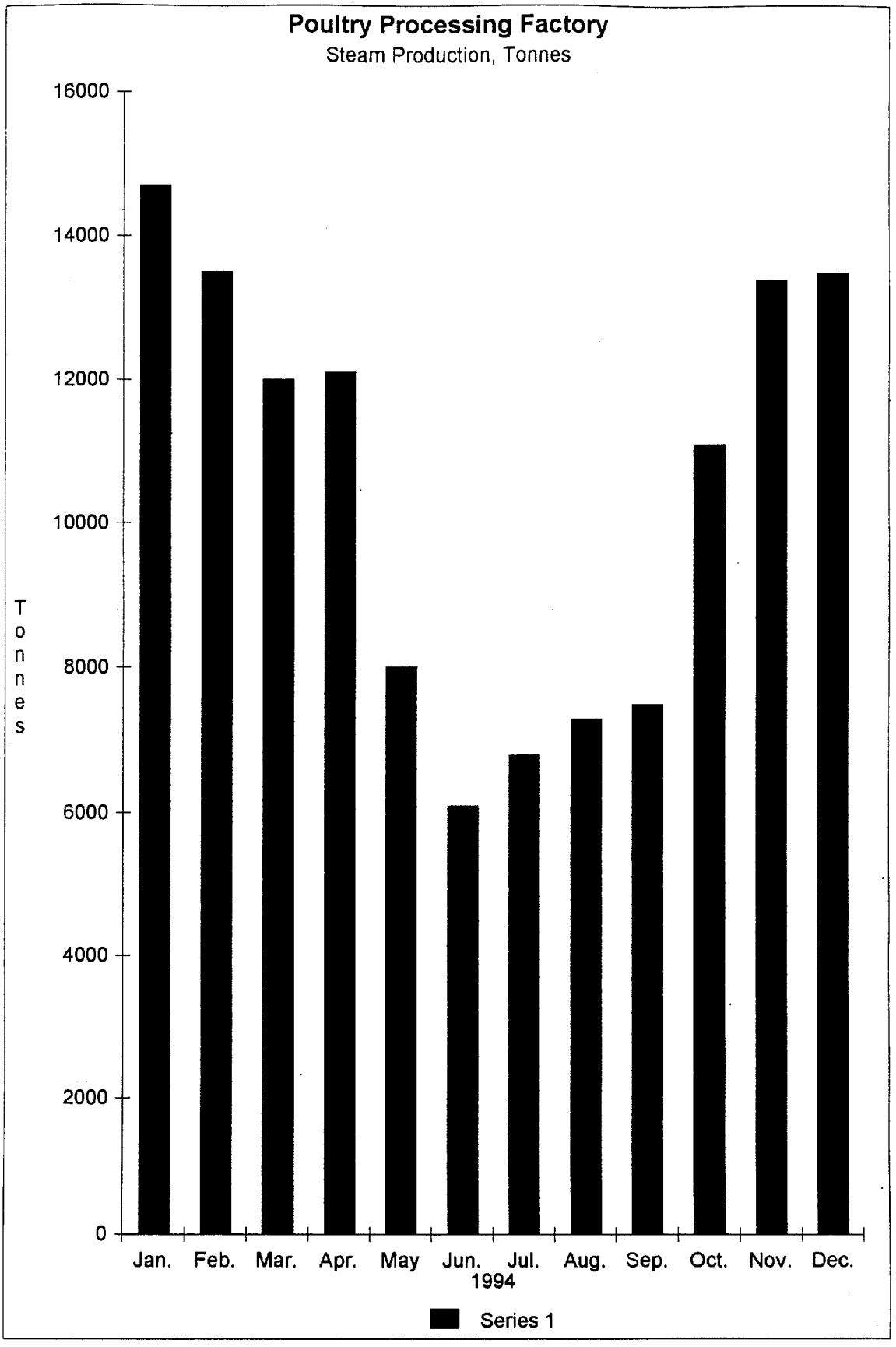
Poultry Processing Factory
Steam Production, Tonnes
16000
14000
12000
10000
8000
6000
4000
2000
0
Tonnes
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1994
Series 1

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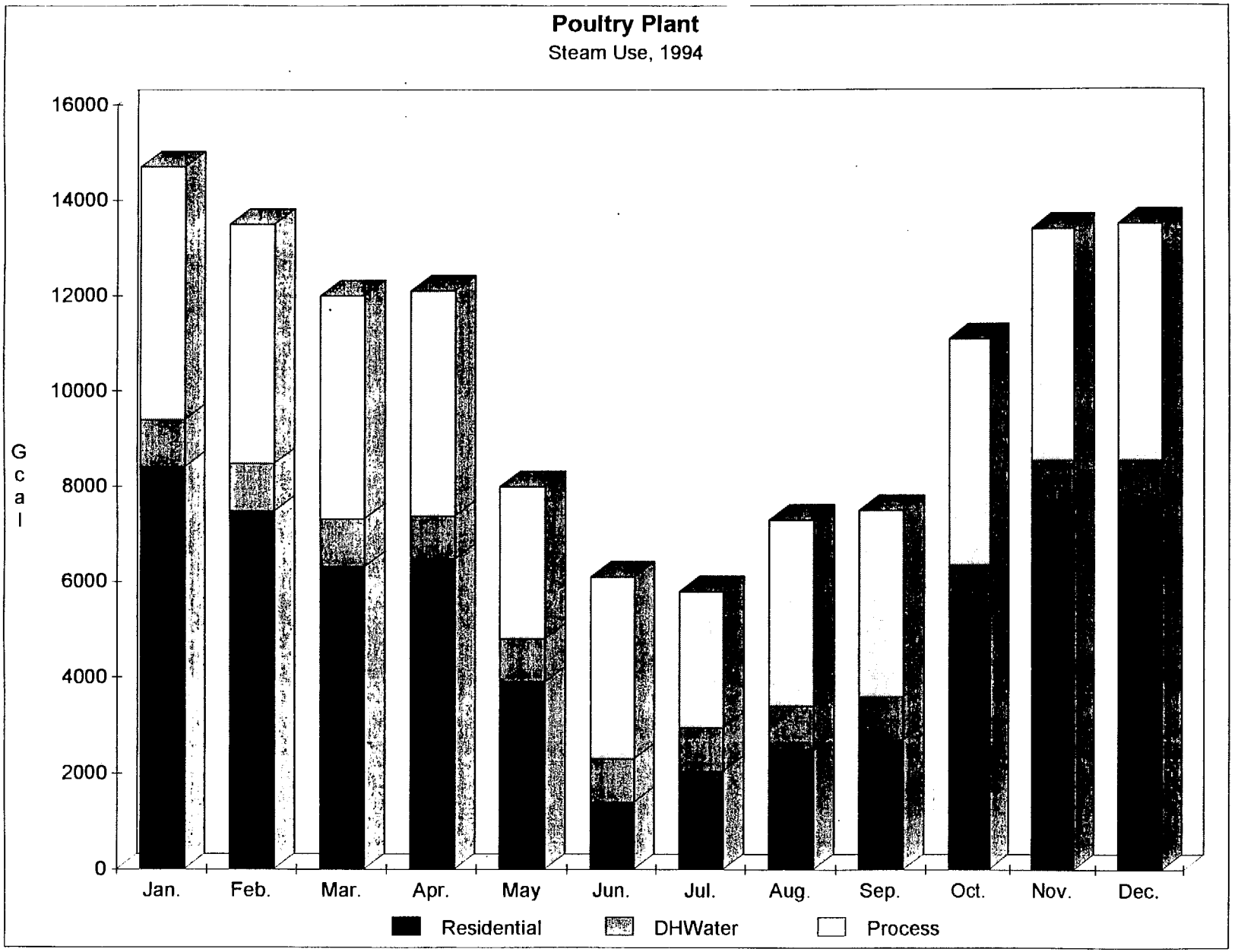
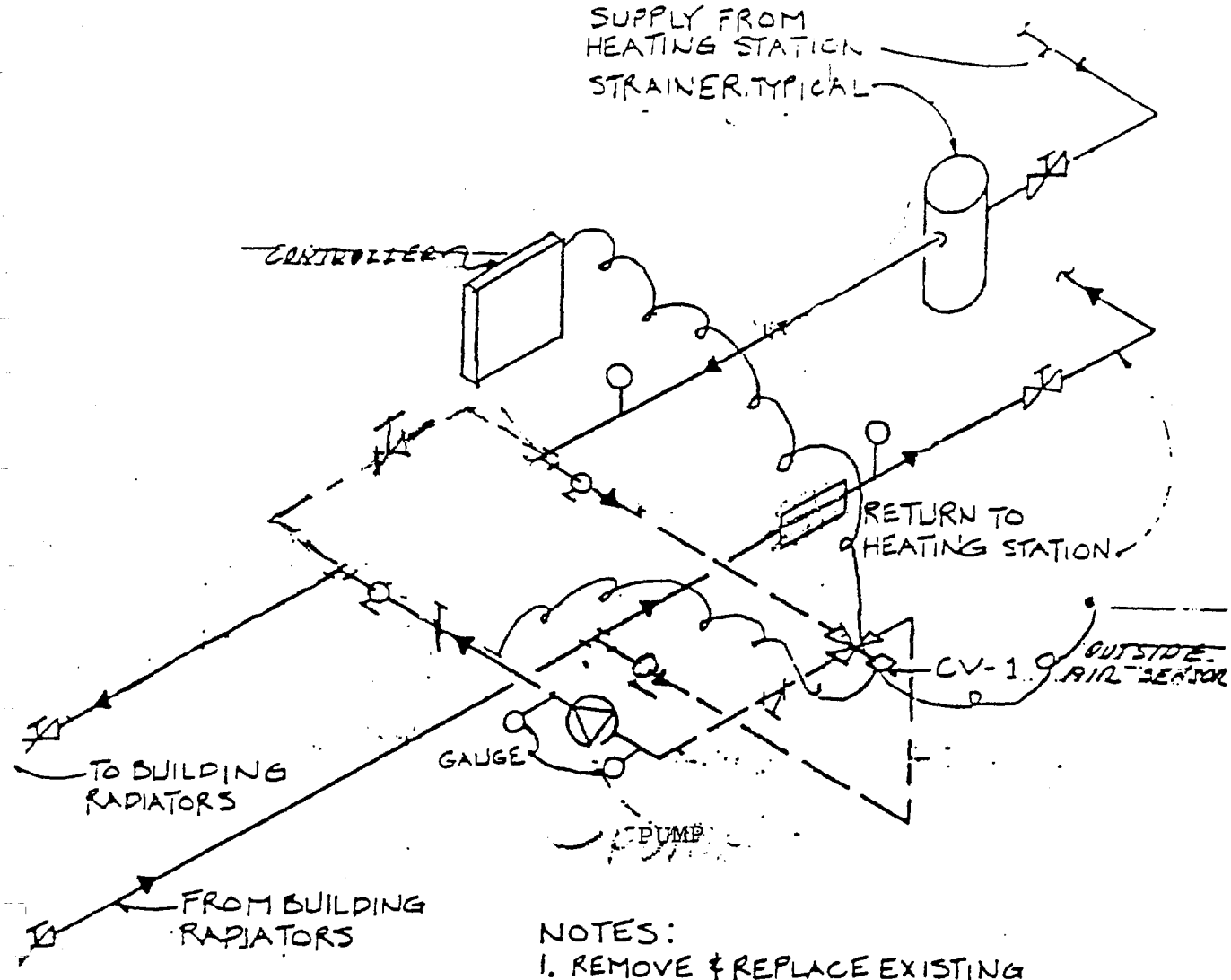
Figure 3


Poultry Plant
Steam Use, 1994
Gcal
16000
14000
12000
10000
8000
6000
4000
2000
0
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
Residential
DHWater
Process

F I G U R E 5

Building Heating with Automatic Control
for Novokuznetsk Poultry Plant



NOTES:

1. REMOVE & REPLACE EXISTING PRESSURE REGULATING VALVE.
2. PIPING SHOWN WITH DASHED LINES IS NEW, SOLID LINES ARE EXISTING
3. ~~////////~~ INDICATES EXISTING TO BE REMOVED.

BALL VALVE

PRESSURE GAGE

BALANCING VALVE WCD

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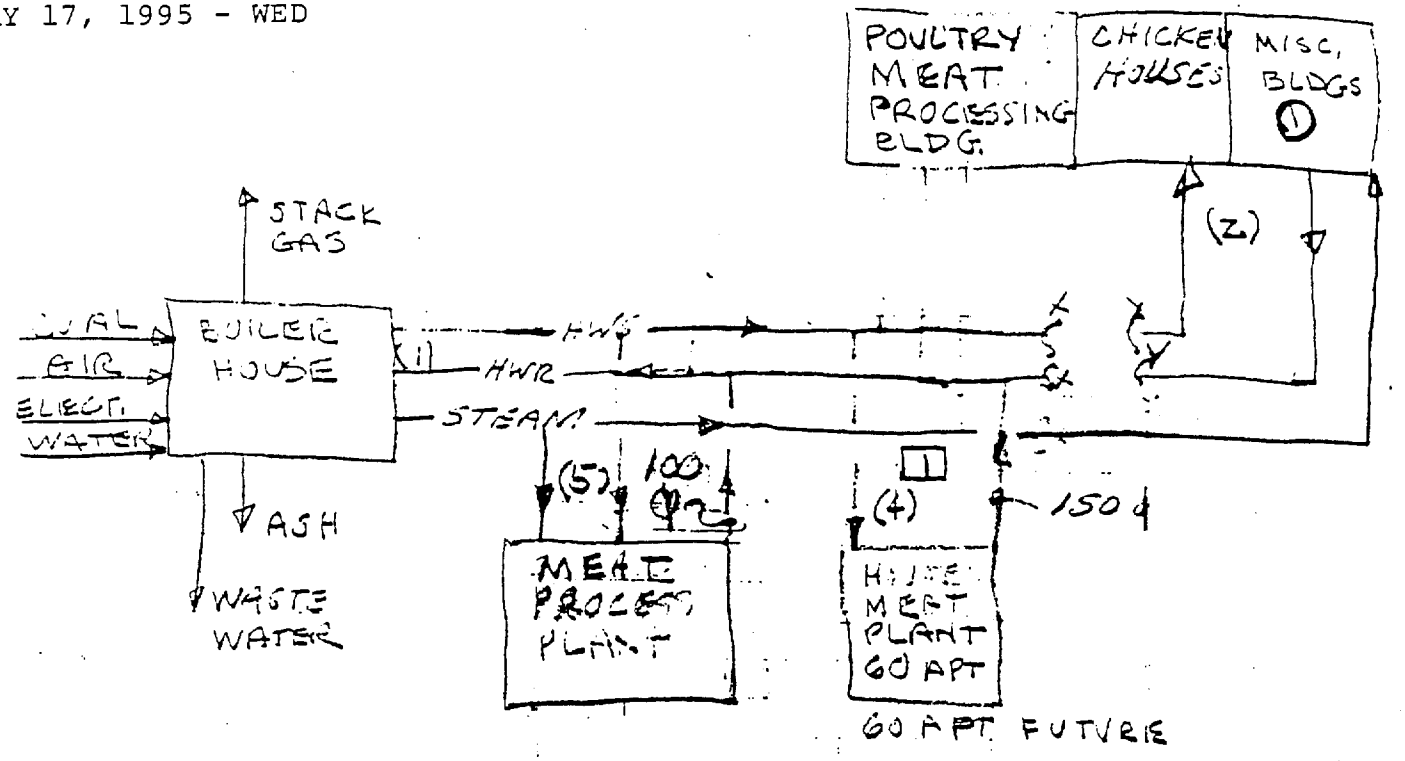
POULTRY PLANT

FIGURE 6

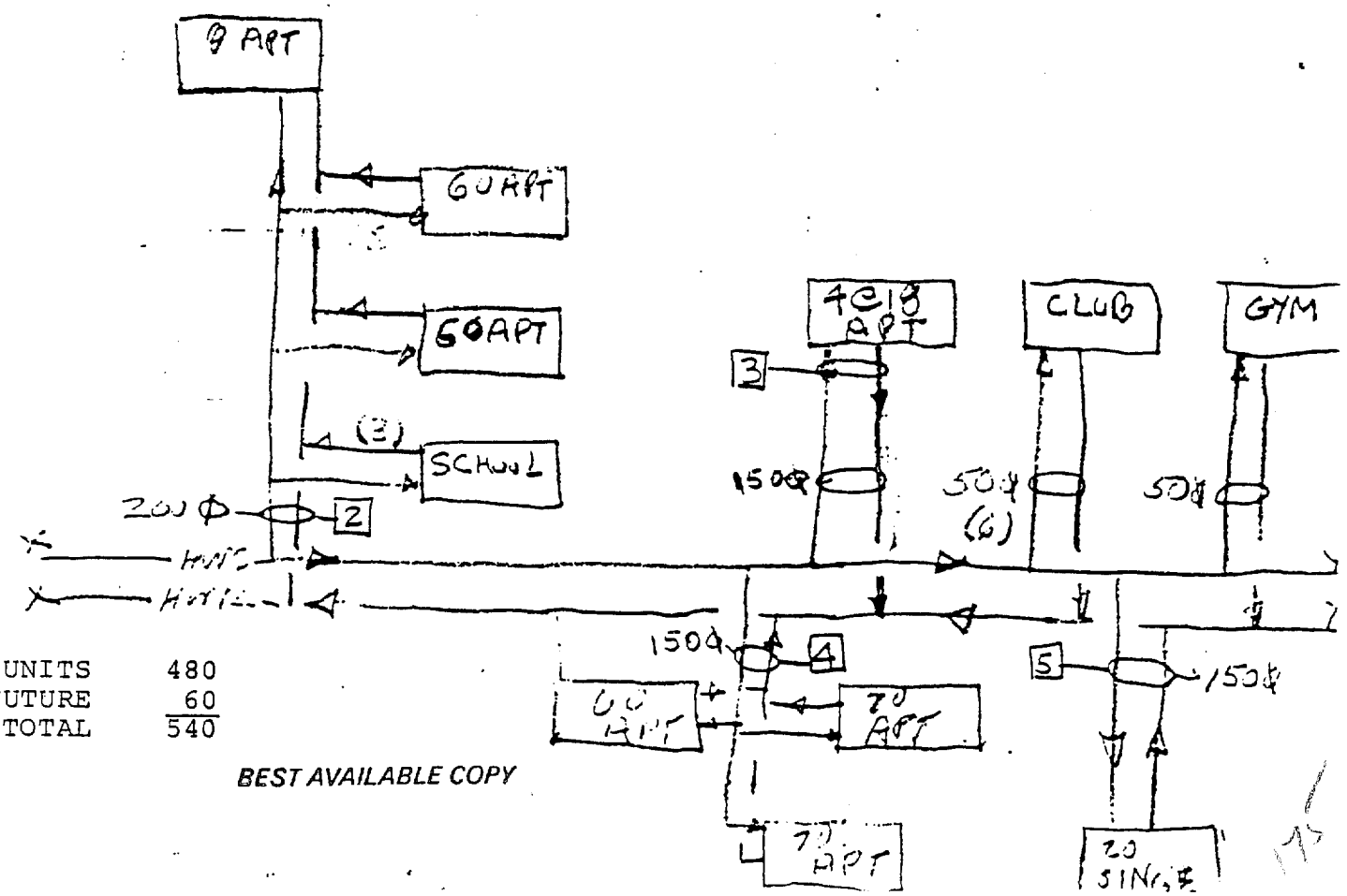
MAY 17, 1995 - WED



(X) METER LOCATIONS DESIRED BY OWNER

[1] TEMPERATURE CONTROL LOCATIONS

(1) ADMINISTRATION, GARAGE, SHOP, POWDER EGG BLDG, CONSTRUCTION DEPT. BLDG, FEED STORAGE & PREPARATION



HOUSING UNITS	480
FUTURE	60
TOTAL	540

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TABLES

Table

Short Term Energy Conservation Opportunities (Poultry Plant)				
Description	**Energy Saving**	**Cost Saving**	**ECO Cost**	**Payback**
1. Repair air and water leaks in boiler house, restore flows to original design values	3%/Year 729t/Year cool	$12,555	$10,000[2]	Less than one year[1]
2. Install an automatic control system on boiler No. 3 (See appendix E)	3200t/year cool	$55,000	$50,000	1.1 year
3. Adjust and balance air and water flows to reduce electricity used by fans and pumps in boiler house	3%/year 244809 kach	$4,582[3]	[2]	Less than one year[1]
4. Repair and replace insulation on 4000m of 200mm dia & 200 mm dia piping (see appendix D)	5646t/year cool	$97,112	$79,200	0.8 year
5. Provide automatic temperature control of water to the housing units (see appendix F)	3662t/year cool	$56,115	$61,200	1.1 year

(1) Based on experiences with similar plants in C.I.S.

(2) Portable test equipment at a cost of $10,000 will be furnished by EPT. Funds to do repair and maintenance provided by the owner.

(3) Based on May 1995 cost of 93.6R/kwh. Total savings based on ECO 1, 2, 3, 4 & 5 will be 13237t/year cool, 54% of 1994 consumption and 3% of the electricity.

Funding Recommendations: EPT shall provide $100,000 to fund ECO 1, 2, 3 and part of 5. Funding for part of ECO No. 1, 2, & 5 shall be provided by the owner.

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Table 3

Energy Data, Poultry Plant
Year - 1994

	Item	Units	Jan.	Feb.	Mar.	Apr.	01-May-95	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	TOTAL
1	Steam Production	Gcal	14700	13500	12000	12100	8000	6100	6800	7300	7500	11100	13400	13500	126000
2	Heat for Residential	Gcal	8400	7480	6320	6480	3900	1400	2050	2500	2700	5350	7550	7550	61680
3	Heat for Commercial	Gcal													
4	Heat for Domestic Hot Water	Gcal	1000	1000	1000	900	900	900	900	900	900	1000	1000	1000	11400
5	Heat for Process Hot Water	Gcal	5300	5020	4680	4720	3200	3800	2850	3900	3900	4750	4850	4950	51920
6	Hot Water for Residential	Tonnes													
7	Hot Water for Residential Heating	Tonnes													
8	Hot Water for Residential Domenstic	Tonnes													
9	Hot Water for Process	Tonnes													
10	Coal Consumption	Tonnes	2920	2700	2370	2382	1600	1030	1350	1455	1490	2210	2350	2475	24332
11	Type of Coal		Gas Coal												
12	Electrical Production		None												

Gross Thermal Efficiency for Hot Water

	Assume low heat value for coal - 5450 Kcal/Kg	1 tonne coal=	5.45	Gcal										
	Assume lab heat value for coal - 7550 Kcal/Kg		7.55	Gcal										
	Efficiency, % - Low Heat Value	92.4	91.7	92.9	93.2	91.7	108.7	92.4	92.1	92.4	92.2	104.6	100.1	95.0
	Efficiency, % - Lab Heat Value	66.7	66.2	67.1	67.3	66.2	78.4	66.7	66.5	66.7	66.5	75.5	72.2	68.6

PREFACE
Audit Report
Novokuznetsk Ice Cream and Cold Storage Facility

This report is the result of an Industrial Environmental Audit carried out April 25 - May 26, 1995 at Novokuznetsk Ice Cream and Cold Storage Facility. The audit was made by a joint US - Russian team with the support of the United States Agency for International Development (USAID) Environmental Policy and Technology (EPT) Project. There were 6 Americans consultants and 17 Russian specialists from the scientific research and design institutes, enterprises and environmental regulatory agencies on the team.

This audit was performed as a part of a training program for the Russian team members on conducting industrial environmental audits.

Factual information provided by Novokuznetsk Ice Cream and Cold Storage Facility formed the basis for evaluating environmental, energy efficiency and worker health and safety conditions at the facility. Opinions formed from this information are the authors and do not necessarily reflect the views of USAID or EPT.....

AUDIT REPORT

Novokuznetsk Ice Cream and Cold Storage Facility

Description of the overall Industrial Audit Program

There is an immediate need for rapid improvement in industrial energy efficiency due to a variety of poor energy utilization practices and lack of proper maintenance of energy systems. Related to the low energy efficiency of facilities is a higher emission of particulate to the atmosphere from the coal-fired boilers. Higher than design coal burning rates subsequently overload the flue gas clean-up equipment which worsens the emission problem. Emission penalties do not alone provide sufficient economic incentive to proceed with projects to reduce emissions. Energy efficiency improvements are cost-effective within the current energy economy and can provide economic incentives that support the concern to clean-up the environment. These energy efficiency improvements will also result in a improvement in air quality by reducing emissions at the source.

Increases in energy prices to equivalent world prices have put additional pressures on industrial firms to conserve energy. Changes within the economic system (energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Along with the industrial audit program to demonstrate the effectiveness of energy efficiency improvements, the overall EPT program provided training on energy efficiency audit practices, use of energy performance measurement equipment and evaluation of energy conservation opportunities.

The Industrial Audit Project is comprised on four distinct tasks:

1. Industrial plant screening
2. Industrial plant energy audit
3. Purchase, ship, and receive equipment to implement audit recommendations
4. Implementation and monitoring

Screening of fifteen industrial plants and communal boilers, the cement plant and the ZapSib Combined Heat and Power Plant was accomplished to provide a basis for selecting the plants to be audited. Criteria used in this selection included;

1) Opportunity for energy savings (with a focus on emission reduction),
2) Reasonable payback period in the Ruble energy economy (also calculated in world prices),
3) Potential replicability of energy saving options in similar plants or systems,
4) Future viability of the plant in the changing economy and operation of the district heating system,
5) Size of the plant,
6) Ownership,
7) Location and impact on local ambient air quality and

8) Other activities such as joint ventures or other bi-lateral aid projects.

The cement plant audit is given due to it's significant impact on the local environment of Novokuznetsk. The additional plants selected for the audit phase are:

1) Abashevkaya Communal Boiler,
2) Ziryanovskaya Communal Boiler,
3) Selected boilers at the ZapSib Combine Heat and Power Plant,
4) The ice cream and cold storage plant, and
5) The poultry processing plant.

An energy audit report has been prepared for each of the six facilities audited and a seventh report summarizing the results of the stack particulate sampling accomplished at each of the five facilities other than the cement plant. The seven reports represent the complete reporting of the energy/environmental audit activities conducted in Novokuznetsk, Russia during the period of April 25 - May 26, 1995.

The energy audit activity, described in detail in each facility report, consisted of a determination of the overall energy efficiency of the plant to identify no/low cost equipment opportunities with short term payback. An assessment was made of the technical and management capabilities and capital investment decision-making process regarding energy conservation applications. At the completion of the energy audit, equipment specifications and other documents required for procurement of U.S. and NIS manufactured equipment or materials will be prepared. Particulate sampling of the stack gasses of the five facilities with coal-fired boiler systems was conducted to determine the current stack gas loading of particulates and particulate emission rates.

Equipment specified in the energy audit will be procured, cleared through customs, and delivered to the plant. Purchased authorization requests will be prepared for approval by USAID/Washington and USAID/Moscow. Requests for Quotes or Tenders as well as purchase orders when suppliers are selected will be issued from the EPT/Moscow office to support the interest in identifying the maximum ability for these demonstration projects to be replicated by other facilities in Novokuznetsk. Equipment will be shipped to the audited sites in Novokuznetsk and technical support will be provided by the Russian team members working on these audits.

In the implementation phase, requirements for installation of the material will be identified. Where possible, this will be done by the personnel of each facility, or alternatively, by Novokuznetsk contractors. Following completion of the installation, an assessment will be made of the effectiveness of the energy conservation application and the effect on emission reduction.

Results of the audit conducted in the Novokuznetsk Ice Cream and Cold Storage Facility are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit.

Section 1
EXECUTIVE SUMMARY

The industrial sector in Novokuznetsk is very well developed, with many large and heavy industries. In addition, there are 160 boiler houses at medium size industries and district heating systems that consume a large percentage of the regional energy use and are major contributors to the particulate emissions within the residential districts of the city. The facilities chosen for the EPT Industrial Audit project are representative of many companies or similar facilities within the city, making them ideal targets for the industrial energy audit work since potential replication is very high. Many of these medium size plants are very viable, but have not yet implemented energy conservation activities. Changes within the system (increased energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Parallel emission reductions can be expected with increases in energy efficiency

Results of the audit conducted in the Novokuznetsk Ice Cream and Cold Storage Facility are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit. Equipment to implement the recommendations from the audit fall in the categories of portable and fixed equipment and are summarized in the following paragraphs.

Portable Test Equipment

A combustion analyzer that meets the following specifications and manufactured by Enerac, Bacharach, CEA Instruments, Land Combustion, Teledyne Analytical Instruments or equal is suitable for this application. Measured Parameters: Flue gas concentrations for oxygen, carbon monoxide, and temperature Calculated Parameters: flue gas, excess air, carbon dioxide and combustion efficiency.

Estimated Cost: $5,000
Estimated Savings: $3,000 per year for a payback period of 1.7 years

Ultrasonic Stethoscope

With the installation of steam traps a maintenance program need to be established in order to maintain the performance of the steam traps.

Estimated cost: $1,000
Estimated savings: $1,500 given the installation of the fixed steam traps for a payback period of 8 months

Fixed Equipment

Oxygen Analyzer

The purpose of this oxygen analyzer with display is to allow the operator visually monitor oxygen content in the flue gas and maintain an optimum air-fuel ratio in the boiler during the combustion process. This device allows for providing just enough combustion air as the coal bed changes to burn the fuel at maximize the overall combustion efficiency and minimize energy losses resulting from excessive air quantities and, in addition, carbon monoxide production and visible smoke is eliminated due to incomplete combustion from too low a combustion air quantity.

Estimated Cost: $3,500
Estimated Savings: $6,000 per year with a payback period of 6 months

Steam Traps

There are no steam traps used in the steam heating system entire plant nor at the service hot water heating system for the plant. Some steam is condensed in the heat exchangers while significant amounts of steam blows through and is condensed in the uninsulated condensate return line. The total steam to each corrugation machines is 1 - 2 tons per hour. Steam traps at the ice cream production shop are in place but do not appear to function properly. Approximately 20 steam traps need to be installed and 12 steam traps need to be replaced.

Estimated cost: $ 6,400
Estimated savings: $12,000 per year for an estimated payback period of 6 months.

Hot Water System Temperature Control

The three hot water tanks currently have no temperature control. The operators have learned how to adjust the steam flow such that under normal conditions there is no boiling of water in the storage tanks. Significant amounts of steam is wasted to the condensate return tank when the temperature of the storage tanks is above required temperature.

Estimated cost: $3,600
Estimated savings: $7,000 for a pay back period of 6 months

Section 2
Plant Description

2.1 Key Plant Data

NAME OF FACILITY:	Novokuznetsk Ice Cream and Cold Storage Facility 654029 Novokuznetsk Kemerovo Oblast, Russia
KEY CONTACTS:	General Director: Sergey Bachurin Chief of Boiler House: Alexander Ovchennchkov

2.2 Operating Data

Table 1 presents a summary of the operating data for the Novokuznetsk Ice Cream and Cold Storage Facility during the year 1994. Energy consumption at the plant was in the form of coal and electricity. During 1994 the boiler house used 2,936 tons of coal to produce thermal energy in the from of hot water and steam for process, heating and hot water requirements. The plant burns coal in three boilers with ratings of 4 tons/h. Figure 1 presents the electrical energy use of the plant by month for 1994. Figure 2 presents the coal use of the plant by month for 1994.

Section 3

Audit Description

The Novokutznsk Refrigeration Plant is located in Novokutznesk, Russia. It manufactures ice cream products and provides low temperature refrigerated storage for various food products. It has a refrigeration capacity of 340 tons of ammonia compressors. The boiler plant consists of 3 - 6 Giga Calorie/Hr (GC/Hr) nominal output capacity coal fired steam boilers with manual dump grates and rotary stokers. The boilers provide steam to heat the plant complex as well as process steam to the ice cream plant.

3.1 Boiler Description

The three boilers at the refrigeration plant are Russian manufactured coal boilers with a nominal capacity of 6 Giga Calories/Hr (gC/hr). They are fired by stokers with rotary overthrow coal distributors. Bottom grates are manual tilting dump grates. Coal is distribute across the grates by the rotary distributor but the fire bed requires frequent manual leveling, about every 20 to 30 minutes. Ash is dumped into a water filled sluice which extends under all three boilers. Combustion air is by a balanced draft system supplied by a 15 kW forced draft fan and a 20 kW induced Draft Fan. There is also a small 3 kW "Sharp firing " or over fire fan. Both the FD and ID fans are equipped with manually operated variable inlet vanes (VIV). The VIV operators do not have an effective positioning lock and quickly return to an indeterminate position after adjustment.

A water side economizer is provided to recover heat from the boiler exhaust. It reduces the stack temperatures from approximately 320 °C to 150 to 170 °C although part of this reduction is due to air leakage in the economizer. (Excess oxygen increased from 12 to 14 percent at the exit of the boiler breeching to over 18 percent at the exit of the economizer).

Water treatment is supplied by a "activated coal" anthracite bed ion exchange water softener. A steam heated dearator removes most of the dissolved air. Since boiler tube life is only 3-6 years, primarily due to internal corrosion, this system is less effective than it should be.

A single stage two barrel cyclone is provide for particulate removal.

3.2 Steam Distribution

The steam produced by the boilers is distributed within the complex at a pressure of 2-3 atmospheres. The major uses of steam are for:

- Heating of hot water for heating of apartments and some factory offices and buildings
- Domestic hot water heating for plant uses and apartments

- Process heating at the ice cream factory
- Comfort heating of rest areas in the refrigeration plant

Hot water for apartment heating is supplied by two shell and tube steam to hot water heat exchangers. These heat exchangers are controlled by a manually adjusted thermostatically controlled valve. Water supply temperatures are manually adjusted to outdoor ambient temperatures according to the following reset schedule.

110 °C at -39 °C -- 35 °C at 10 °C

Water is heated for domestic use in 3 - 5 cubic meter steam heated tanks with U-tube heat exchangers. Each tank is rated to raise 5 cubic meters of water from 5 °C to 75 °C in one hour (0.7 gC/hr). Domestic water is supplied to the 12 apartments and for use within the refrigeration plant complex. The tanks are not equipped with steam traps and are suspected as the source of considerable live steam returning to the condensate tank.

Frost removed from the refrigeration plant coils, pipes, etc. Is melted in a steam heated pit. There is also a significant amount of waste heat that escapes from this pit, particularly in cold weather. The pit is approximately 1.5 meters by 3 meters by 0.5 meters deep. It is filled to a level 1 meter above ground level at least once a day sometimes twice. Because of the large proportion of air in the frost it is difficult to estimate the weight of ice melted but assuming 50 percent by volume is air the estimated daily ice melt is:

1.5*3*0.5*0.5 *2 = 2.25 m^3/day at a density of 0.9 kG/l this is
0.9*2.25*1000l/m^3 = 2,025 kg/day or, at 80 kCal/kG
80*2,025 = 162,000 kCal/day and for 250 days/year (excludes weekends)
162,000*250= 40,500,000 kCal = 40.5 gCal

Steam is used in the ice cream plant for:

Ice Cream Mixing Tank	-	1,300 m^3 / hr
Butter Melting	-	2.1 m^3 / hr
Pasteurizer	-	2,600 m^3 / hr
Chocolate Boiler	-	1.3 m^3 / hr
Calorifier (Space heat)	-	12,000 m^3 / hr

Seam is used in the personnel warming areas, the scale operators office and restrooms of the cold storage warehouse in simple pipe radiators with manual temperature regulation. There is a significant amount of over heating. Steam is also used to heat the cold storage fork lift maintenance shop.

3.3 Condensate System

Condensate is collected at condensate tanks in the basement of the ice cream plant and in the basement of the cold storage ware house. Condensate pumps controlled by high-low limit float switches pump condensate back to the central condensate tank at the boiler house. Considerable live steam was observed escaping from the main condensate tank. This was to be primarily coming from non condensed steam from the domestic water heaters.

3.4 Water Treatment

Water treatment for boiler water consists of filtration through an "activated" coal bed which is regenerated with a salt solution. This is similar to a zeolite resin bed and removes most of the hardness from the water when properly maintained.

3.5 Combustion Tests

Combustion tests were performed on boilers number 2 and 3. Boiler 1 was being overhauled. Boiler 2 was operating as the primary boiler and boiler 3 as secondary. That is boiler 3 was the first to be shut down as load decreased. On one day boiler 3 was kept on line so tests could be conducted and boiler 2 shut down. Table I details the results of the combustion tests. Tests were made primarily at the boiler breeching before the economizer. A few tests were run at the exit of the economizer to determine air leakage in the economizer.

Note in Table I (attached) that the percent O2 increased from about 12-14 percent at the boiler breech to over 18 percent at the exit of the economizer. This is an indication of air leaks between these points. Several leaks were identified with the hot wire anemometer. The leakage was sufficient to prevent the Combustion Analyzer from giving any readings for Excess Air and CO2 calculated readings. Leaks in the economizer result in increased energy consumption due to:

- Reduced Flue gas temperatures resulting in less heat recovery from the flue gas to the feed water.

- Increased flue gas flow to the induced draft fan resulting in increased fan consumption.

It should be noted that the flue gas O2 concentration fluctuated between 12 and 16 percent when the fire bed was being raked. This could contribute to some of the increase at the economizer outlet. Assuming an increase from 12 to 16 percent the leakage rate is 82 percent of the flue gas flow on a volume basis , i.e., the leakage increased the flow rate at the exit of the economizer by 83 percent. This would increase the fan power consumption by the same amount. The reduction in recovered heat is harder to determine since the leakage is not all before entering the economizer. It is estimated the heat recovery by the economizer could be reduced by as much as 25 percent.

3.6 Refrigeration Plant

The refrigeration plant consists of six German built screw type ammonia compressors and eight older Russian built reciprocating compressors. The screw compressors are tandem cascade compressors. They are used as the primary compressors and the reciprocating units serve as standby. The compressors serve two evaporator circuits one operating a -28 °C and one at -40 °C suction temperatures. Liquid ammonia is supplied to overhead serpentine coils in the cold storage facility and to blast freezers in the ice cream plant.

Heat is rejected in three water cooling towers. Each tower is equipped for cold weather operation.

Section 4

Energy Conservation Opportunities

4.1 Oxygen Control for Boilers

Combustion tests using a Bacharach Portable Combustion Analyzer (CA) of boilers 1 and 2 show that the flue gas oxygen content at the boiler breech is from 13 to 14 percent. Manual adjustment of the FD fan reduced the O2 to 12 to 12.5 percent.. Maintaining the combustion air in the range will improve combustion efficiency by 3 to 4 percent. Based on reported coal use in 1994 of xxxxx metric tons, this will result in a reduction in coal use of xxx tons and a savings of xx,xxx,xxx Roubles. At present there is no oxygen sensor present and FD fan adjustments are made manually by adjusting the forced draft fan inlet vanes by physical observation of the fire bed. A visual O2 display system with a remote FD VIV fan control will allow the operator to maintain O2 levels in the 8-10 percent range and will encourage the adjustment each time the fire bed is raked.. There would also be a savings in fan energy consumption due to lower flue gas flows although this is neglected in energy savings calculations.

Annual Coal Use	xxxxxx
Estimated Reduction %	4.5%
Coal Cost per Ton (Roubles)	100,00
Annual Savings (Roubles)	xxxxxxx
Estimated Cost (Roubles)	3,750,000
Estimated Payback (months)	7

4.2 Install Steam Traps on DHW Heaters

The Domestic hot water heating tanks do not have any steam traps on them. Live steam was observed blowing off the main condensate tanks.

Annual Coal Use	xxxxxx
Estimated Reduction %	1%
Estimated Reduction -	metric tons
Estimated Savings - kR/y	19,968
Estimated Cost - kR	2,250,000
Payback - Months	

4.3 Replace Steam Traps on Ice Cream Plant

Presently one steam trap serves the butter melter, ice cream mixer and Pasteurizer. Another serves the calorifier. Both traps are of the thermodynamic type and are prone to leak through. Replacement with a float and thermostatic or bucket trap will reduce life steam losses by 75 to 90 percent. Presently it is estimated that steam losses are 6-10 percent of the use, new traps, one for each device total of 4, will reduce this by at least 75 percent. Estimated savings are:

Coal Savings	
Present Annual Steam Use tons/year	
Present loss-percent	8
Loss After Replacement-percent	2
Annual Steam Savings-tons/year	
Annual Heat savings @ 1gC/ton	
Average Boiler Efficiency %	81
Fuel Savings GC/year	
Coal Heating Value - kC/kG	5,760
Annual Fuel Savings - tons	
Coal Cost R/ton	100,000
Annual Cost Savings kR	
Estimated Cost - kR	3,000
Payback - months	

* See TAS computer calculations in Appendix zz

4.4 Rehabilitate Steam Flow Meter and Track Coal Consumption

There is an existing steam flow meter installed in the main steam header. This meter has been inoperative for some time. Repairing it and tracking the steam produced will assist operators in operating the plant efficiently. The operators should also track coal use by counting the number of skip loads used by each boiler. This combined with the steam meter will allow calculation of energy use per ton of steam and notify supervisors of approaching problems. A coal analysis should also be obtained with each coal delivery. If this is done the estimated savings are 1-3 percent of coal use.

Annual Coal Use	xxxxxx
Estimated Reduction %	2%
Estimated Reduction - metric tons	
Coal Cost R/ton	100,000
Estimated Savings - kR/y	
Estimated Cost - R	10,000
Payback - Months	

Install Thermostatically Controlled Radiator Valves

Personal comfort areas in the refrigeration plant are equipped with serpentine pipe type radiators controlled by manually adjusted valves. This results in extensive overheating of the areas. Installing Thermostatically controlled valves will reduce steam heating requirements by 20 to 40 percent in these areas.

Coal Savings	
Present Annual Steam Use tons/year	331.8
Steam use Reduction - percent	25

Annual Steam Savings-tons/year	83.0
Average Boiler Efficiency %	81
Fuel Savings GC/year	102.4
Coal Heating Value - kC/kG	5,760
Annual Fuel Savings - tons	17.8
Coal Cost R/ton	100,000
Annual Cost Savings kR	1,780,000
Estimated Cost - kR	5,000,000
Payback - Years	2.9

Section 5

Specifications

5.1 Oxygen Control Specification

Provide an automatic control system capable of continually sensing the excess oxygen (0-20 percent) in coal fired boiler flue gases and displaying the result at a digital display at the boiler control panel. Provide an electrically operator to adjust the position of the Variable Inlet Vanes of the forced draft fan (FDF) that is manually controlled by a switch at the same position as the display (Mechanized Electrical single rotation model 100/25 0.25 rpm, 120 Ohms with 220 vac-24vdc, 10VA power supply). Replace or repair the existing Variable Inlet Vanes and operating mechanism.

Mounting of Sensor

Oxygen sensor shall be mounted int he boiler breech between the boiler and economizer as close as possible to the boiler outlet. Sensor leads shall be in a flexible metal heat shield conduit for a distance of 2 meters then in heat shielded rigid conduit to the site of the display.

FIGURES

Figure 1

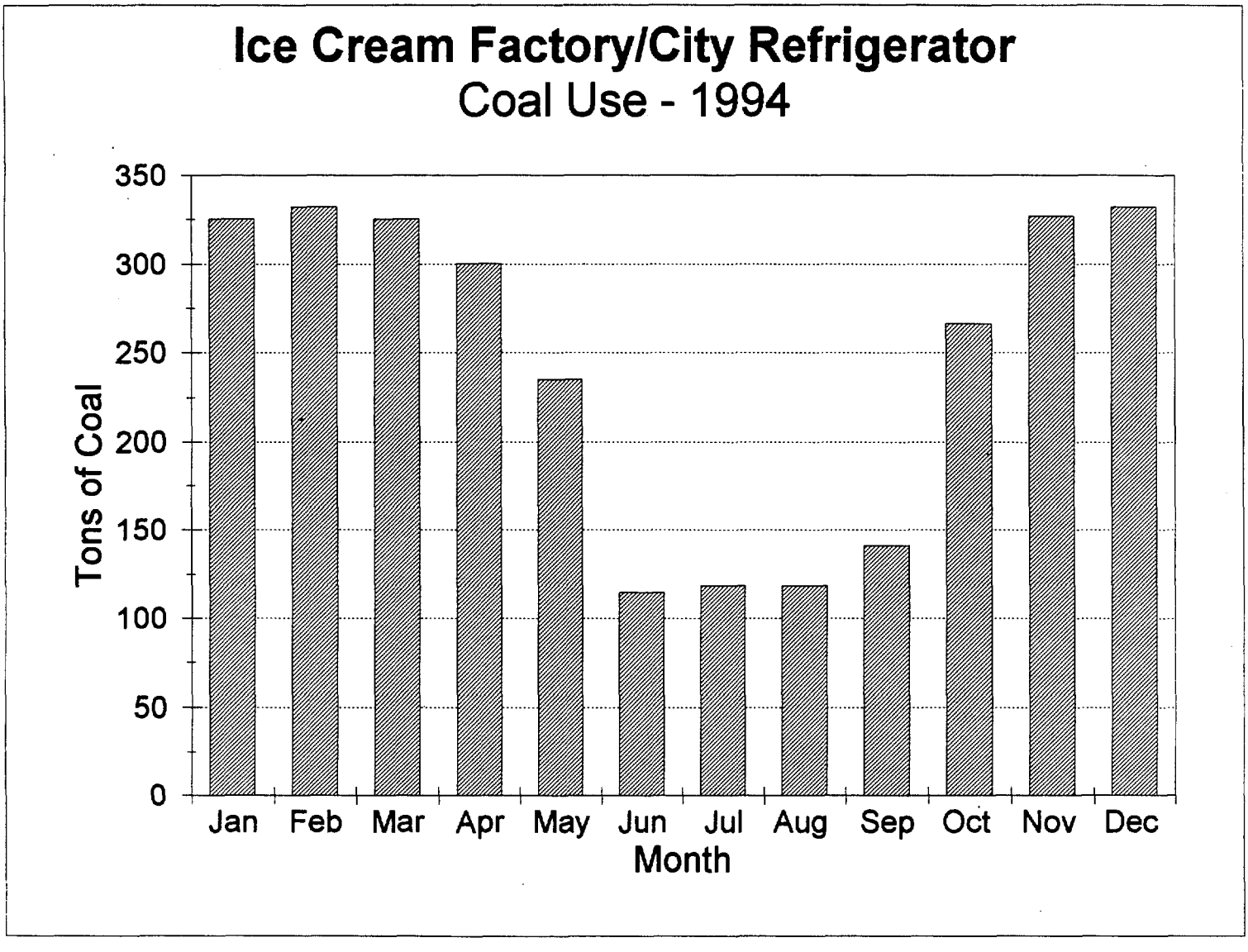
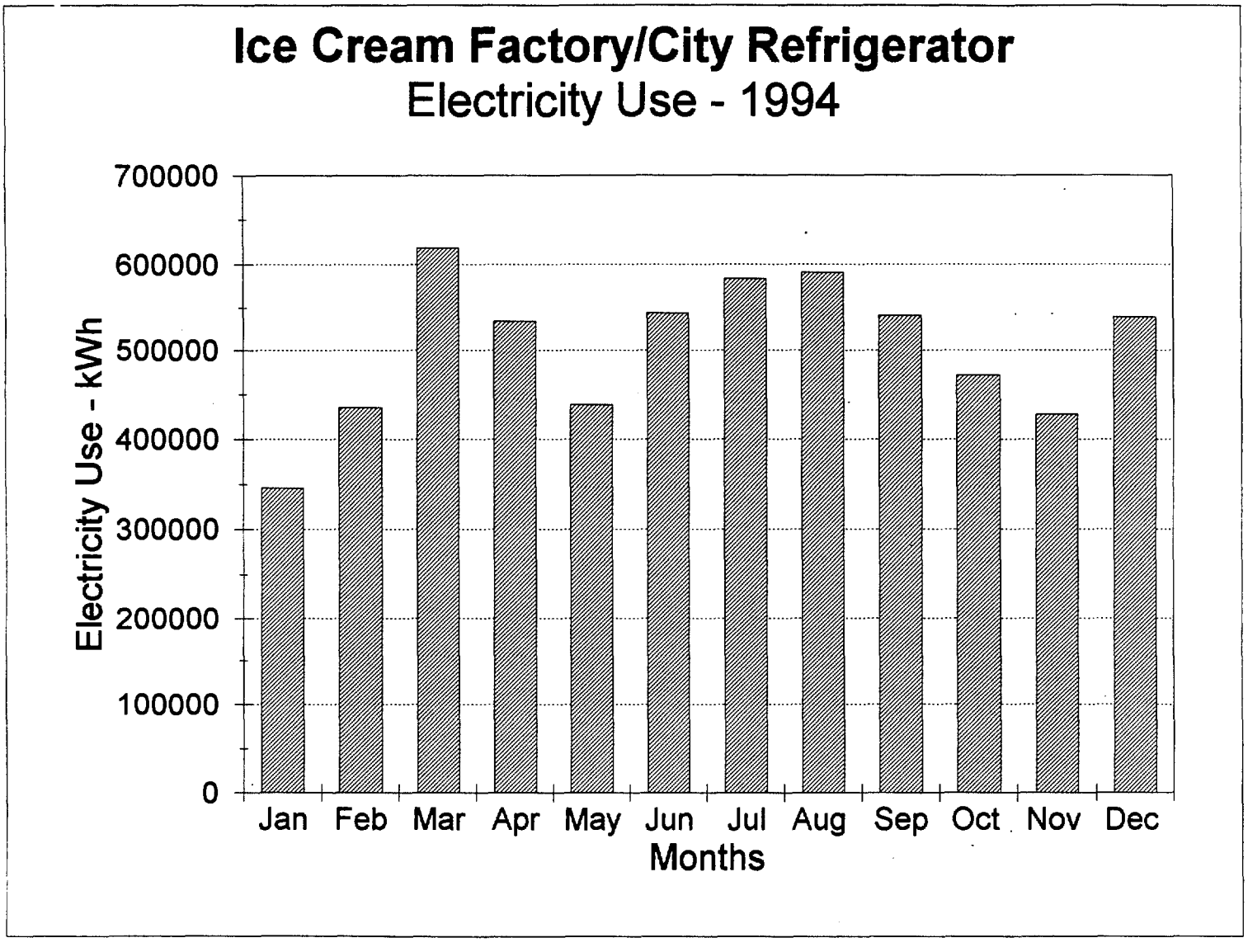

Ice Cream Factory/City Refrigerator
Coal Use - 1994
Tons of Coal
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Figure 2


Ice Cream Factory/City Refrigerator
Electricity Use - 1994
Electricity Use - kWh
700000
600000
500000
400000
300000
200000
100000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

TABLE

Table 1- Energy Profiles for 1994 at the Novokuznetsk Ice Cream Factory

Ice Cream Factory/City Refirgerator

Month	Electricity Use kWh	Average Demand kW
Jan	346000	465
Feb	435600	648
Mar	618178	831
Apr	534000	742
May	438200	589
Jun	543400	755
Jul	583000	784
Aug	590120	793
Sep	540692	751
Oct	471800	634
Nov	428000	594
Dec	538815	724
Annual Total	6067805	

Ice Cream Factory/City Refirgerator
Coal Requirements

Month	Coal Tons	Average Demand Tons/hour
Jan	325.6	0.44
Feb	332.2	0.49
Mar	325.6	0.44
Apr	300.3	0.42
May	235.4	0.32
Jun	114.62	0.16
Jul	118.36	0.16
Aug	118.36	0.16
Sep	141.35	0.20
Oct	266.2	0.36
Nov	326.7	0.45
Dec	332.2	0.45
Annual Total	2936.89	

COMBUSTION CALCULATIONS

.....COMBUSTION CALCULATIONS 07-21-1995 15:10:44

==========

*** RUN IDENTIFICATION ***

PROJECT NAME:	NVK REFR. PLANT
FUEL TYPE & SOURCE:	ANTHR. COAL
RUN NO.	00002

*** ULTIMATE ANALYSIS, % BY WEIGHT ***

1. CARBON %	47.4
2. HYDROGEN %	4
3. SULFUR %	.3
4. OXYGEN %	16.8
5. NITROGEN %	4
6. WATER %	8
7. ASH %	19.5
8. H. HEATING VALUE, BTU/LB	10260
9. % OF ASH THAT IS FLY ASH	30
10. TEMPERATURE OF FUEL, F	80
11. FUEL SP HT, BTU/LB-F COAL=.3,OIL=.53	.3

*** OTHER DATA INPUTS ***

1. LEAKAGE IN AIR HEATER (0?) %	0
2. EXCESS AIR, (20?) %	224
3. UNDIL EXIT GAS TEMP, (300?) F	205
4. AMBIENT AIR TEMP, (80?) F	80
5. CARBON IN REFUSE, (0?) %	15.5
6. BAROMETRIC PRESS,(29.92?)INHG	29.92
7. PRECIPITATOR EFFICENCY,(99?)%	.7
8. RADIATION LOSS, (1.5?) %	1.5
9. MANUFACTURERS MARGIN, (1?) %	1
10. HEAT ABSORBED, MMBTU/HR	12
11. RELATIVE HUMIDITY, (60?) %	60
12.EMISS,NOx, lb/mmBtu HHV (.1?)	.1
13.EMISS,CO, lb/mmBtu HHV (.2?)	.2
14.EMISS,UBHC, lb/mmBtu HHV(.09?)	.09
15.EMISS,Part, lb/mmBtu HHV(.01?)	.01
16.EMISS Base Dry Excess O2%(3?)	3

*** ORSAT ANALYSIS ***

1. % VOL O2 :	13.5
2. % VOL CO2 :	5.6
3. % VOL CO :	.18

==========

RESULTS

*** PERCENTAGE LOSSES ***

LOSS DUE TO CO2 IN GAS %	39898E-5
LOSS DUE TO CO IN GAS %	967E-5
LOSS DUE TO SO2 IN GAS %	111E-5
LOSS DUE TO O2 IN GAS %	78445E-5
LOSS DUE TO N2 IN GAS %	4.2237
LOSS DUE TO STEAM IN GAS %	36849E-5
LOSS OF STEAM LAT HEAT %	4.4600
LOSS DUE TO CARB IN ASH %	4.9156
LOSS DUE TO UNBURNED CO %	1.2975
LOSS DUE TO RAD & MFG MRG %	2.5
TOTAL LOSS %	18.959
FUEL TEMP CREDIT, BTU/LBF	0

*** GAS & AIR FLOWS ***

BOILER EFFICIENCY, %	81.040
TOTAL FUEL HEAT , MMBTU/HR	14.807
FUEL BURN RATE, KLB/HR	1.4432
AIR INTO BURNERS, KLB/HR	26.553
GAS LVING FURN, KLB/HR	27.662
AIR HTR LKG, KLB/HR	0
FLY ASH LVG FURN, KLB/HR	8442E-5
FLY ASH LVG PRECIP,KLB/HR	8383E-5
BOTTOM ASH PRODUCED,KLB/HR	19699E-5
MOISTURE IN AIR, LB/LBDAIR	1313E-5

*** FLUE GAS CHARACTERISTICS....WET ***

VOLUME CO2 %	5.3236
VOLUME CO %	17111E-5
VOLUME N2 %	75.069
VOLUME O2 %	13.749
VOLUME SO2 %	1410E-5
VOLUME H20 %	5.6724
TOTAL OF ABOVE	100.00
MOL WT OF GAS LVG HTR	28.839
DENS @ 60F/30INHG LB/CUFT	7599E-5
DILUT TEMP LVG AIR HTR F	205
CORR DENS @ FLOW CONDITIONS	5926E-5

*** GAS ANALYSIS BY WEIGHT, and EPA EMISSIONS ***

CO2 Klb/hr	2.2468
CO Klb/hr	4595E-5
SO2 Klb/hr	865E-5
O2 Klb/hr	4.2201
H20 Klb/hr	97937E-5
N2 Klb/hr	20.161
TOTAL Klb/hr	27.662
EMISS,NOX (NO2) lb/hr	1.4807
EMISS,NOX (NO2) ppmvd 3% O2	99.685
EMISS,CO lb/hr	2.9614
EMISS,CO ppmvd 3% O2	327.53
EMISS,UBHC (CH4) lb/hr	1.3326
EMISS,UBHC (CH4)ppmvd 3% O2	257.93
EMISS,PARTICULTe, lb/hr	14807E-5

.....COMBUSTION CALCULATIONS 07-21-1995 15:15:13

==========

*** RUN IDENTIFICATION ***

PROJECT NAME:	NVK REFR. PLANT
FUEL TYPE & SOURCE:	ANTHR. COAL
RUN NO.	003

*** ULTIMATE ANALYSIS, % BY WEIGHT ***

1. CARBON %	47.4
2. HYDROGEN %	4
3. SULFUR %	.3
4. OXYGEN %	16.8
5. NITROGEN %	4
6. WATER %	8
7. ASH %	19.5
8. H. HEATING VALUE, BTU/LB	10260
9. % OF ASH THAT IS FLY ASH	30
10. TEMPERATURE OF FUEL, F	80
11. FUEL SP HT, BTU/LB-F COAL=.3,OIL=.53	.3

*** OTHER DATA INPUTS ***

1. LEAKAGE IN AIR HEATER (0?) %	0
2. EXCESS AIR, (20?) %	224
3. UNDIL EXIT GAS TEMP, (300?) F	205
4. AMBIENT AIR TEMP, (80?) F	80
5. CARBON IN REFUSE, (0?) %	15.5
6. BAROMETRIC PRESS,(29.92?)INHG	29.92
7. PRECIPITATOR EFFICENCY,(99?)%	.7
8. RADIATION LOSS, (1.5?) %	1.5
9. MANUFACTURERS MARGIN, (1?) %	1
10. HEAT ABSORBED, MMBTU/HR	12
11. RELATIVE HUMIDITY, (60?) %	60
12.EMISS,NOx, lb/mmBtu HHV (.1?)	.1
13.EMISS,CO, lb/mmBtu HHV (.2?)	.2
14.EMISS,UBHC, lb/mmBtu HHV(.09?)	.09
15.EMISS,Part, lb/mmBtu HHV(.01?)	.01
16.EMISS Base Dry Excess O2%(3?)	3

*** ORSAT ANALYSIS ***

1. % VOL O2 :	11.5
2. % VOL CO2 :	7
3. % VOL CO :	.18

==========

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RESULTS

*** PERCENTAGE LOSSES ***

LOSS DUE TO CO2 IN GAS	%	40148E-5
LOSS DUE TO CO IN GAS	%	779E-5
LOSS DUE TO SO2 IN GAS	%	111E-5
LOSS DUE TO O2 IN GAS	%	78658E-5
LOSS DUE TO N2 IN GAS	%	4.2352
LOSS DUE TO STEAM IN GAS	%	36884E-5
LOSS OF STEAM LAT HEAT	%	4.4600
LOSS DUE TO CARB IN ASH	%	4.9156
LOSS DUE TO UNBURNED CO	%	1.0445
LOSS DUE TO RAD & MFG MRG	%	2.5
TOTAL LOSS	%	18.721
FUEL TEMP CREDIT,	BTU/LBF	0

*** GAS & AIR FLOWS ***

BOILER EFFICIENCY,	%	81.278
TOTAL FUEL HEAT ,	MMBTU/HR	14.764
FUEL BURN RATE,	KLB/HR	1.4389
AIR INTO BURNERS,	KLB/HR	26.547
GAS LVING FURN,	KLB/HR	27.653
AIR HTR LKG,	KLB/HR	0
FLY ASH LVG FURN,	KLB/HR	8418E-5
FLY ASH LVG PRECIP,	KLB/HR	8359E-5
BOTTOM ASH PRODUCED,	KLB/HR	19642E-5
MOISTURE IN AIR,	LB/LBDAIR	1313E-5

*** FLUE GAS CHARACTERISTICS....WET ***

VOLUME	CO2	%	5.3438
VOLUME	CO	%	13741E-5
VOLUME	N2	%	75.088
VOLUME	O2	%	13.752
VOLUME	SO2	%	1407E-5
VOLUME	H20	%	5.6638
TOTAL OF ABOVE			100
MOL WT OF GAS LVG HTR			28.843
DENS @ 60F/30INHG	LB/CUFT		7600E-5
DILUT TEMP LVG AIR HTR	F		205
CORR DENS @ FLOW CONDITIONS			5927E-5

*** GAS ANALYSIS BY WEIGHT, and EPA EMISSIONS ***

CO2	Klb/hr		2.2542
CO	Klb/hr		3688E-5
SO2	Klb/hr		863E-5
O2	Klb/hr		4.2192
H20	Klb/hr		97743E-5
N2	Klb/hr		20.157
TOTAL	Klb/hr		27.653
EMISS,NOX (NO2)		lb/hr	1.4764
EMISS,NOX (NO2)	ppmvd 3% O2		99.468
EMISS,CO		lb/hr	2.9528
EMISS,CO	ppmvd 3% O2		326.82
EMISS,UBHC (CH4)		lb/hr	1.3287
EMISS,UBHC (CH4)	ppmvd 3% O2		257.37
EMISS,PARTICULTe,		lb/hr	14764E-5

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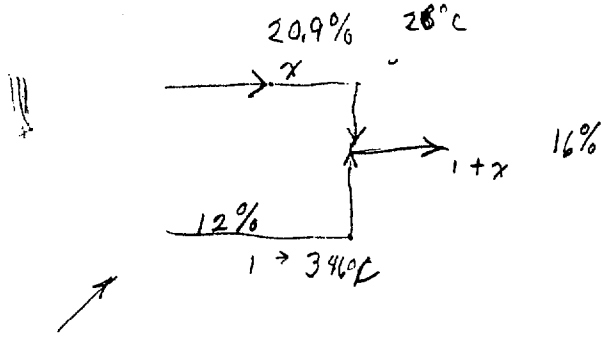
#3 Boiler Exit

Time	T°C	%O_2	%CO_2	%E A	EFF	%CO	PPM NOx	SO2
9:49	346	12.6	7.2	155	70.6	120	136	127
9:51	327	14.3	4.9	208		146	124	93
10:00	282	16.1	—	—	—	148	114	63

Boiler varies from 12% O_2 >16% when coal bed is raked and/or new coal is added



$.209x + .12(1) = (1+x).16$

$.209x + .12 = .16 + .16x$

$.209x - .16x = .04$

$.049x$

$x = .82$ % leakage

but this is at 178°C convert to mass at

20.9 + 78 + 1%

20.9 × 32 =	6.69	→ 23%	→ 20.3%	→
78 × 28 =	21.84	→	66.3	→
1 × 44	4.4		13.4	→
	32.94		100.0	

electricity ↔

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Refr Plant
Boiler 2 Exit
Time T O_2 CO_2 EA EFF CO

Hot Water temp 35.3 at 10 → 110 at -39
return 33 70

domilic water heaters 3 ea
5 m^3
5°C → 75 C
Recovery
60 min @ 5 Kg/cm
110 0.2 "

16 May
At exit

14:12	330	13.4	5.7	168	70	136		NOx
14:14	323	13.4	5.7	156	71.2	135		
14:16	334	12.6	6.4	129	72.5	120		
Tape @ 14:17								
14:20	329	13.2	5.9	161	70.3	146	191	
After Econ								
14:27	154	18.1						
1428	149	18.1				172	68	
1430	148	18.1				160	69	
						144	69	

Boiler # 2 Lower Steam 1.9-2.0 Kg/cm²

1516	196	16.3				93	54	
Yelgen adjusts Spread Coal Out								
1522	213	14.1	4.9	228	79.1	384 134	88	
1524	205	14.8	4.8	218	78.8	144	114	81
Adjusts FD fan								
	232	12.7	6.4	143	81.4	111	122	125

Upper

1538	169	13.9	5.4	191	86.8	90	118	76
1540	178	13.8	5.4	190	84.8	108	119	80
42	171	14.4	5.0	208	85.6	153	104	71
Raked Red								
46	172	13.9	5.4	195	85.9	162	136	77
Tape at 1549								

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PREFACE
Audit Report of Selected Boilers at the ZapSib Combined Thermal and Power Station

This report is the result of an Industrial Environmental Audit carried out April 25 - May 26, 1995 at ZapSib (West Siberian Steel Company). The audit was made by a joint US - Russian team with the support of the United States Agency for International Development(USAID) Environmental Policy and Technology (EPT) Project. There were 6 Americans consultants and 17 Russian specialists from the scientific research and design institutes, enterprises and environmental regulatory agencies on the team.

This audit was performed as a part of a training program for the Russian team members on conducting industrial environmental audits.

Factual information provided by ZapSib formed the basis for evaluating environmental, energy efficiency and worker health and safety conditions at the facility. Opinions formed from this information are the authors and do not necessarily reflect the views of USAID or EPT.....

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AUDIT REPORT

# of Selected Boilers at the ZapSib Combined Thermal and Power Station

Description of the overall Industrial Audit Program

There is an immediate need for rapid improvement in industrial energy efficiency due to a variety of poor energy utilization practices and lack of proper maintenance of energy systems. Related to the low energy efficiency of facilities is a higher emission of particulate to the atmosphere from the coal-fired boilers. Higher than design coal burning rates subsequently overload the flue gas clean-up equipment which worsens the emission problem. Emission penalties do not alone provide sufficient economic incentive to proceed with projects to reduce emissions. Energy efficiency improvements are cost-effective within the current energy economy and can provide economic incentives that support the concern to clean-up the environment. These energy efficiency improvements will also result in a improvement in air quality by reducing emissions at the source.

Increases in energy prices to equivalent world prices have put additional pressures on industrial firms to conserve energy. Changes within the economic system (energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Along with the industrial audit program to demonstrate the effectiveness of energy efficiency improvements, the overall EPT program provided training on energy efficiency audit practices, use of energy performance measurement equipment and evaluation of energy conservation opportunities.

The Industrial Audit Project is comprised on four distinct tasks:

1. Industrial plant screening
2. Industrial plant energy audit
3. Purchase, ship, and receive equipment to implement audit recommendations
4. Implementation and monitoring

Screening of fifteen industrial plants and communal boilers, the cement plant and the ZapSib Combined Heat and Power Plant was accomplished to provide a basis for selecting the plants to be audited. Criteria used in this selection included;

1) Opportunity for energy savings (with a focus on emission reduction),
2) Reasonable payback period in the Ruble energy economy (also calculated in world prices),
3) Potential replicability of energy saving options in similar plants or systems,
4) Future viability of the plant in the changing economy and operation of the district heating system,
5) Size of the plant,
6) Ownership,

20b

7) Location and impact on local ambient air quality and
8) Other activities such as joint ventures or other bi-lateral aid projects.

The cement plant audit is given due to it's significant impact on the local environment of Novokuznetsk. The additional plants selected for the audit phase are:

1) Abashevkaya Communal Boiler,
2) Ziryanovskaya Communal Boiler,
3) Selected boilers at the ZapSib Combine Heat and Power Plant,
4) The ice cream and cold storage plant, and
5) The poultry processing plant.

An energy audit report has been prepared for each of the six facilities audited and a seventh report summarizing the results of the stack particulate sampling accomplished at each of the five facilities other than the cement plant. The seven reports represent the complete reporting of the energy/environmental audit activities conducted in Novokuznetsk, Russia during the period of April 25 - May 26, 1995.

The energy audit activity, described in detail in each facility report, consisted of a determination of the overall energy efficiency of the plant to identify no/low cost equipment opportunities with short term payback. An assessment was made of the technical and management capabilities and capital investment decision-making process regarding energy conservation applications. At the completion of the energy audit, equipment specifications and other documents required for procurement of U.S. and NIS manufactured equipment or materials will be prepared. Particulate sampling of the stack gasses of the five facilities with coal-fired boiler systems was conducted to determine the current stack gas loading of particulates and particulate emission rates.

Equipment specified in the energy audit will be procured, cleared through customs, and delivered to the plant. Purchased authorization requests will be prepared for approval by USAID/Washington and USAID/Moscow. Requests for Quotes or Tenders as well as purchase orders when suppliers are selected will be issued from the EPT/Moscow office to support the interest in identifying the maximum ability for these demonstration projects to be replicated by other facilities in Novokuznetsk. Equipment will be shipped to the audited sites in Novokuznetsk and technical support will be provided by the Russian team members working on these audits.

In the implementation phase, requirements for installation of the material will be identified. Where possible, this will be done by the personnel of each facility, or alternatively, by Novokuznetsk contractors. Following completion of the installation, an assessment will be made of the effectiveness of the energy conservation application and the effect on emission reduction.

Results of the audit conducted in the ZapSib Combined Thermal and Power Station are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit.

Section 1
EXECUTIVE SUMMARY

The industrial sector in Novokuznetsk is very well developed, with many large and heavy industries. In addition, there are 160 boiler houses at medium size industries and district heating systems that consume a large percentage of the regional energy use and are major contributors to the particulate emissions within the residential districts of the city. The facilities chosen for the EPT Industrial Audit project are representative of many companies or similar facilities within the city, making them ideal targets for the industrial energy audit work since potential replication is very high. Many of these medium size plants are very viable, but have not yet implemented energy conservation activities. Changes within the system (increased energy prices, privatization, etc.) will create a new emphasis on the necessity to increase energy efficiency and reduce energy intensity of production. Parallel emission reductions can be expected with increases in energy efficiency.

Results of the audit conducted in the ZapSib Combined Thermal and Power Station are presented in this report giving an overview of the facility, energy audit results, recommendations for no cost and low cost energy conservation opportunities and specification of equipment to implement the recommendations of the audit. Equipment to implement the recommendations from the audit fall in the categories of portable and fixed equipment and are summarized in the following paragraphs.

Portable Test Equipment

Two Sets of the Following Equipment

Infrared Thermometer: Infrared digital thermometer shall be equal to Model RAYPM30L2U as manufactured by EPD Technology Corp., 14 Hayes Street, Elmsford, NY, 10523, USA. Unit range: -10 to 540C with digital read out, 9 volt battery and 220 volt, 50 cycle adaptor.

Combustion Analyzer

A combustion analyzer that meets the following specifications and manufactured by Enerac, Bacharach, CEA Instruments, Land Combustion, Teledyne Analytical Instruments or equal is suitable for this application. Measured Parameters: Flue gas concentrations for oxygen, carbon monoxide, and temperature Calculated Parameters: flue gas, excess air, carbon dioxide and combustion efficiency.

Velocity and Pressure Meter: pressure range from -250 to +250 mm water, velocity from 0 to 30 meters/sec., and temperature range from 0 to 300C. Unit shall have digital or analog readout, pitot tube probe and thermocouple sensor, power options - battery and 220 volt, 50 cycle, battery recharger and instruction book.

Digital Thermometer, No. 52 as manufactured by Fluke Corp. PO Box 9090, Everett, WA 98206, USA Wattmeter: Instrument to measure volts, amps, ohms AC and DC.

Estimated cost of portable equipment: $20,000

Estimated increase in efficiency 1 percent for a savings of $250,000 for a pay back period of 1 month.

Fixed Equipment

An automatic oxygen trim system will be provided for boilers #11 and #6. The purpose of this oxygen analyzer and control system is to visually monitor and automatically maintain an optimum air-fuel ratio in the boiler during the combustion process. This device allows for providing just enough combustion air by automatic adjustment of the combustion air inlet guide vanes to completely burn the fuel and maximize the overall combustion efficiency and minimize energy losses resulting from excessive air quantities and, in addition, carbon monoxide production and visible smoke is eliminated due to incomplete combustion from too low a combustion air quantity.

The oxygen monitoring and control system shall be similar to the Rosemount World Class Oxygen Analyzer with two zirconium oxide sensor probes a General Purpose Microprocessor-Based Controller similar to Rosemount Model 1500 capable of performing at least four trend outputs, having a scan rate of 4 times a second, containing six automatic/manual stations and will control complex systems consisting of as manyas three loops with four controlled outputs. The controller will control both the left and right sides of the steam generating system. Trim system annunciation shall monitor performance of both the boiler and the actual oxygen trimming function. Display values must include as a direct readout, percent oxygen and stack temperature (degrees C). Output from the controller will signal the existing actuators for the forced draft fan for the right and left sides of each boiler.

The system shall require no special sequencing or programming and all inputs must be dialed in using individual adjustable switches. The switch input value must be of the permanent storage type with no batteries required for retention of information. Further, these values shall be expressed in common engineering terms in SI units. Input values shall be, but no limited to, the lowest boiler firing rate and the highest firing rate for at least two fuels, mazut and natural gas; a radiation loss factor; and a percent low fire rate (turndown). The actuator for trimming must be mechanically limited as to the amount of oxygen trim applied throughout the firing range. The system shall incorporate an aspirator air sampling method which continuously provides a fast, accurate flue gas sampling for oxygen level control.

Estimated Cost: $65,000 total for both boilers #11 and #6
Estimated Savings: $260,000 for a 3 month payback period

Section 2

POWER PLANT AND DISTRIBUTION SYSTEM

Electric energy steam and thermal water are produce and distributed in an integrated system that is comprised of a combined thermal and power plant and a heating station. The thermal and power plant also supplies steam and thermal water directly to ZapSib Steel. Because the power plant and the district heating are so interrelated, the description of the overall system includes only a description of the boilers. The industrial end-user and district heat distribution systems are also a part of the effectiveness of the total integrated system. Due to the limited time of this audit, work was focused on boilers only. The main focus of the audit, therefore was on the ZapSib Thermal and Power Plant (ZIPP) and specifically on boilers #6 and #11.

The ZapSib Thermal and Power Plant is one of three power and thermal plants serving the Novokuznetsk area. It provides the electrical power, steam and a portion of the thermal water required by Novokuznetsk. The plant has seven turbines and 11 boilers as is shown in Figure 1. The steam boilers are used to cogenerate electric power for Novokuznetsk and thermal energy for the ZapSib District and ZapSib Steel.

2.1 Electrical and Thermal Capacity

The installed capacity for electric power generation at the plant is 550 MW. The installed thermal capacity is 700 Gcal/hr from the steam cogeneration system. The major items of equipment in the plant are the eleven steam boilers, seven steam turbines, thermal water heat exchangers, water treatment system, cooling towers, steam and water distribution system, and the voltage transformers.

Steam boiler units 1 through 6 have 240 ton per hour steam capacity and were supplied by Barnaul. They were built in 1963 and use a common steam header to feed three turbines rated at 1- 60 MW and 2- 50 MW as shown in Figure 1. Boilers 7 - 11 have 420 ton per hour steam capacity and were supplied by Taganrog Boilers, also of Russian design, were completed in 1983 and supply steam to 3 110 MW rated turbine units. All boilers operate predominately on coal but have the capacity to burn natural gas coke gas, and blast furnace gas. Boilers 1 - 11 are connected into a common header that supplies steam at 150 bar, 550 C to a common header that feeds steam to seven turbines.

All boilers have a dual combustion air/exhaust path where the exhaust gasses are used to pre-heat the combustion air. The boilers are operated with a balanced draft configuration. Boilers 1 -5 each have two forced draft fans with two speeds and ratings of 250 kW and 400 kW. The two induced draft fans also operate at two speeds with ratings of 700 kW and 1100 kW. The large power of the induced draft fans is required to overcome the pressure drop of the combustion air pre-heater. Boiler feed water is supplied by six four MW pumps to a common header. Boilers 7 - 11 have two speed forced draft fans with ratings of 400 kW and 700 kW and two speed induced draft fans rated at 1000 kW and 1400 kW. Both the forced draft and induced draft fans have inlet guide vanes to control air flow and to maintain a negative pressure in the combustion chamber.

Considering the size of the plant, the time available for the audit, and the areas of highest energy conservation potential, the audit team decided to focus on the steam boiler operation. The basic function of the steam boilers is to produce steam at 550 ^{0}C and 130 bar pressure. This steam is fed to the turbines to generate electricity. After the steam is run through the turbines it enters a heat exchanger at 110 ^{0}C to transfer heat to the water used in the district heating system. In addition, some of the steam, about 200 metric tons/hr, is delivered directly to ZapSib Steel with little condensate return.

2.2 Key Plant Data

NAME OF FACILITY:	ZapSib Thermal and Power Station, Owned and Operated by Kuzbassenergo
KEY CONTACTS:	General Director, Mr. Wagner
TECHNICAL DIRECTOR:	Mr. Dobrinsky
DIRECTOR OF MAINTENANCE OPERATIONS:	Victor Bochkarev

2.3 Operating Data

Table 1 and Table 2 present a summary of the operating data for the ZapSib Thermal and Power Station Boiler #6 and Boiler #11 during the year 1994. Steam production at the plant was limited by the availability of primary energy. However, the supply of energy has been a problem for several years and 1994 was taken to be a typical operating year representative of what is expected in the coming years. During 1994 the boiler #6 produced 599,958 tons of steam for use in power production and thermal energy outputs for a 27 percent capacity factor. Distribution of the steam output by month and fuel consumption by month are shown in Figures 2, 3 and 4 respectively. During 1994 the boiler #11 produced 1,586,230 tons of steam for use in power production and thermal energy outputs for a 43 percent capacity factor. Distribution of the steam output by month and fuel consumption by month are shown in figures 5, 6, and 7 respectively.

Section 3

ZAPSIG TEPS COMBUSTION ANALYSIS

Initial tests were performed at the exit of the superheater on the left side of boiler 11. Results of the tests were somewhat ambiguous with O2 readings much higher than expected ,i.e., 6 to 11 percent, versus the indicated 6 percent in the control room. After 5 minutes the combustion analyzer O2 sensor failed. Inspection of the O2 sensor showed a great deal of condensed water present in both filters and in the tubing to the sensor. It is suspected that the test point was close to a leak in a super heater tube.

A second combustion analyzer was used to test the boiler after the air preheater. Results at this point were more consistent and no water was present in the coalescing filter or the tubing. This is a further indication that a minor leak was present at the superheater since a small leak would diffuse rapidly into the rest of the flue gas to where it would not effect the CA at the preheater exit.

Inspection of the results at the preheater exit indicates that the boiler can operate very efficiently, in the late afternoon O2 levels declined to less than 4 percent after operators adjusted the FD fan. This level indicates that there is very little leakage into the preheater from the atmosphere also. The earlier readings of 8.6-9.9 percent also show that the boiler does not operate this efficiently continuously, particularly at low loads, and that combustion air adjustments require close attention from the operators. This indicates that automatic O2 control will be an effective energy reduction measure.

Tests were also performed on boiler 8 at the economizer exit. Results here indicate that the closer attention to O2 control is need here also. O2 measurements were 6.2 to 7.4 percent versus an objective of 3-4 percent.

More extensive tests were run on Boiler 6 since it was being operated as a base load unit. (Boiler 11 is also operated this way normally but due to turbine problems was varying in load during our tests). Tests were run both at the superheater exit and at the preheater exit. An increase in O2 between these two points of 1.5 to 2 percent indicates the presence of some air leakage into the preheater. This reduces the heat recovery from the preheater and increases induced draft fan power consumption.

Boiler 6 like boiler 11 shows that with attention by the operators the boiler can be operated very close to the ideal level of 3 to 4 percent excess oxygen. Although no great variation in excess O2 was noted during the test this may be due to operator awareness of the tests being conducted after the tests on number 11.

Combustion Analysis Results

Combustion tests were performed on three boilers, number 6, 8 and 11 at various locations. Boilers 6 and 8 are 200 gC/hr, 150 bar boilers, boiler 11 is a 410 gCal/hr, 150 bar unit. The results of these tests are presented in the attached table.

Section 4

ENERGY CONSERVATION OPPORTUNITIES

4.1 Oxygen Control for Boilers

Combustion tests using a Bacharach Portable Combustion Analyzer (CA) of boiler 11 show that the flue gas oxygen content at the exit from the economizer varies from 3.5 percent to over 14 percent. Design conditions call for 3 to 4 percent. Maintaining the combustion air in the design range will improve combustion efficiency by 1 to 10 percent, averaging at least 2 percent. Based on estimated coal use by boiler 11 in 1994 of 75,000 metric tons, this will result in a reduction in coal use of 1,500 tons and a savings of 150 million Roubles Although an oxygen sensor is installed with a display in the control room adjustments are made manually by adjusting the forced draft fan inlet vanes (from the remote position in the control room) and the O_2 level tends to drift, up to an observed 14.4 percent in one period. An automatic control system will maintain O2 levels in the 3-4 percent range more reliably. There would also be a savings in fan energy consumption due to lower flows although this is neglected in energy savings calculations.

Estimated Annual Coal Savings (metric tons)	1,500
Coal Cost per Ton (Roubles)	100,000
Annual Savings (Roubles)	150,000,000
Estimated Cost (Roubles)	100,000,000
Estimated Payback (months)	8

4.1.1 Oxygen Control Specification

Provide an automatic control system capable of continually sensing the excess oxygen (0-18%) in coal fired boiler flue gases up to 750 °C and resetting the position of the inlet guide vanes (inlet damper) of the forced draft fans (FDF) to maintain a flue gas oxygen content of 4+- 0.2-percent (adjustable from 3 to 8 percent). The output of controller shall be a 0-5 milli-amp signal compatible with Russian standard practice to a Russian manufactured motorized controller (Mechanized Electrical single rotation model 250/63, 0.25 rpm, 120 Ohms with 220 vac-24vdc, 10VA power supply.

The system shall also sense boiler static pressure and flue gas temperature at the oxygen probe location and display same.

The system shall be PC based with capability for future expansion. Processer shall be a minimum of an Intel 486DX2-66 with a minimum of 8 megabytes of memory. Processer bus shall be ISA/PCI. Provide a hard disk with a minimum of 340 MB and a 3.5 inch floppy disk. Display shall be a minimum of a 14 inch VGA color monitor. Operating system shall be MSDOS with Windows 3.11 or later.

Mounting of Sensor

Oxygen sensor shall be mounted at the exit from the superheater. Sensor leads shall be in a flexible metal heat shield conduit for a distance of 2 meters then in heat shielded rigid conduit to the site of the controller.

Type of Sensor

Temperature Rating - Must withstand continuous exposure to 500 °C flue gases.

Particulates sensor shall be suitable for operation in a highly concentrated hot particle environment. Particulate loadings of up to 25 grams/standard cubic meter may be encountered.

Other Flue gas contents - Sulpher oxides content of flue gas may range up to 2000 parts per million by volume.

Controller Mounting

Provide a mounting rack for the controller in the existing Boiler control room. Locate the monitor, keyboard and console where it is readily accessible to the operators.

Displays

Provide digital display (separate from monitor) of flue gas oxygen content in percent, flue gas temperature in degrees C, and static pressure in mm of water at sensor location. Provide visible and audible error indications whenever any are out of range. The audible alarm shall have a disable switch which shall reset whenever the alarm condition is corrected.

Software

Provide software that will calculate and display combustion efficiency based on a user input fuel analysis. Software shall also be capable of graphical display of measured variables and generation of trend lines, etc. The latter capability may be provided by a standard spreadsheet package such as Microsoft Excel if data is readily exchanged,for example in Excel by opening the file as a comma delimited (CSV) file. In Excel or other spreadsheets templates or other application macros must be provided to display time ordered measured values and trend lines.

Data Storage

Provide non-volatile (hard disk or equivalent) storage capability for up to 30 days of data for 10 points at 15 minute intervals. Provide 3.5 inch removable (floppy disk) storage for transfer of data for off site analysis.

Manual Control

Provide a manual failure mode for control of combustion air in case of controller failure by means of a manually adjustable control. The system shall shift to manual control and sound an audible alarm whenever output of oxygen sensor is out of range.

Power Supply

Provide an uninterruptible power supply and power conditioning system to operate the system for a minimum of 30 minutes without line power. Power system shall tolerate frequencies from 40-60 HZ, voltages of 220 volts plus or minus 25 percent and voltage spikes of up to 1000 volts of up to 20 microseconds. Provide audible and visual alarms of power failure and software to automatically shut down system without software or hardware damage if unattended and power failure exceeds 30 minutes.

Other

The entire system shall be suitable for operation in a dusty environment and shall be protected as necessary.

TABLES

Table 1 - Energy Profiles of Boiler #6 at ZapSib Boiler House

ZapSib Thermal and Power Station, Boiler #6
Steam Production

Month	Energy Tons	Average Demand Tons/hour
Jan	99943	134
Feb	95004	141
Mar	94723	127
Apr	113766	158
May	21154	28
Jun	0	0
Jul	12200	16
Aug	3163	4
Sep	0	0
Oct	7831	11
Nov	94612	131
Dec	57562	77
Annual Total	599958	

ZapSib Thermal and Power Station, Boiler #6
Coal Consumption

Month	Coal Tons	Average Demand Tons/hour
Jan	11070	14.9
Feb	9051	13.5
Mar	9602	12.9
Apr	14263	19.8
May	2631	3.5
June	0	0.0
July	1270	1.7
Aug	446	0.6
Sept	0	0.0
Oct	1064	1.4
Nov	12281	17.1
Dec	7380	9.9
Annual Total	69058	

ZapSib Thermal and Power Station, Boiler #6
Natural Gas Consumption

Month	Gas 1000 m3	Average Use 1000m3/h
Jan	1716	2.3
Feb	2668	4.0
Mar	1400	1.9
Apr	1418	2.0
May	1054	1.4
Jun	0	0.0
Jul	275	0.4
Aug	0	0.0
Sep	0	0.0
Oct	70	0.1
Nov	1369	1.9
Dec	380	0.5
Annual Total	10350	

Table 2 - Energy Profiles for Boiler #11 at ZapSib Thermal and Power Station

ZapSib Thermal and Power Station, Boiler #11
Steam Production

Month	Energy Tons	Average Demand Tons/hour
Jan	221801	298
Feb	245147	365
Mar	88906	119
Apr	142352	198
May	223831	301
Jun	124991	174
Jul	13037	18
Aug	19995	27
Sep	29032	40
Oct	50419	68
Nov	202003	281
Dec	224716	302
Annual Total	1586230	

ZapSib Thermal and Power Station, Boiler #11
Coal Consumption

Month	Coal Tons	Average Demand Tons/hour
Jan	21902	29.4
Feb	25820	38.4
Mar	8989	12.1
Apr	14117	19.6
May	32345	43.5
June	16910	23.5
July	1553	2.1
Aug	2286	3.1
Sept	4036	5.6
Oct	6949	9.3
Nov	26085	36.2
Dec	26862	36.1
Annual Total	187854	

ZapSib Thermal and Power Station, Boiler #11
Natural Gas Consumption

Month	Gas 1000 m3	Average Use 1000m3/h
Jan	2144	2.9
Feb	415	0.6
Mar	554	0.7
Apr	2650	3.7
May	1721	2.3
Jun	579	0.8
Jul	0	0.0
Aug	30	0.04
Sep	0	0.0
Oct	0	0.0
Nov	552	0.8
Dec	355	0.5
Annual Total	9000	

Table
ZAPSIG - TEPS Combustion Analysis

BOILER 11 - Super Heater exit -Left

May 10, 1995

Time	T °C	%O2	%CO2	%EA	EFF	PPM CO	PPM NOX	PPM SOX
11:35	655	11	7.6	104	51.7	165	378	251
11:38	658	8.1	9.8	59	61.3	75	384	281
11:39	661	6.9	107	46	64	67	389	281

Combustion analyzer O2 sensor failed due to water ingestion - ?? Steam leak

BOILER 11 - After Air Preheater -Left

May 11,1995

10:43	225	13.7	5.5	179	80	7	156	10
15:56	234	9.3	8.9	75	86.4	13	213	47
15:59	235	8.6	9.4	65	87	11	257	147
16:01	235	9.9	8.4	84	85.7	12	242	154
16:21	235	8.9	9.2	69	87.5	6	265	97
16:29	241	4	12.9	22	90.2	13	303	
16:32	241	4.4	12.6	25	90	35	310	
16:34	242	3.5	13.3	19	90.5	20	293	

May 12,1995 - Boiler at Low Load

10:36	220	14.4	4.9	208	78.7	6	148	0
10:38	224	14.5	4.9	213	78	7	145	0
10:41	226	14.1	5.2	195	78.9	7	145	6
10:52	235	12.2	6.7	132	82.7	10	189	28
10:56	235	13.6	5.6	175	79.6	11	181	42

May 12,1995 - Boiler 8 Left Side after preheater

11:45	254	7.4	10.3	51	87.3	23	338	190
11:49	252	6.2	11.3	39	88.2	7	382	215

May 12,1995 - Boiler 6 Right Side after preheater

12:48	177	6	11.4	38	93.4	5	440	123

May 12,1995 - Boiler 6 Left Side after preheater

12:57	191	5.4	11.9	32	92.3	5	489	122

May 12,1995 - Boiler 6 After Superheater - Left Side

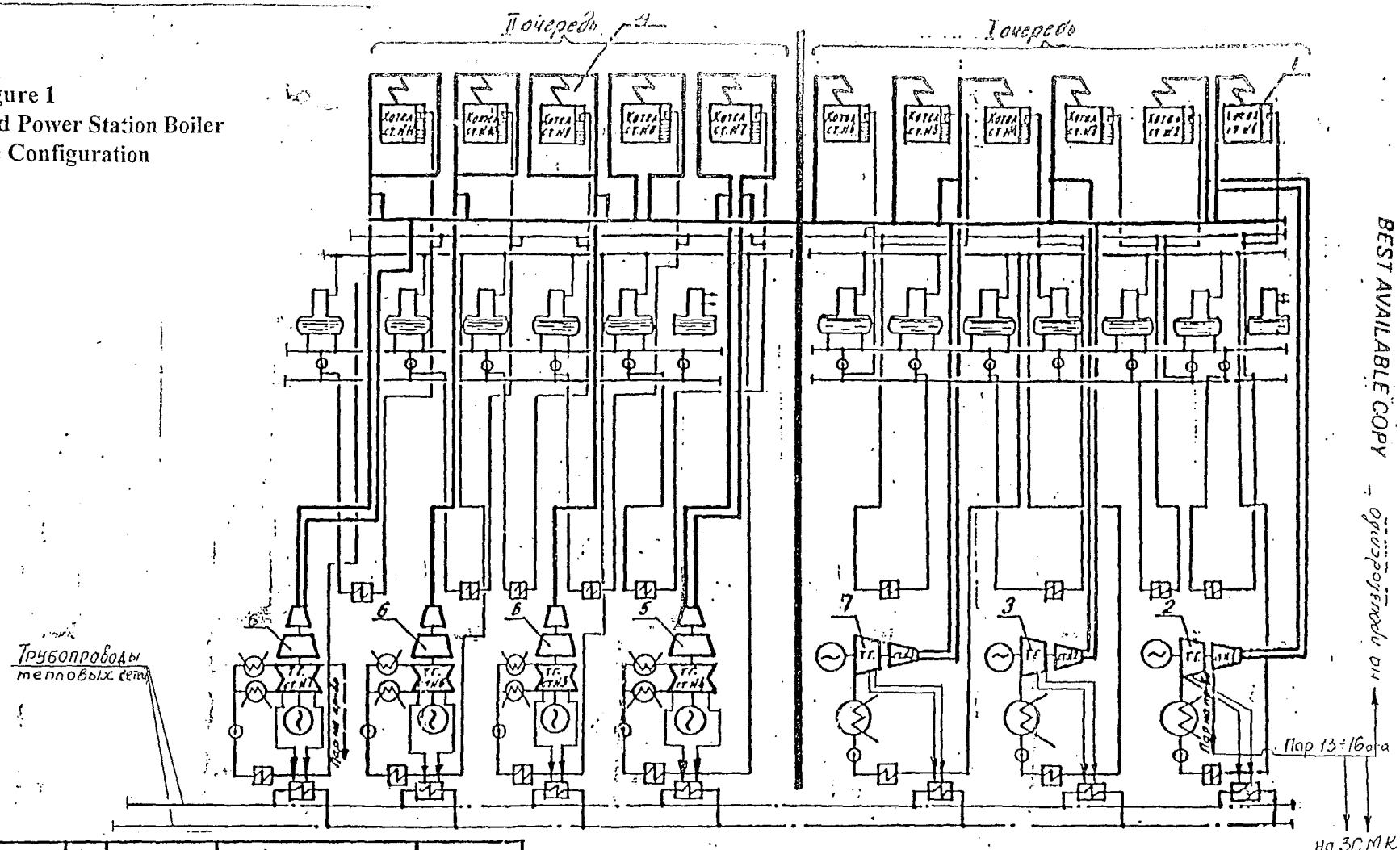
15:14	573	4	12.9	22	73.7	486	478	197
15:17	573	3.5	13.3	18	74.4	163	452	209

May 12,1995 - Boiler 6 After Superheater -Right Side

15:25	600	3.6	13.2	19	73	65	484	
15:28	602	2.7	13.9	14	74	51	428	

FIGURES

Figure 1
Zar Sib Thermal and Power Station Boiler and Turbine Configuration



№ п/п	Наименование	Кол-во	Тип	Краткая характеристика	Принеч.
1.	Котел паровой	6	БКЗ-210-140	Д=210 т/час P_p=140 ата t_p=560°С	6 котлов I очереди
2.	Турбина паровая	1	ПТ-60-130/13	N=60 мвт P_p=130 ата t_p=555°С	1 турбина I очереди
3.	Турбина паровая	1	Т-50/60-130	N=50 мвт P_p=130 ата t_p=555°С	1 турбина I очереди
4.	Котел паровой	5	ТП-87-1	Д=420 т/час P_p=140 ата t_p=560°С	5 котлов II очереди
5.	Турбина паровая	1	Т-100-130	N=100 мвт P_p=140 ата t_p=555°С	1 турбина II очереди
6	Турбина паровая	3	Т-180/120-130	N=180/120 мвт P_0=130 ата; t_p=555°С	3 турбины II очереди

P_0=130 ата II турбина

Изм	Лист	N докумен.	Подпись	Дата	Западно-Сибирская ГЭЦ
					Принципиальная

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Figure 2 - 1994 Steam Production from Boiler #6 at ZapSib Power Station

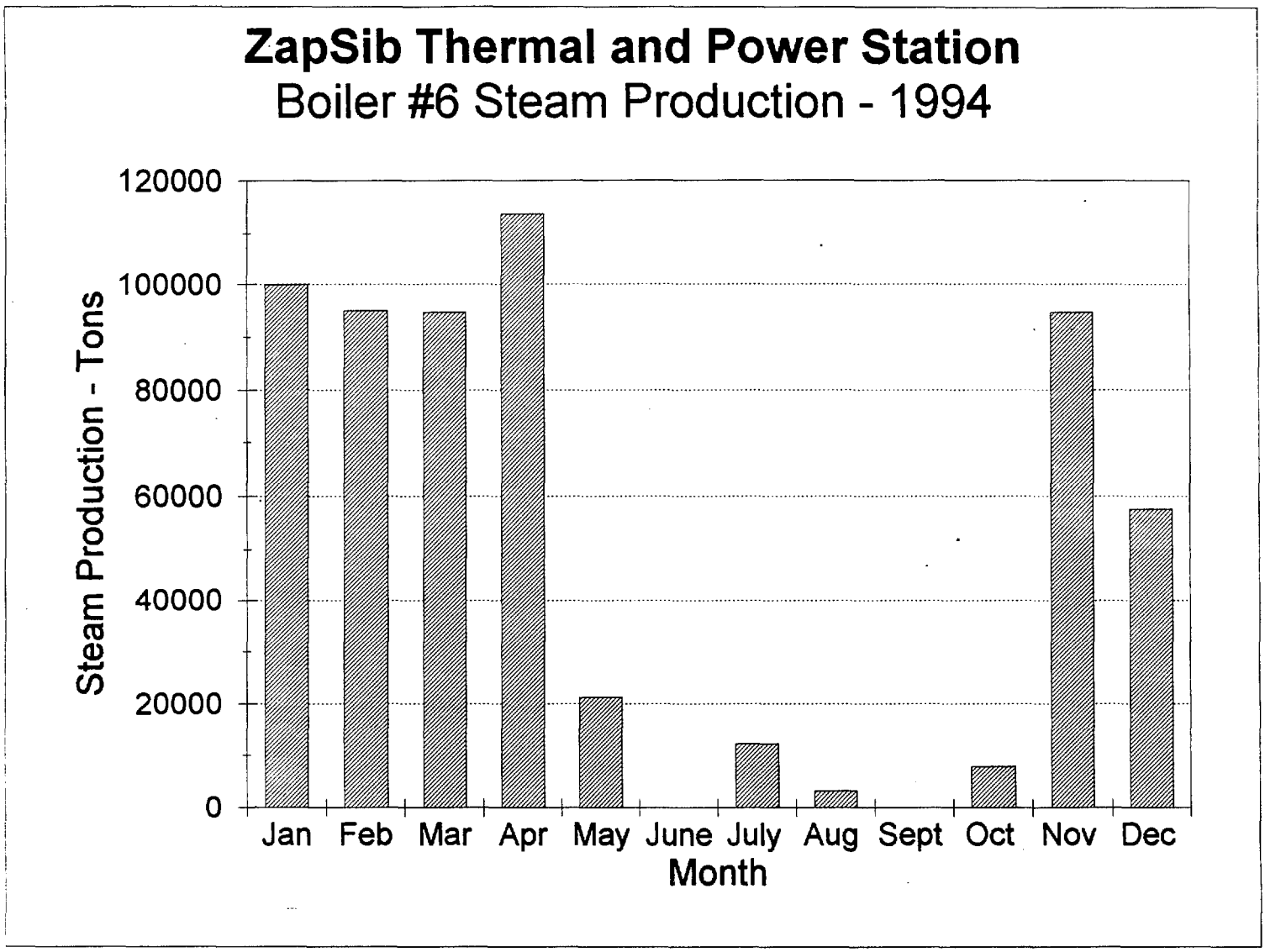


FIGURE 3

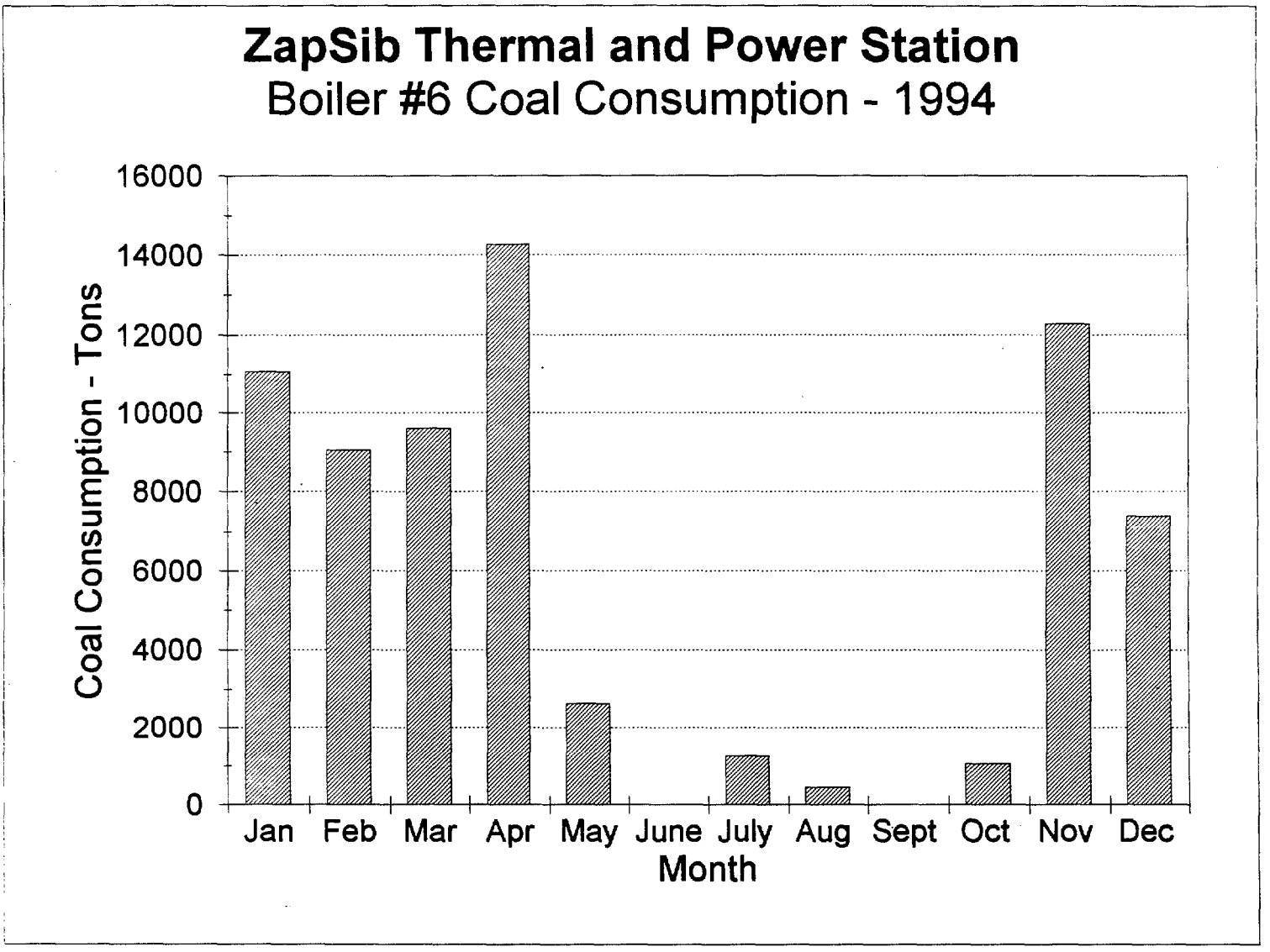

ZapSib Thermal and Power Station
Boiler #6 Coal Consumption - 1994
Coal Consumption - Tons
16000
14000
12000
10000
8000
6000
4000
2000
0
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Month

FIGURE 4

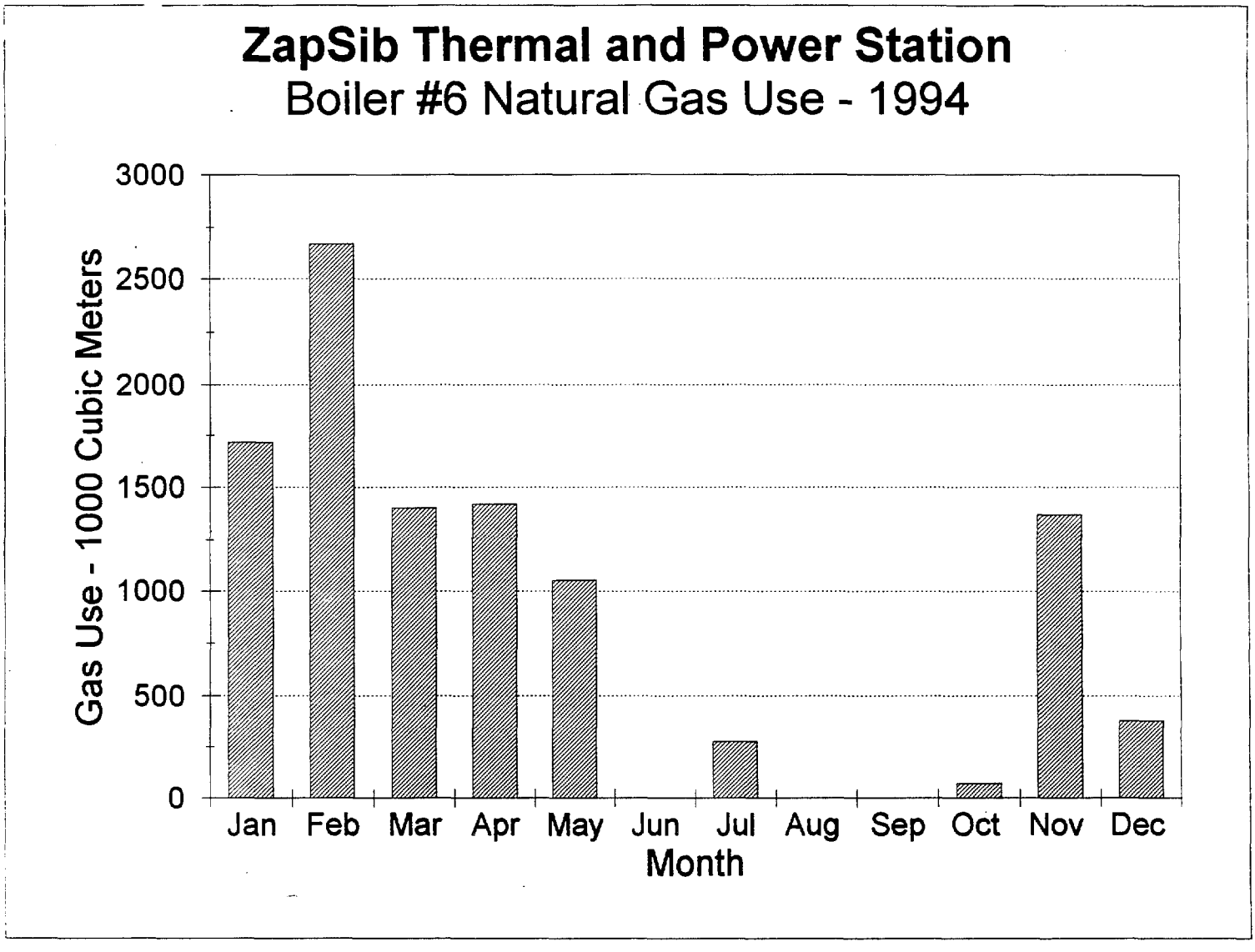

ZapSib Thermal and Power Station
Boiler #6 Natural Gas Use - 1994
Gas Use - 1000 Cubic Meters
3000
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

FIGURE 5

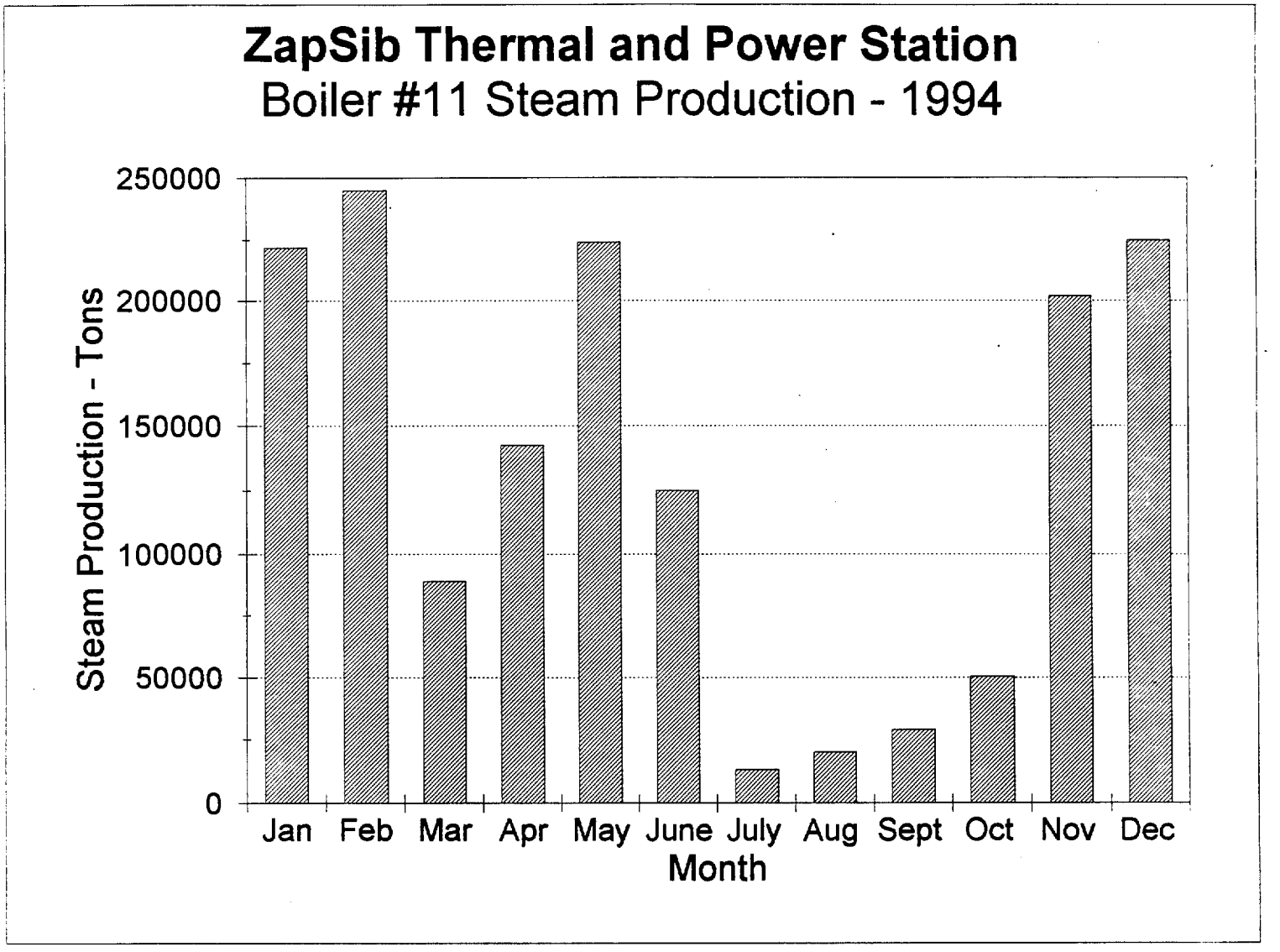

ZapSib Thermal and Power Station
Boiler #11 Steam Production - 1994
Steam Production - Tons
250000
200000
150000
100000
50000
0
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Month

FIGURE 6

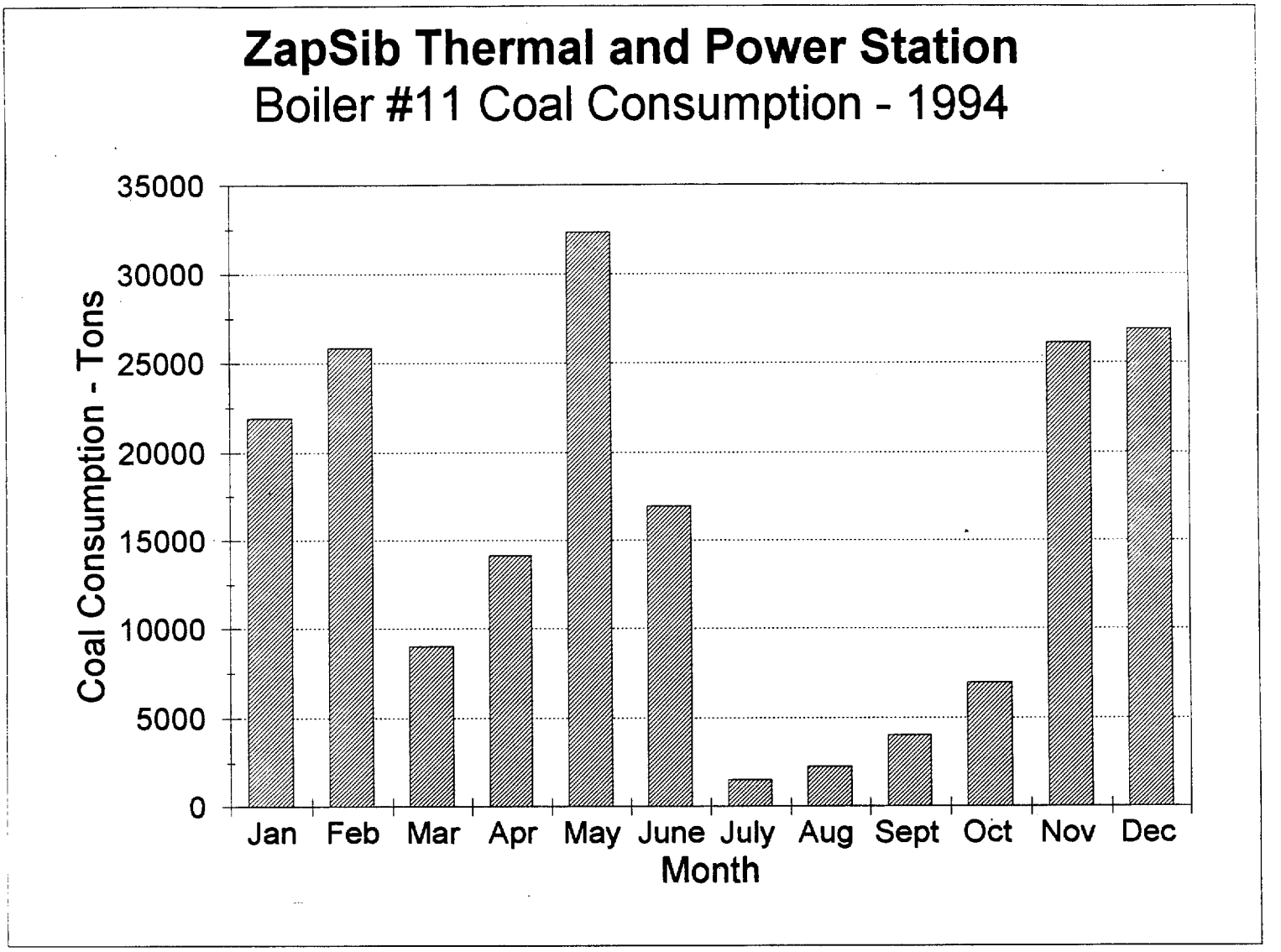
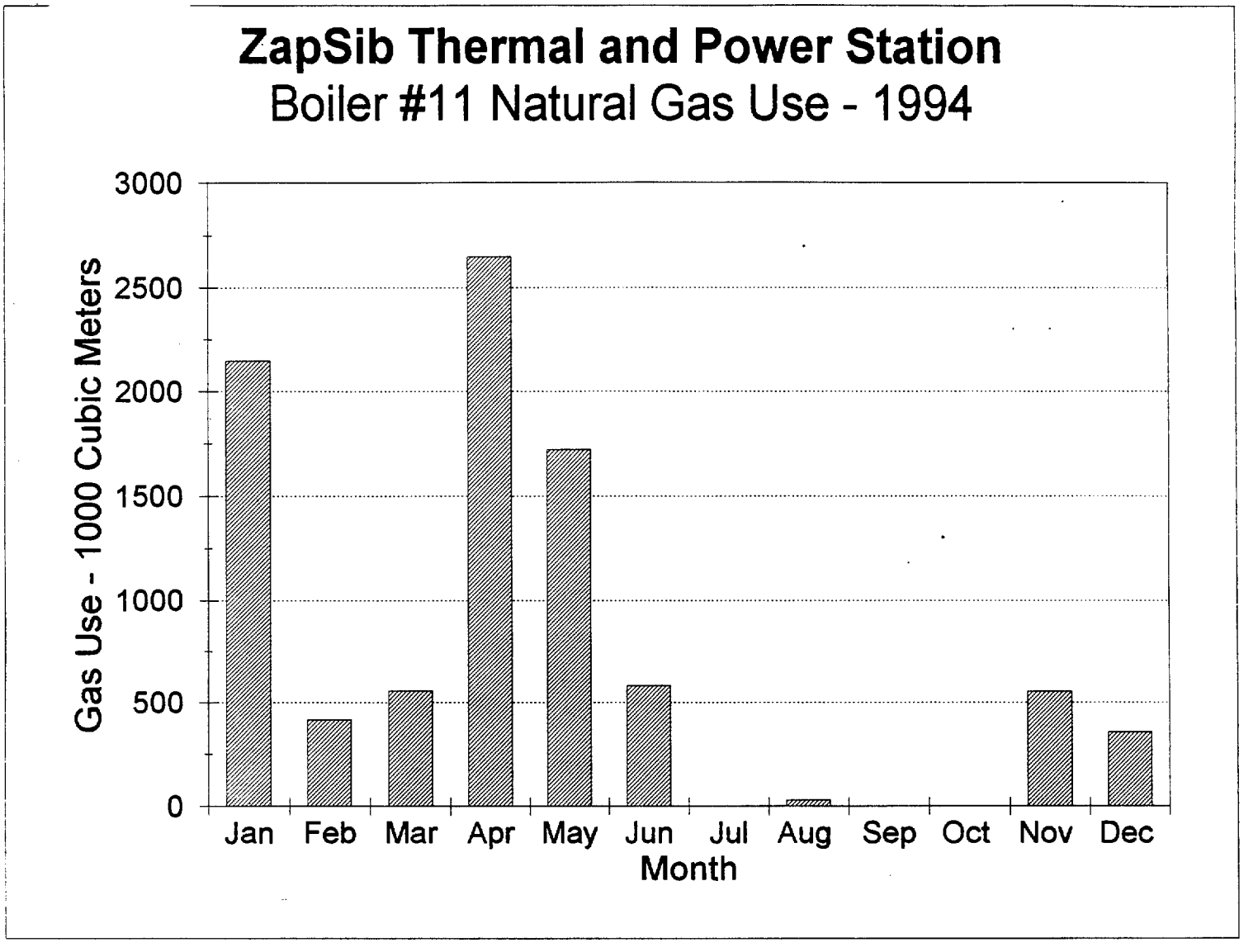

ZapSib Thermal and Power Station
Boiler #11 Coal Consumption - 1994
Coal Consumption - Tons
35000
30000
25000
20000
15000
10000
5000
0
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Month

FIGURE 7


ZapSib Thermal and Power Station
Boiler #11 Natural Gas Use - 1994
Gas Use - 1000 Cubic Meters
3000
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month