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# Environmental Policy and Technology Project

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## TECHNICAL REPORT

**Novokuznetsk**
**Clean Coal Demonstration Final Report**

**by Rutherford (Bo) Poats - August 1997**
**Delivery Order 10, Task 5**

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## Section 1
# Purpose

## 1.1 Background

The Novokuznetsk clean coal demonstration project was undertaken to demonstrate the emission and energy efficiency improvements of using prepared coal. The demonstration was carried out within a representative range of small boiler technologies that are commonly used in Novokuznetsk and throughout the former Soviet Union.

The clean coal demonstration project was developed in August 1994, during the assessment mission of the EPT/Novokuznetsk Air Pollution Team.[1] The program was implemented in three field test phases Phase I under joint participation in November 1995, Phase II under Russian team members' direction in April 1996, and Phase III under joint participation in December 1996. These three phases provide strong evidence that substantial boiler efficiency and emission improvements result from firing prepared coal.

The project built on extensive laboratory and field research performed by the local Russian company Ecougol, under the leadership of Dr Ekaterina Volynkina.[2] This research profiled the small industrial boiler population, its fuel usage, and emission characteristics. Ecougol's research included extensive field and laboratory testing at 10 boiler installations over the period 1992-1993 This and other research[3] established the fact that a significant amount of Novokuznetsk's air pollution was attributable to the city's small, low-stack boilers. The preliminary results of this research suggested that reduced emissions and boiler efficiency gains from the use of appropriately prepared coals could exceed the incremental cost of coal preparation. However, because emission fees and penalties are based on estimated rather than actual emissions, and boiler efficiencies have not, previously, been rigorously tested, boiler houses have had little incentive to use cleaner fuels or to invest in efficiency upgrades Moreover, the lack of commercial coal preparation facilities makes it difficult to produce field-scale test volumes of prepared coal.

Therefore, the EPT Project decided to evaluate the use of prepared coal in low-stack boiler emissions as one component of a broader strategy to address the air pollution problems in Novokuznetsk Other components of the air pollution program included providing equipment and training in energy efficiency auditing, ambient air monitoring and modeling, stack emissions testing, and visible emissions testing The program included installation of combustion control equipment in six large boilers, which demonstrated that reducing emissions pays for itself in improved combustion efficiency. Finally, the program established and equipped local companies that are providing energy auditing and combustion control equipment installation independent of the EPT project

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[1] See "Trip Report of Novokuznetsk Air Pollution Team", August 1994

[2] See, for example, Volinkina, Ekaterina, "Information for Making a Data Base on Atmosphere Pollution In Novokuznetsk", 1994, and Volinkina, Ekaterina, "The Requirements for Fuel Quality for Layer and Torch Layer Stokers", 1994, Novokuznetsk

[3] For example, see "Novokuznetsk Environmental Situation and Environmental Protection Measures", by Joint Stock Company Sibgipromez, Novokuznetsk 1993

## 1.2 Nature of the Problem

The problem of emissions from low-tack industrial and communal heating boilers is well documented [4] Most of the 160 small boiler houses located in the immediate Novokuznetsk area are old, poorly maintained, and rarely renovated. The normal coal burned in these stoker boilers contains a high "fines"[5] content, which is a mismatch to their grate-based combustion technology.[6] These boilers typically operate at low efficiencies (i.e , 65 to 70 percent ) and their operators have had little incentive to improve either efficiency or emissions performance These low-stack boilers have been shown to contribute 10-20 percent of total suspended particulates, 5 to 15 percent of carbon monoxide (CO), and significant quantities oxides of sulfur (e g., SO2) and nitrogen (NOx). These emissions are of great health concern owing to:

1 the less efficient pollution control devices and poor dispersion of emissions from low-stack small boiler houses in comparison to the emissions from larger industrial processes and combined heat and power (Thermal Electric) stations,

2 the direct effect on the large number of people who live and work around these low stack boilers; and

3 the peak emissions from these boiler houses that occur during the winter when thermal inversions occur and dispersion of the pollutants is limited.

The small boiler houses contribute as much as 50 percent of the particulate air pollution during peak winter periods. The direct effect of these boiler emissions to population centers is severe in Novokuznetsk and other cities of the former Soviet Union, which rely on small, low-stack stoker-boilers for heat and hot water Small boiler houses are located close to the populations they serve, and support local industrial or public enterprises (e.g , a coal mine, other local commercial or public operations).

## 1.3 Economic and Technical Issues

The Clean Coal Demonstration focused on small boiler operations, since reduced emissions from these sources can quickly produce improvements in the local and regional air quality The demonstration also was designed to show that burning clean coal can result in economic benefits, due to the need to purchase less (if more expensive) coal, and reduce ancillary costs, such as coal transport and ash disposal. Therefore, the Clean Coal Demonstration justifies the development of a "transitional" coal sorting facility that is critical in bridging the gap until larger scale investments in clean and efficient central district heat and power systems can be afforded.

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[4] See footnotes 2 and 3, above

[5] Fines refer to coal sizes of less than 6 mm or about 1/4 inch

[6] As stated in Schmidt, Charles, "Types of Boilers and Coal Burning Systems for Industrial and Institutional Boiler Operation", Department of Engineering, University of Wisconsin, April 19, 1979 "Regardless of the boiler plant, the most significant element in operation is to start off with the right type of coal This point cannot be overemphasized Unless the impact of fuel upon the rest of the system is recognized, no matter how diligent the maintenance or how sincere the desire to operate or design a plant, total disaster will occur unless fuel is matched with fuel burning equipment "

Effective fourth quarter 1995, the communal boiler houses[7] were transferred to local municipal governments, as part of Rosugol's restructuring plan for the coal industry.[8] This provides an opportunity for a leadership role to be played by the City-owned communal boiler houses, to demonstrate more economically efficient and environmentally benign operations With restructuring, most customers are now required to pay a higher price for coal Prices as high as 100,000 rubles/ton, for instance, provide a significant incentive to improve fuel efficiency

Many of the small boiler houses should eventually be shut down and replaced by a more efficient centralized heat and hot water system or a more efficient combustion system Shutting down, however, is economically painful and will not occur overnight Therefore, for the foreseeable future, most of the boiler houses will remain in operation despite their antiquated technology, owing to their vital role in providing heat and hot water to small commercial and public operations

In order for the Clean Coal Demonstration Project to provide a basis for policy and investment changes, it was made very clear by senior Oblast and City officials that the demonstration program must be undertaken in a rigorous and scientifically acceptable manner Thus, a defensible "mass balance" characterization of the boiler operations was required in the clean coal demonstration if the results were to carry any scientific and, hence, policy merit.

With this background, the EPT project, in cooperation with Russian experts, local industry representatives, and City and Oblast officials, specified the protocols under which the Clean Coal Demonstration was carried out.

[7] Typically, a large low-stack boiler house will contain 4-6 boilers, with half dedicated to industrial process heat and hot water, and the other half to communal (e g , housing, common buildings, etc ) steam heat and hot water

Section 2

# Test Protocol

## 2.1 Introduction

Prior to implementation, the Clean Coal Demonstration Program defined its test methodology and objectives under a protocol jointly developed by the U.S and Russian technical and policy specialists associated with the task.[1] The protocol was developed in consultation with the owners of the boiler houses, coal suppliers the NVK City Administration and Ecological Committee, and the Kemerovo Oblast Administration, Regional Ecological Committee, and Environmental Fund. Their endorsement was sought to ensure that the test results would be accepted as a tool for adjusting local environmental and energy policies

The test protocol set forth the purpose, performance requirements, and responsibilities of the parties engaged in the Clean Coal Demonstration Program, as designed by the EPT project team's U S and Russian members The protocol was specifically developed at the request of the City of Novokuznetsk's Department of Administrative Services (DAS) and at the request of the Kemerovo Oblast Government's Administration Offices The Novokuznetsk DAS has responsibility for clean air monitoring and emissions penalty enforcement Similarly, the Oblast's Administrative Offices have charge over the Regional Ecological Committee which collects and controls emission fees Oblast-wide.

## 2.2 Test Facilities and Methods

Three stoker boiler types were selected for the field demonstration, based on their representation of widespread stoker-boiler designs and sizes in NVK and the broader Kemerovo Oblast These sites were 1) the Dimitrova mine Russian design traveling grate, mechanized feed boiler #6, 2) the Abashaevskaya mine Chinese design reverse traveling grate, mechanized feed boiler #2, and 3) the Laundry Depot fixed grate, hand feeder boiler, a common smaller low-stack boiler design throughout the region.

The primary test at each boiler house was to compare sorted and unsorted G-Mark coal to demonstrate the effectiveness of sorting to reduce the fines content In addition, a 50:50 mixture of sorted G-mark and sorted T-mark coals were tested at the Dimitrova and Abashaevskaya sites, and T-mark coal was tested at the Laundry Depot site.

Each boiler site was tested for its emission and boiler efficiency levels under varied operating heat loads Tests included (1) 70% of rated capacity and (2) maximum load, which varied from 75 to 100% of rated capacity, representing a peak heating season operating level. The base coal was the coal being burned at the facility. The test coals were financed through emission credits and the direct use of funds from the Kemerovo Oblast's Environmental Fund, specifically from the Oblast's budget for the winter Program for 1995-1996 The EPT Project budget provided some funds for sieving of

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[1] The Team comprised U S members R Poats and C Schmidt, and direct Russian counterparts, L Kon, E Volinkina and L Petukova, Bill Howe and Tom Higgins , Y Pryanichnicov and V Eroshenko

coals, but did not directly subsidize coal preparation costs

For each combination of capacity and fuel, the fuel was burned for approximately six hours, allowing 2-5 test runs each day. A 2-hour start up period was provided to establish stable combustion conditions for each of the test fuels

### *2.2.1 Coal Preparation, Transport, and Storage*

Test coal required sieving to a size range not normally provided by commercial preparation plants. This task necessitated using a sieve and labor provided by the Finnartsib, under the control of the Zapsib Metallurgy Plant, in Phase I, and by an independent operator of the Baidaevskaya cleaning plant in Phases II and III

At the boiler site, local labor prepared a graded and smoothed receiving and storage area for the test coal to be run in each test boiler In addition, plant personnel assisted the boiler demonstration Team

### *2.2.2 Laboratory Testing and Support*

Laboratory tests were conducted on the coal, flue gas, flyash and slag in order to calculate boiler efficiency (by mass balance), collector efficiency, emission characteristics, composition and physical properties of flyash, slag and intermediate flow rates, pressures and temperatures. These tests determined unburned residue in the slag, the flyash size, and constituents, including the concentration of harmful mineral and metallic pollutants in flyash.

All tests were performed in the NVK area except the benzopirenes test, which was farmed out to an independent laboratory in the Tomsk area Primary testing responsibility was given to Ecougol in Phase I, and to ZabSib Lab with supplemental lab support provided by the Siberian Metallurgical Institute in Phases II and III

## *2.3 Local Participation*

The roles and responsibilities of the various local parties engaged in the Clean Coal Demonstration Program is described below

| | |
|---|---|
| Oblast Administration· | Approved test and authorized coal mines, preparation plants and test boiler owners, provided emission fee investment credits to fund the cost of test coal preparation and transportation to the test sites. |
| City Administration. | Estimated and confirmed local costs of performing boiler audit requiring emission fee credits, other sources of funds. Acted as local coordinator of demo, including preparation of test protocol and coal supply contracts Provided local coordination and liaison with the Oblast. |
| Participating Enterprises | Provided logistic and material support to the project. Provided reliable cost estimates for extraordinary costs (e g., |



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| | |
|---|---|
| | coal preparation and delivery) |
| Ecougol. | Provided laboratory testing and staff for field work at boiler houses |

## 2.4 Test Measurements

The tests executed in performance of the Clean Coal Demonstration Program are summarized in Exhibits 2-1 through 2-6 Exhibits 2-1 and 2-2 present the formulae utilized to calculate boiler efficiency for steam and hot water boilers, respectively. Boiler efficiency is expressed as the ratio of heat output over heat input Heat output is measured from the multiple of steam (or water) flow and the enthalpy change in steam (or water) temperature Heat input is equal to the demonstrated heat value of the coal input, represented by the sum of the coal combustion process "products." These include· hot water, flue gas, slag mechanical collector dust, stack dust and skin heat loss Inputs needed to measure the heat value of each of these boiler combustion outputs are shown in Exhibit 2-1 The heat represented by each of these "products" of coal combustion is calculated from the test data collected in tests No 1 through No. 3, as well as the Flue Gas Test shown in Exhibit 2-5

Calculation of the efficiencies of the cyclone collectors used in most of these low stack boilers is shown in Exhibit 2-3. Two calculations of collector efficiency are given. Particulate sizing at inlet and outlet provides an indication of the effectiveness of the collector for its typical load (sizing)



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## Exhibit 2-1

### Steam Boiler Efficiency (BLR. EFF.) Calculations

$$\text{BLR. EFF.} = \frac{\text{Steam Production Heat}}{\text{Heat of Coal Input}} = \frac{\text{Heat Output}}{\text{Heat Input}}$$

Steam Production Heat } = (Steam Flow) (Enthalpy Steam – Enthalpy Feedwater)

$= ({}^{m3}/_{Hr} \times {}^{kg}/_{m3})\ [({}^{CAL}/_{g} - {}^{CAL}/_{g})\ ({}^{KCAL}/_{1000CAL})\ ({}^{1000g}/_{kg})$

Heat Of Coal Input = Steam Heat + Flue Gas + Slag + Dust Collected + Stack Dust + Skin Heat Loss

Steam = As Above

Flue Gas = Flue Gas Flow, ${}^{m3}/_{Hr}$
Flue Gas Temperature, °C, $H_2O$, Combustables
Flue Gas Analysis, $0_2$, $CO_2$, CO, NOx
Coal Analysis (Test No 1 & No 2)

Slag = Mass Flow, ${}^{kg}/_{Hr}$
Heat Value, ${}^{KCAL}/_{kg}$

Stack Dust = Mass Flow, ${}^{kg}/_{Hr}$

Skin Heat Loss = American Society of Mechanical Engineering Curve

## Exhibit 2-2

### Hot Water Boiler Efficiency (BLR. EFF.) Calculation

$$\text{BLR. EFF.} = \frac{\text{Hot Water Heat}}{\text{Heat of Coal Input}} = \frac{\text{Heat Output}}{\text{Heat Input}}$$

Hot Water Heat } = (Water Flow) (Enthalpy Supply Water - Enthalpy Return Water)
$({}^{m3}/_{Hr} \times {}^{Kg}/_{m3})\ [({}^{CAL}/_{g} - {}^{CAL}/_{g})\ ({}^{KCAL}/_{1000CAL})\ ({}^{1000g}/_{Kg})$

Heat of Coal Input = Hot Water + Flue Gas + Slag + Dust Collected + Stack Dust + Skin Heat Loss*

**As Determined in Exhibit 2-1*



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## Exhibit 2-3

Mechanical (Cyclone) Dust Collector Efficiency Calculations

A. Efficiency = $\frac{\text{Flyash – Soot Outlet (Collector Outlet)}}{\text{Dust Collected + Flyash – Soot Outlet}}$

B. Efficiency = $\frac{\text{Flyash – Soot Outlet}}{\text{Flyash Inlet}}$

C Particle Size of "Flyash-Soot Outlet" Indicates Condition of Collector

D. Particle Size Of "Flyash-Inlet" Indicates What A Mechanical Dust Collector Should Collect

Particulate emission calculations were calculated using four units of measure, as shown in Exhibit 2-4 A) mass per unit time, B) mass per heat input (and output), C) mass per flue gas volume, and D) mass per flue gas volume corrected to standard temperature and oxygen mix The measure utilized to calculate emission rates is normally the useful heat input or heat output basis (B) Emissions per useful heat input provides an indication of emissions from a given level of energy (i e , coal) input The useful heat output basis provides a measure based on available heat, thus accounting for energy efficiency effects. For this reason, the summary results of this report focus on the useful heat output measure, while the detailed results shown in Annexes B-1 through B-3 provide the full range of emission rate units.

## Exhibit 2-4

**Particulate Emissions Calculations**

A. Mass Per Time; $^{Kg}/_{Hr}$

B. Mass Per Heat Input, $^{Kg}/_{KCAL}$

C. Mass Per Flue Gas Volume; $^{Kg}/_{1000m3}$

D Mass Per Flue Gas Volume, Corrected To Standard Temperature and 6% $O_2$; $^{Kg}/_{1000\ STD\ m3}$

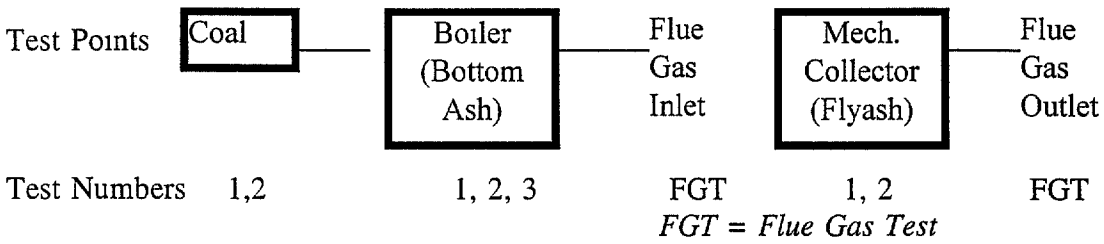
Exhibit 2-5 provides a profile of the samples pulled and tests taken at each stage of the clean coal demonstration program Tests No 1 and No 2 were applied to not only the coal, but also to the bottom ash (slag) and flyash collected from the boiler and collector operations, respectively The flue gas test (FGT) was applied both at collector inlet and outlet. These data were critical both for profiling the gas and solids composition of the boiler mass flow at each stage, and as inputs to the efficiency calculations summarized in Exhibit 2-1. All together, roughly 80 test data needed to be recorded for each coal test run.

Exhibit 2-6 shows inputs required to calculate the materials balance on the boiler operations, thereby insuring a useful efficiency measure Flow rates calculated are uniformly in Kg/hour, and a full material profile of solids is created, based on the coal (and ash) test measurements (Nos 1-3) With a full materials balance on the boiler (as well as a gas balance on the mechanical collector), inconstencies in data normally can be isolated and either properly qualified or thrown out of the data set.

Rigorous test methods and procedures were critical to garnering local and regional support for the program. These efforts served to provide a basis on which economic, policy, and capital investment decisions can be made.

## Exhibit 2-5

**Clean Coal Demonstration Tests: Coal, Boiler, Bottom Ash, Collector and Flue Gas**
(Objective Coal and Flue Gas Balance From Flue Gas Determine Coal Input In $^{Kg}/_{Hr}$)




*FGT = Flue Gas Test*

Coal-Test 1, 2 & 3

**Test No.1 – Coal**

- Fixed Carbon_____%
- Volatile Mat _____%
- Ash _____%
- Moisture _____%

  100 00%
- Heat Value _____ $^{KCAL}/_{Kg}$
- 7Sulfur _____%

**Test No. 2 – Coal**

- Carbon, C _____
- Hydrogen, $H_2$_____
- Oxygen, $O_2$ _____
- Nitrogen, $N_2$ _____
- Chlorine, $CL_2$_____
- Sulfur, S _____
- Ash _____
- Water _____

  100%

**Test No. 3. – Ash**

- Silica, $SCO_2$ _____%
- Alumina, $AL_2O_3$ _____%
- Titania, $TiO_2$ _____%
- Ferric Oxide, $Fe_2O_3$ _____%

- Combustible As Methane (CHg)_____%$CH_4$

Test No 3 Ash (continued)

- Volume _____ $^{m3}/_{Hour}$
- Lime, CaO _____%
- Magnesia, MgO _____%
- Potassium Oxide, $K_2O$_____%
- Sodium Oxide, $Na_2O$ _____%
- Sulfur Trioxide, $SO_3$ _____%
- PHOS, Pentoxide, $P_2O_5$_____%
- Strontium Oxide, SrO_____%
- Barium Oxide, BaO _____%
- Manganese Oxide, $Mn_3O_4$ ___%

**Test No. 4 – Ash Fusion Temperatures**
**Test No. 5 – Coal Size**

**Flue Gas Test**

- Volume _____
- Temperature _____0C
- Oxygen _____%$O_2$
- Carbon Dioxide_____%$CO_2$
- Water Vapor_____%$H_2O$
- Carbon Monoxide___%CO
- Sulfur Dioxide_____%$SO_2$
- Nitrogen Dioxide____%$NO_2$
- Nitrogen Oxide_____%NO



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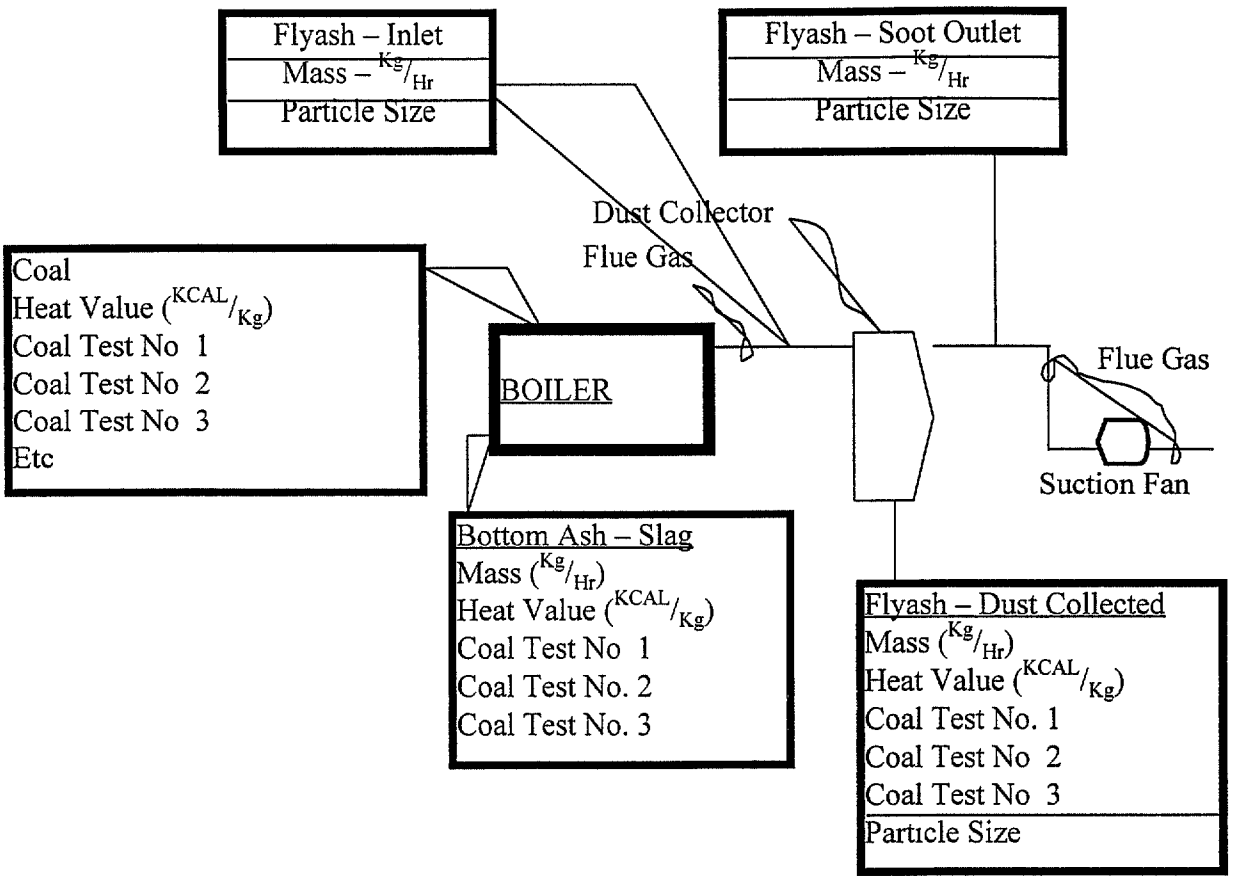
## Exhibit 2-6

### Calculation of Solid Material Balance



Section 3

# Test Results

## 3.1 Overview

Three test phases were undertaken between November 1995 - December 1996

**Phase I** took place during November 21 - December 1, 1995 with a joint U S. and Russian team, and included performing tests at the Dimitrova boiler house (a Russian-design mechanical traveling-grate boiler), and the Abashaevskaya boiler house (a mechanical reverse traveling-grate boiler of Chinese design) The coal in Phase I had low fines content, but relatively high ash content, primarily because there are no proper coal sizing facilities in the Novokuznetsk area The test G-mark coal was obtained from Kuznetskaya mine and sieved at the Zapsib-owned Finnartsib site This sieve is normally used for sorting industrial wastes, and significant ash contamination was likely introduced in screening and handling of the coal on site Moreover, Kuznetskaya coal (and much of the G-mark coal from the Novokuznetsk area) is highly friable and susceptible to increased ash content in the sieving process In Phases II and III, greater care was taken to control ash content in the sieving process, but this increased the cost of cleaning and transport, and resulted in higher fines content in Phase II

**Phase II** testing was carried out at the Dimitrova and Abashaevskaya boiler houses in April 1996 by a Russian team Phase II coal was obtained from the Baidaevskaya washing plant and then sieved before transport While low in ash (owing to washing), the Phase II coal was high in fines content, in part owing to the fine nature of coal concentrate, but also due to transport and handling at both loading and boiler sites

**Phase III** testing was carried out at the Dimitrova, Abashaevskaya, and the Laundry Depot boiler houses during December 1996 by a joint U S and Russian team The Laundry Depot had a small (< 2 Gkal/hr) hand-fired, fixed-grate boiler, which is commonly used in Novokuznetsk and the greater Kemerovo Oblast Coal quality under Phase III was carefully controlled to obtain both low ash and low fines

The execution of three separate field tests demonstrated the value of controls, not only in coal quality, but also boiler operations, emission control equipment, testing methods, and equipment Differences in these variables account for most of the differences in results obtained

## 3.2 Phase III Results

The detailed results of the Phase III Clean Coal Demonstration field tests are presented in Annexes B-1 through B-3 They include the following

- Boiler operating properties (i e , steam flow, boiler load, feedwater temperature, steam and feedwater enthalpy, boiler outlet oxygen, economizer outlet flue gas temperatures),
- Coal quality, including percent fines, percent ash and coal heating value,
- Bottom ash characteristics, including heating value, percent carbon and percent ash,

- Flyash characteristics, including heating value, carbon and ash content,
- Combustion efficiency and heat loss, including heat losses by source and net combustion efficiency measured on both a heat input and heat output basis, and
- Emission control efficiency, including measurement of mechanical (dust) collector inlet and outlet emissions, collector flows, deviation and overall collector efficiency

The charts and tables that follow summarize the data, focusing on the key drivers of the clean coal combustion and emission characteristics

### *3.2.1 Dimitrova Test Results*

The Dimitrova boiler house is a mechanical, traveling-grate boiler of Russian design, with a rated capacity of 25 tons/hour of steam It is one of the most efficiently operated boiler houses of this design in the Novokuznetsk area, and is useful in extrapolating the test results to the other 1,400 boilers in the Kemerovo Oblast This boiler design accounts for approximately 85-90 percent of total stoker boiler capacity in the Novokuznetsk area and represents the majority of the area's low-stack boiler coal combustion and related particulate air emissions Dimitrova is owned by Kuznetskugol, a large regional coal company headquartered in Novokuznetsk, and affiliated with Rosugol Dimitrova's management appears motivated to improve boiler operations

The 1996 tests at Dimitrova provide a comparison of boiler efficiencies and air emissions properties using sorted and unsorted G-mark[1] coals In 1996, five tests each were conducted on unsorted and sorted G-mark coals Results are summarized in Table 3-1 and detailed in Annex B The unsorted coal had a fines content ( percent < 6 mm) of 42 8 percent, compared to 16 8 percent for the sorted coal (Exhibit 3-1) Boiler efficiency improved by approximately 9 percent due to sorting Some of this improvement increase was accounted for by the lower ash content of the sorted coal, but most was due to more complete combustion of carbon In Phase I testing, boiler efficiency improved by over 3 percent, despite the sorted coal having 61 percent more ash than the unsorted coal Even better improvements can be expected from boilers which are not as efficiently operated as Dimitrova, or where sufficient time is allowed to optimize boiler operation with sorted coal (due to the limited sorted coal available, it was impossible to optimize the boiler operation with the sorted coal)

Particulate matter (PM)[2] emissions were reduced by approximately 38 percent During Phase III, the mechanical collector averaged 66 to 68 percent efficiency, compared to 87 to 89 percent in Phase I In the Phase I tests, sorting reduced PM emissions by 42 percent

[1] G-mark coal is a local bituminous coal with gassy characteristics (i e , high volatility), which in local production is also highly friable, meaning it breaks easily into fine particles of less than 6 mm, or 1/4 inch
[2] Particulate matter (PM) is also often referred to as Total Suspended particulates (TSP)



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**Table 3-1**
**Summary Results of Dimitrova Phase III Clean Coal Demonstration Testing**

| Coal Tested: | Unsorted | Sorted |
|---|---|---|
| Tests | 5 | 5 |
| Fines (%< 6 m) | 42 8 | 16 8 |
| Ash (%) | 15 47 | 7 70 |
| Combustion Efficiency (%) | 71 29 | 77.93 |
| PM Emissions (kg/Gcal) | 4 88 | 3 02 |

### *3.2.2 Abashaevskaya Test Results*

The Abashaevskaya boiler is a reverse-traveling, chain-grate stoker boiler of Chinese design, which was converted from a Russian designed, mechanical, traveling-grate stoker boiler (similar to Dimitrova) Abashaevskaya is also owned by Kuznetskugol Abashaevskaya is one of Kuznetskugol's larger producing mines and its management is highly capable However, since it supplies coal from its local mine, it has little incentive to reduce fuel consumption

The Abashaevskaya communal boiler is a hot water boiler, rated at 22 Gcal/hour The Chinese grate boilers of this type do not represent a major component of Novokuznetsk boiler capacity, but there are to plans to convert additional boiler houses to the Chinese design In the past year, for example, the Ziryanakovskaya boiler house has converted In addition to testing sorted and unsorted G-mark coal, a blend of the two was tested to determine whether an intermediate level of fines would improve boiler efficiency and particulate emissions This was also a response to problems in maintaining combustion with sorted coal in previous (Phase I and Phase II) testing Boiler loads of just 50-66 percent of rated capacity were possible with unsorted coal in 1995 tests and insufficient combustion could not be maintained with sorted coal to take useful measurements In 1996, with improved coal quality, unsorted coal averaged an 80 percent boiler load, while sorted G-mark coal averaged a 63 percent boiler load The mix of sorted and unsorted coal averaged an 88.6 percent boiler load

Boiler load is an important parameter A weakness of the Chinese units is that they reduce capacity from the previous Russian-design grates, and if they also cannot pull load and are less efficient, then they are less economical Our test results at Abashaevskaya demonstrated that, with the proper fuel, these boilers can have reasonable thermal efficiencies and particulate emissions However, when burning ill-suited coal, the Chinese design exhibits both poor efficiency and emissions performance

Phase III test results at Abashaevskaya are summarized in Table 3-2. The mixed coal produced better results than either the sorted or unsorted coals The ideal level for these chain grate stokers appears to be in the 20-25 percent fines range, vs 10-15 percent fines for the Russian design grates Indeed, a compelling reason for the introduction of the Chinese grate design is its better performance with high fines coal, prevalent in Novokuznetsk G-Mark coals (and in many locations in China).

**Table 3-2**
**Summary Results of Abashaevskaya Phase III Clean Coal Demonstration Testing**

| Coal Tested | Unsorted | Sorted | Mixed |
|---|---|---|---|
| Tests | 3 | 2 | 3 |
| Fines (%) | 36 53 | 17 65 | 23 80 |
| Ash (%) | 14 15 | 13 36 | 14 64 |
| Combustion Efficiency (%) | 65.25 | 66.28 | 70.56 |
| PM Emissions @ Collector Inlet (kg/Gcal) | 9 29 | 5 40 | 3 74 |

A fundamental problem in all the tests, but especially at Abashaevskaya, was the difficulty in achieving and maintaining coal segregation The time constraints on testing prevented full combustion of coal from previous runs Also, insufficient time was available to to stabilize combustion of the sorted coal

As boiler operators develop a feel for the qualities of a new coal, they make adjustments to the oxygen and air mixture, coal feed rates, and numerous other operational parameters to achieve better combustion This had been the case with the existing unsorted coal However, there was neither the time nor the quantity of sorted coal available to do so on the sorted coal Therefore sorted coal performance is likely to improve when adequate supplies become available to enable stable combustion to be achieved and as operating experience with sorted coal increases

With these caveats regarding coal supply and combustion stability, the Abashaevskaya results can be interpreted more definitively Particulate emissions for Abashevskaya are shown for samples taken between the boiler and the air pollution control device (cyclone collector, or collector inlet), rather than the discharge to the atmosphere (collector outlet) This was necessary, since the erratic performance of the cyclones made it impossible to use outlet readings to measure the changes in the boiler due to changes in coal quality Collector efficiency ranged from 35-68 percent for the unsorted coal runs, dropping to 15-36 percent for the sorted coal runs, and to 10-27 percent for the mixed coal runs In comparison, Dimitrova tests had collector inlet PM values of 14 3 kg/Gcal for existing coal, and 9 4 kg/Gcal for the sorted G-mark coal

In summary, energy efficiency of the Abashaevskaya boiler improved by approximately 8 percent and emission rates were reduced by 60 percent with the mix of sorted and unsorted G-mark coal with fines in the 20-25 percent range The sorted G-mark performed between that of the unsorted and the mixed coals Thus, while more testing of such mixtures is suggested, the initial findings are that coal with a fines content of 20 to 25 percent is suggested to optimize emissions and combustion efficiency at Abashaevskaya Because such a mixture would require preparation of only half of the volume of coal burned, the cost of using sorted coal is less than if all sorted coal were required

### *3.2.3 Laundry Depot Results*

The Laundry Depot boiler is a fixed-grate, hand-fed stoker boiler of approximately 3 5 tons steam/hour capacity, or about one-seventh the capacity of the Dimitrova boiler The Laundry Depot represents a common class of boilers, present at nearly 90 of Novokuznetsk's 160 boiler houses Such boilers account for approximately 10 percent of Novokuznetsk's total low-stack boiler capacity, or about 115,000 Gcal/hour of capacity

The Laundry Depot boiler house is burning a sorted T-mark coal, one well-suited for these fixed grate boilers T-mark coal falls between a low level anthracite and a high level bituminous coal, with relatively low volatile and high fixed carbon content The test coals, which included various sorted and unsorted G-mark grades and combinations of G-mark and T-mark coals, all under-performed the existing sorted T-mark In essence, the test demonstrated the benefits of other fixed grate stokers converting to a T-mark coal

As with the Dimitrova and Abashaevskaya tests, the combustion efficiency and emission properties of the coal were the primary focus of the tests Other key variables included boiler load levels and collector efficiency The results of the Laundry Depot tests are detailed in Annex B-3, and summarized in Table 3-3

**Table 3-3**
**Summary Results of Laundry Depot Clean Coal Demonstration Phase III Testing**

| Coal Tested: | (1) Existing T-mark | (2) Sorted G-mark | (3) Sorted G+T | (4) Unsorted G |
|---|---|---|---|---|
| # Tests | 3 | 2 | 1 | 3 |
| % Coal Fines | 10 7 | 12 7 | 8 6 | 32 6 |
| Ash (%) | 12 41 | 6 20 | 9 21 | 15 49 |
| Combustion Efficiency* (%) | 81 1 | 80 5 | 79 4 | 79 7 |
| PM Emissions (kg/Gcal) | 0 17 | 3 51 | 1 40 | 1 00 |
| * Efficiency excluding carbon loss, owing to inadequate fly ash sample | | | | |

The results from the Laundry Depot tests demonstrate the far superior emissions performance of the existing sorted T-mark coal, but are somewhat inconclusive in combustion efficiencies, owing to the lack of flyash data for the sorted G/T mix and for the unsorted G-mark test coal The efficiencies do not account for carbon loss, notably because insufficient flyash was collected for analysis Without the flyash data, carbon losses could not be included in combustion efficiency calculations

The existing data suggest that the T-mark is a far superior coal, not only based on emissions, but also on efficiency grounds Given the relatively low particulate emissions from the Laundry Depot boiler, the primary motivating factor for burning the cleaner T-mark coal will be the coal price, as any emission fees are negligible.

Recently T-mark coal has been priced the same as G-mark coals Because T-mark coal is less friable than G-mark, the cost of unprepared T-mark coal (with10-15 percent fines) likely would not cost more than sorted G-mark coal, even if a slight premium was charged for the T-mark coal at the mine mouth Locally, T-mark coal is produced largely at the Bungarskaya and Norganaskaya mines

In summary, the Phase III test results demonstrated that

1 Use of sorted G-mark coals produced efficiency gains of greater than nine percent in the best operated Russian design mechanical-grate, stoker boilers, and even greater improvement can be expected from other boilers of similar design

2 Use of sorted G-mark coals produced particulate emission reductions of 40 percent at the best operating Russian design boilers, and even better results can be expected at other boiler houses with poor combustion control records

3 Such boilers represent approximately 85 percent of Novokuznetsk's small, low-stack boiler capacity, so that further efforts should focus on these boiler types

4 The Chinese grate boilers (Abashaevskaya) demonstrate that best emission (60 percent reduction) and efficiency performance (8 percent improvement) is achieved with a blend of sorted and unsorted G-mark coal, with fines in a range of 20-25 percent

5 The costs of producing a blended coal are less than for a fully screened coal because only half of the coal volume must be sized

6 The small fixed grate, hand-fired stokers show substantially better emissions performance utilizing T-mark coal

7 As long as the cost of T-mark is near the G-mark cost, it should be encouraged for use in such boiler houses

8 Meanwhile, further testing should be undertaken by local specialists to accurately measure the boiler efficiency effects of T-mark vs G-mark coals. This may take a longer test duration, as the small boiler size and flow rates make it difficult to obtain a sufficient flyash sample

## 3.3 Phase I Results

(A complete technical report for Phase I Dimitrova and Abashaevskaya tests was prepared previously by Charles Schmidt Associates Each of these reports includes detailed analyses of coal input, boiler efficiency, and emissions Annex D provides a summary of the key results of Phase I testing This section is designed to provide a summary of Phase I results for comparison purposes only )

Phase I testing was conducted at Dimitrova in November 1995 Existing (unsorted) G-mark coal was compared with sorted G-mark and a mix of sorted G-mark and T-mark coal Coal preparation during Phase I did not effectively control for ash contamination,

and as a result the sorted G-mark had an ash content some 50-60 percent higher than the unsorted coal Nevertheless, the sorted G-mark coal still provided better boiler efficiency and emissions performance than the existing coal, largely due to lower fines content

Table 3-4 provides a tabular summary of the Dimitrova Phase I test results With sufficient stabilization of operating conditions following the introduction of a new coal, improved boiler efficiency can be expected as air mixture and operator combustion controls are fine-tuned to meet the coal's property Thus, the 10 5 percent "best case" improvement is indicative of a potential standard achievable with proper boiler stabilization and operator adjustments Remarkably, this high efficiency reading was obtained despite a lower heating value for the sorted G-mark coal owing to much higher ash content Boiler efficiency for the mix of sorted G-mark and T-mark coal averaged a 6 8 percent improvement over the existing (base) coal

**Table 3-4**
**Summary Results of Dimitrova Clean Coal Demonstration Phase I Testing**

| | Unsorted G-mark | Sorted G-mark | Sorted G/T Mix |
|---|---|---|---|
| Tests | 4 | 3 | 3 |
| Fines (%) | 41 60 | 13 57 | 20 07 |
| Ash (%) | 17 54 | 28 34 | 23 76 |
| Efficiency (%) | 71 05 | 73 20 | 75 85 |
| PM Emissions (kg/Gcal) | 3 15 | 1 83 | 3 00 |

The emissions performance of the sorted G-mark coal was even more impressive than the efficiency performance The sorted G-mark coal reduced average stack emissions by 42 percent despite a 61 percent higher ash content In short, the effects of higher ash content were more than offset by the positive combustion and emission effects associated with the sorted G-mark coal's lower fines content

Average stack emissions for the mix of sorted G and T-mark coal showed only minor improvement over the existing coal (-4 8 percent), but a significant improvement in net boiler efficiency (+6 8 percent)

Phase I's testing of the Abashaevskaya boiler house was less successful, owing to the inability to achieve stable boiler combustion with sorted G-mark coal due primarily to the high ash content of the sorted coal, which limited the boiler load For the two existing coal runs, thermal efficiencies of just 55 and 60 percent were achieved owing to high excess air and relatively low temperature readings

## 3.4 Phase II Results

Phase II testing was undertaken in April 1996 by a Russian team Tests were performed both at Dimitrova and Abashaevskaya, utilizing a test coal which was prepared so as to maintain low ash content, but which resulted in relatively high fines content relative to Phase I (and Phase III's) test coals A separate report was prepared by Santekhproject on

the Phase II Results The summary provided in this section is for comparison purposes only

The Dimitrova test results are summarized in Table 3-5 The test coal had lower ash and slightly higher fines than the unsorted coal PM emissions declined approximately 25 percent Adjusted for efficiency, PM emissions were reduced by 38 85 percent, or just below the 42 percent reduction achieved in Phase I testing

**Table 3-5**
**Summary Results of Dimitrova Clean Coal Demonstration Phase II Testing**

| | Existing G-mark | Low Ash G-mark |
|---|---|---|
| Tests | 2 | 3 |
| Coal Fines (%) | 42 | 48 |
| Ash (%) | 15 3 | 11 3 |
| Efficiency (Est %) | 65 | 81 |
| PM Emissions (kg/hr ) | 255 | 185 |
| PM Emissions (kg/Gcal) est | 78 | 48 |

Interestingly, despite the comparable percentage reduction in emissions achieved, the coal quality and absolute emission levels differed markedly between Phases I and II In Phase I, emission rates measured in kg/hour averaged only 35 for existing coal, versus 62 kg/hour in Phase II. This difference in outlet emission rates is explained both by the slightly higher average boiler load achieved in Phase II versus Phase I (85 percent vs 78 percent), and the lower level of collector efficiency shown in Phase II (74 percent) versus Phase I (89 percent)

In Phase I the reduction in emissions was attributable to reduced fines content, as ash in the test coal was 61 percent higher than in the existing coal In Phase II, average ash content of the test coal was 26 percent lower than the existing coal, while fines were 13 percent higher Thus, the emissions reduction in Phase II appears to be linked to improved boiler efficiency and lower ash content However, in Phase III, with both low ash and low fines coal, outlet emissions on a useful heat basis were also reduced by just 40 percent However, this result was achieved with collector efficiency averaging just 66 percent in Phase III In short, a comparison of Phase I, II and III results at Dimitrova underline the importance of effective emissions control operations, and the importance of effective boiler operations, along with proper coal quality

The efficiency improvements in Phase II for Dimitrova averaged 25 percent However, these estimates were based on a simple formula for combustion efficiency, which did not include a full materials balance of boiler inputs and outputs, as described in Section 2

The Phase II tests at Abashaevskaya were plagued by the same problems as occurred in Phase I, namely the boiler load achieved was insufficient to produce useful results Loads of only 50 percent were obtained on both the existing and test coals Emission rates ranging from 27-43 kg/hour of PM were measured However, stable boiler combustion

could not be achieved due to insufficient air flow through the grates, a result of low ash fusion temperature and high caking value, or free swell index of the test coal Interestingly, analysis of the bottom and flyash from the tests showed a higher heat value in the existing coal, despite the higher ash content of the existing coal, suggesting that less of the test coal energy was lost in ash

In summary, the Phase II testing provided a useful exercise in coal preparation, as the fine concentrate material from the Baidaevskaya preparation plant was utilized as the test coal Unfortunately, this G-mark concentrate is highly friable its fines content increased from approximately 27 percent at Baidaevskaya to 45-50 percent on entry to the boiler, with both transport and handling at the boiler house increasing the fines content This source of low ash coal was utilized as a Phase III test coal, and further refined to sort fines content down to a 10-15 percent range before shipping to the boiler houses for testing With care exercised in shipping and handling, the delivered fines content in Phase II testing was kept under 20 percent, a desired target, and ash under 15 percent

Section 4

# Economic Analysis

## 4.1 Key Results

The key results of the Clean Coal Demonstration Program can be grouped into two basic categories

1 energy efficiency gain
2 emissions reduction

The major economic issue is whether the results of the Clean Coal Demonstration Program will motivate boiler owners and their suppliers to invest in coal preparation, emission reduction, and boiler efficiency improvements The major policy issue is whether incentives are needed to stimulate investment in prepared coal supply and its use This section addresses these questions by reviewing the benefits demonstrated from the testing and the various investment cost, public policy, and enforcement hurdles to their effective implementation

### *4.1.1 Energy Efficiency*

The energy efficiency benefits of properly sorted coal with normal or reduced ash content have been shown to average in the 8-10 percent range, with a 10 percent improvement obtained in Phase III testing at Dimitrova for the sorted G-mark versus the existing, unsorted G-mark coal At Abashaevskaya, an 8 percent net boiler efficiency improvement was obtained with the mix of sorted and unsorted G-mark compared to the base coal At the Laundry Depot, the existing T-mark coal was shown to have efficiency benefits ranging from 0 7 percent to 2 1 percent for sorted G-mark and unsorted G-mark coal, respectively These efficiency gains are less critical as long as the delivered price of T-mark and G-mark are comparable, i e , the efficiency benefits of T-mark coal in such fixed grate boilers appear to be exceeded by the emission reduction and ancillary operating benefits of the T-mark coal

In evaluating the efficiency results obtained from the boiler tests, it is important to recognize the range of results obtained, as these are indicative of the deviation that might be expected from future tests or actual boiler conversions to prepared coal Moreover, it is also necessary to recognize that some of the control variables in effect for the tests may differ in future tests and/or pilot conversions Taking the Phase III (1996) testing at Dimitrova as the most reliable sample, the individual boiler efficiency readings from the five base coal tests ranged from 66 percent to 75 percent, averaging 71 percent. Boiler efficiencies for the five sorted coal tests at Dimitrova (1996) ranged from 77 percent to 79 percent, averaging 78 percent, or 10 percent improvement over the base coal result In 1995 (Phase I) testing at Dimitrova, the base coal boiler efficiencies ranged from 70 percent to 73 percent, whereas the sorted G-mark produced net boiler efficiencies ranging from 69 percent to 79 percent, despite a 61 percent higher ash content. The higher end of this range provides evidence of the potential efficiency gain when coal quality is combined with stable combustion and proper operator controls Based on the difference between Phase I's best sorted coal efficiency result and the average net boiler

efficiency obtained from the base coal runs, the potential gain is at least 10 percent, without the addition of combustion control equipment

The efficiency benefits derived from properly prepared coal extend beyond the direct benefit of higher boiler efficiency Proper coal preparation enables maximum benefit to be derived from combustion controls and other boiler efficiency equipment Without prepared coal, the efficiency benefit from automatic combustion controls, for example, would be approximately halved [1] In addition to combustion control systems, the payoff from such low cost investments as overfire air and hopper evacuation systems are significantly enhanced by first matching coal quality to boiler combustion design Thus, the potential payoff from an investment in prepared coal should be supplemented by the incremental efficiency gain from boiler hardware investments, with roughly half the efficiency benefit from these systems a result of improved coal quality In short, an investment in prepared coal should be valued both from the perspective of the immediate (fuel only) benefit, and from the additional efficiency performance obtained from combining combustion control systems with prepared coal Of course, emission reduction and other direct and indirect cost reduction benefits must also be factored in

The efficiency benefits obtained from sorted coal are the primary motivation for investing in higher quality prepared coal This investment could take the form of high transport costs for long-haul prepared coal deliveries to Novokuznetsk, or a capital investment in a local coal preparation plant A preparation plant[2], such as that currently being proposed for the Novokuznetsk area, should be designed to serve the needs of the city's small boiler houses, with excess fines delivered to a TES (pulverized coal) market and excess sorted coal to an export market

A coal sorting facility located in the Novokuznetsk region could supply the city's boiler houses with sorted coal at a premium of 10-20 percent above existing coal prices, if incremental production and delivery costs were kept moderate Based on the Phase I-III test results for Dimitrova (the most common Russian boiler design, representing nearly 85 percent of Novokuznetsk's low-stack boiler capacity), a 10 percent premium for prepared coal would be recoverable on boiler efficiency gains alone The key issue to be addressed is the likely cost of a prepared coal meeting a quality specification consistent with an expected 10 percent, or more, improvement in net boiler efficiency from the coal quality alone This question is addressed in Section 4 2.

### *4.1.2 Emissions Reduction*

The second major benefit from the use of properly prepared coal is its superior emissions performance Test results at the Dimitrova boiler house showed a 38 percent reduction in particulate emissions from the collector outlet[3] in 1996, and a 41 percent reduction one

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[1] This estimate is based on field experience gained by the U S -based Novokuznetsk boiler controls vendor, Control Techtronics International (CTI), in the equipping of five Polish boiler houses with automatic combustion control systems, as confirmed by the U S experience of Charles Schmidt, the project's boiler engineering consultant and a 35-year expert in stoker boiler operations

[2] The fundamental problem for Novokuznetsk's small boiler population is the lack of a functional energetic coal preparation plant within an economic transport distance from the City environs Most coal preparation plants are designed for metallurgical coal, and are not designed to produce a sorted "stoker-quality" size product Rather, they are designed to simply "cut" coal sizing in a 0-25 mm and 25+ mm size class

[3] Measured in kg of emissions per Gcal of energy produced

year earlier from using sorted G-mark coal Collector efficiency levels were consistent within each year's testing, but did drop noticeably between the 1995 and 1996 test periods at Dimitrova (i e., from around 87 percent efficiency in 1995 to around 67 percent in 1996)

At Abashaevskaya, the mix of sorted and unsorted G-mark reduced particulate emissions by 60 percent from the existing coal tests, while the sorted G-mark alone produced a 42 percent reduction in particulate emissions In this case, collector efficiency levels dropped by nearly 50 percent during the sorted coal runs Thus, a near doubling of the reduction in particulate emissions could be expected with an equivalent collector efficiency level

At the Laundry Depot the existing T-mark coal (with naturally low fines content) resulted in a far superior emissions performance Collector outlet emissions for the existing T-mark coal were just 5 percent, 9 percent and 16 percent of sorted G-mark, G-T mix, and unsorted G-mark levels, respectively

Other harmful toxic emissions are associated with reduced particulate emissions and, similarly, will be reduced in concert with particulate emissions These include benzopirenes, which are commonly associated with unburned fines, and ferric oxides, which are extremely harmful in fine form, as they can directly penetrate blood cells through the lungs.

Enforcement of the emission testing and penalty system in Novokuznetsk and most areas of Russia is limited Most fees, when enforced, are credited against a beneficial investment, and most stacks are not directly measured for actual emissions Rather, a formula based on fuel use and optimal emission control efficiency is utilized As a result, the ability to "monetize" emission reduction benefits into a direct (Rbl/ton) financial benefit from burning clean coal (and undertaking other emission control strategies) has been limited With the consistent test results obtained from the Clean Coal Demonstration Program, a reliable basis now exists to associate a specific credit level with those boilers using prepared coal Actual and expected emission levels will be known and more accurately measured as a result of the Clean Coal Demonstration Program. Hence a more accurate basis exists for levying fees on those boiler houses that do not use an appropriate coal, enhancing the payoff from emissions enforcement efforts

In section 4 3, the monetary benefits of reduced emission levels are directly measured, and approaches to cost-effectively monitoring and motivating boilers to reduce emission levels are discussed

## 4.2 Coal Preparation Plant Configuration and Costs

The coal preparation plant configuration in this analysis is represented by a relatively small and simple plant design, configured primarily to classify sized coal to the small stoker boiler market in and around Novokuznetsk The cost of such a facility can be estimated at $2 00-$4 00 per ton by extrapolating from previous coal preparation plant cost studies [4] The lower end of that range reflects a simple sorting and Baum Jig[5]

[4] The primary coal preparation plant cost reference study this section will draw on is entitled, ""An Engineering/Economic Analysis of Coal Preparation Plant Operation and Cost", by Hoffman-Muntner

cleaning process, only addressing the larger coal size fractions This configuration is more applicable to the level of sophistication needed to produce sized stoker coal for Novokuznetsk's boiler houses The upper end reflects a plant with the capability to clean all size fractions (i e , by froth flotation), with cyclones and thermal drying These estimates are subject to inflation and could escalate as much as 100 percent, depending on specific regional cost factors, plant utilization rates, and other key variables affecting cost

The key coal characteristics affecting preparation plant costs are (1) the final specifications sought for the prepared coal and (2) the washability of the coal Key drivers on the plant side include plant utilization rates and the nature of the cleaning and de-watering processes needed to meet the target prepared coal specifications, given the nature of the raw coal input

In its simplest form, a coal preparation plant could be designed to simply "scalp" and sort coal into a basic set of size classes The scalping function refers to the initial separation of coal in a workable size range (e g , 200 mm and less), starting with the removal of large rock pieces and tramp iron From there, a coal crushing and jig operation breaks the coal into finer size classes, typically running from 0-13 mm, 13-25, or 13-50, and 50-200 mm classes One key to successful sorting, particularly with the highly friable G-mark coal prevalent in the region, is to undertake an initial sort so that only larger pieces (i e , > 13 mm) are subject to crushing In this manner, the native fines content of the coal, which may run as high as 40-50 percent, is not increased by crushing material that is already in or approaching the fines class.

The basic components of a coal preparation plant include

- storage facilities (covered or open) for raw and clean coal,
- a tramp iron removal system at the coal inlet point,
- a crusher to break coal size down into manageable limits,
- a conveyor and belt system (for raw and sorted coal, and refuse),
- screens for sorting, including a scalper at plant inlet and size separation screens to yield the desired mix of stoker (6-25 mm ) and other size ranges, including fines (< 6 mm) removal,
- a cleaning system of varying sophistication depending on the cleaning procedure utilized, ranging from simple water to heavy media (magnetite) and complex chemical froth flotation, supplemented by cyclone separation systems,
- a drying operation, ranging from expensive thermal drying to basic draining and spin drying techniques, and
- a loading system for rail and truck transport

Regardless of the sophistication in coal cleaning techniques, the basic equipment required for coal preparation largely remains unchanged The Hoffman - Muntner Corp study for the U S Department of Energy[6] estimated an operations and maintenance (O&M) cost of

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Corporation, for the U S Department of Energy, July 1978

[5] The Baum Jig is a machine used for classifying materially differing specific gravities by pulsating a stream of water through the bed of material, causing the material to "jig" up and down, and the heavier material to settle to the bottom and the lighter material to rise to the top, at which point they are floated or drawn off separately

[6] See Hoffman - Muntner, "An Engineering/Economic Analysis of Coal Preparation Plant Operation and Cost", for the U S Department of Energy, July 1978, pp 155-160

$2 70/ton of coal output for a basic Baum Jig plant of 600 tons per hour input capacity, operating at 30 percent of capacity, and amortized over a 10 year period The capital amortization cost on an estimated $4 million investment cost added $0 65/ton of cleaned coal output, placing the total at $3 35/ton This figure could be lowered through a combination of

- higher capacity utilization,
- longer amortization period,
- lower interest rates,
- lower capital costs (e g , use of existing equipment),
- lower O&M costs, based on cheaper labor, overhead, supplies, maintenance, energy, and/or
- investment incentives, such as investment tax credits, emissions fee credits, etc

Thus, a reasonable estimate of plant O&M costs is placed around $2 40 - $3.00/ton, assuming a +/- 10 percent O&M cost range around the Hoffman - Muntner estimate This level is consistent with the Sibhyproshakht estimate of $3 00/ton for a more complex plant design An additional $0 50 - $0 80/ton allowance is made for amortization of the fixed capital costs, depending on capital cost levels, effective interest rates, and loan terms Thus, a total expected coal preparation cost range of $2 90 - $3 80/ton appears reasonable, with revenues determined by the mix (and price) of the upgraded coal produced, relative to the base coal feedstock price.

If the low end of this unit cost range can be achieved, and unit sales prices of the plant's output can gross a $3-$4/ton premium over the base (feedstock) coal, then the economic rationale for a coal preparation plant appears viable Importantly, these estimates are based on conservative capacity utilization levels and an independent set of financial assumptions

**Table 4-1**
**Coal Preparation Plant: Financial Profile**

| Assumptions | | | | |
|---|---|---|---|---|
| Capacity in tpa = | 1,000,000 | | | |
| Useful Output | 900,000 | | | |
| Cost = | $4,000,000 | | | |
| Debt Component = | $3,200,000 | Units | Annual Esc | |
| O&M Cost = | 10% | Of Cap Cost | 5% | |
| Depr Term = | 20 | yrs | | |
| Other Fixed Costs = | 2% | Of Cap Cost | 5% | |
| Labor Costs = | 10% | Of Cap Cost | 6% | |
| Feedstock Cost = | $19 00 | per ton | 5% | |
| Transport Cost/Ton = | $2 50 | per ton | 5% | |
| Sales Price to TES = | $23 50 | per ton | 5% | |
| Sales Price to BHs = | $24 50 | per ton | 6% | |
| Ash Sales Price = | $10 00 | per ton | 2% | |
| Tax & Emission Credits = | $0 50 | per ton | 5% | |
| Percent Utilization = | 50% | of total | | |
| Percent Fines = | 50% | of useful | | |
| Debt % = | 80% | Of Cap Cost | | |
| Equity % = | 20% | Of Cap Cost | | |

| | | | | |
|---|---|---|---|---|
| Interest/Discount Rate = | 15% | Per annum | | |
| Loan Term = | 10 | yrs | | |
| | | | | |
| Year | 1 | 2 | 3 | 4 |
| Debt Service Pmts | $637,607 | $637,607 | $637,607 | $637 607 |
| Total | $6,376,066 | | | |
| Equity Component | $800,000 | | | |
| Interest Component | $5,576,066 | | | |
| Costs | | | | |
| O&M | $400,000 | $420 000 | $441,000 | $463,050 |
| Labor | $400,000 | $424,000 | $449,440 | $476,406 |
| Other Fixed Costs | $80,000 | $84,000 | $88,200 | $92,610 |
| Fuel | $9,500,000 | $9,975,000 | $10,473,750 | $10,997,438 |
| Depr | $108,000 | $108,000 | $108,000 | $108,000 |
| Transport | $1,250,000 | $1,312,500 | $1,378,125 | $1,447 031 |
| Total Costs | $12,375,607 | $12,537,107 | $13,126,682 | $13,745,735 |
| Total Variable Costs | $988,000 | $1,036,000 | $1,086,640 | $1,140,066 |
| Per Ton Var Cost | 2 20 | 2 30 | 2 41 | 2 53 |
| Avg (25 yrs ) | 4 23 | | | |
| Revenues | | | | |
| TES Sales | $5,287,500 | $5,551,875 | $5,829,469 | $6,120,942 |
| BH Sales | $5,512,500 | $5,843,250 | $6,193,845 | $6,565,476 |
| Ash Sales | $500,000 | $510,000 | $520,200 | $530,604 |
| Tax & Emission Credits | $112,500 | $118,125 | $124,031 | $130,233 |
| Total | $11,412,500 | $12,023,250 | $12,667,545 | $13,347,255 |
| Net Revenues | ($963,107) | ($513,857) | ($459,137) | ($398 481) |
| **IRR** | **14.08%** | | | |
| **Net Present Value** | **$370,221** | | | |

A financial model for a small and simple coal preparation plant is summarized in Table 4-1 Here, the plant is assumed to be sized at one million tons per annum gross input capacity Capital costs are assumed to be $4 million, with an 80 20 debt/equity ratio Ninety percent of total capacity is assumed available as prepared coal, with a 50 50 split between sized stoker and fines output The coal fines are assumed to be targeted to the TES market at a $2/ton mark-up over the delivered cost of raw coal feedstock, and the sized coal is assumed to be priced at a $3/ton mark-up (+14 percent) over the delivered coal feedstock price of $21 50 ($19 at minemouth plus $2 50 in transportation and handling) Capacity utilization is set at 50 percent, reflecting the relatively simple process and the relatively captive (local) customer base The non-fuel and transport variable operating costs start at just $2 20/ton output, based on an assumed 50 percent capacity utilization rate, but rise with inflation assumptions, averaging $4 23/ton of coal output over the 25-year forecast horizon

As shown in the model's assumptions, a $0 50/ton tax and emission credit assumption is required to maintain a positive net present value (NPV) with these assumptions This credit reflects the emission reduction value of prepared coal (see discussion below on particulate benefits) to the stoker boiler customer base The credit is needed in order to yield a positive return under the set of assumptions shown The $370,000 NPV corresponds to a 14 percent return on equity, arguably a low figure given the assumed 15 percent interest and discount rate An alternative to this emission credit would be to assume a higher sales price of prepared coal, but based on market value, such an

assumption would likely meet with customer resistance Another possibility would be to obtain financing for the facility at a more favorable interest rate, which might be possible from a lending institution that recognized the public benefits of loans, such as The World Bank or EBRD

The tax and emission credit could take a number of forms The credit could be applied as an investment tax credit, whereby for each ton of prepared coal produced the coal preparation plant owner is provided with $0 50 worth of tax exemptions (This assumes a positive tax exposure on the part of the preparation plant owner ) Alternatively, the credit could go to purchasers of the prepared coal, effectively lowering their purchase price by $0 50/ton, hence allowing a $0 50/ton premium to be placed on the sales revenue figures shown for prepared coal to the stoker boiler market

Before addressing potential economic and policy incentives, it is instructive to take note of the full value derived from prepared coal

As coal prices rise, the efficiency incentive will carry a greater monetary value With existing (un-sorted) G-mark coal prices around 110,000-120,000 rubles/ton ($18-$20 U S. equivalent), a 10 percent decrease in coal cost attributable to higher boiler net efficiency is equivalent to $1 80-$2 00 of savings from the coal alone In addition, one must account for the reduced transport cost associated with a 10 percent reduction in tonnage hauled With transport averaging around $3/ton in the greater Novokuznetsk area, a 10 percent efficiency gain translates to a further $0 30 reduction in delivered coal costs Numerous other cost reduction or externality benefits must also be considered, such as

- Emissions reduction gains, including reduced particulate matter emissions, reduced CO, NOx, SO2 and carcinogens associated with fine particulates, conservatively estimated at $0 30/ton based on PM emission rates and current emission fee structures (assuming collection or crediting of fee liability),

- Boiler and related equipment repair and replacement savings, as clean coal with reduced fines is less corrosive, resulting in longer lasting equipment and lower annual maintenance costs, estimated at one half of annual maintenance expenditures of 2 percent fuel costs, or about $0 20/ton,

- Boiler bottom and flyash disposal costs, reduced by approximately 20 percent, based on the Dimitrova 1996 results (see Annex B-1), or an estimated $0 02/ton of coal input savings, based on a $1/ton ash disposal cost and one ton of ash per 10 tons of coal burned, and

- Pulverization cost savings, owing to the coal's delivery on a sized basis ready for introduction to the feeder, estimated at $0 10/ton, based on a total energy cost of $0 20 (or 1 percent) per ton with half attributable to the pulverizer.

Totaling these economic benefits produces an additional benefit of $0 82/ton, or about 4 percent of the delivered cost of coal, estimated at $22/ton for G-mark coal in the Novokuznetsk area in 1997 A significant additional benefit discussed in Section 4 1 concerns the additional energy efficiency leverage value that prepared coal provides in combination with investments in boiler combustion efficiency equipment This additional payout is estimated at 5 percent, based on an incremental 10 percent efficiency boost

obtainable from such systems as overfire air and automatic combustion controls Thus, based on $22 delivered coal, an additional savings of $1 10/ton is achievable from prepared coal This places the total potential benefit from prepared coal at

| | | | |
|---|---|---|---|
| 1 | Direct boiler efficiency gain of 10 percent | = | $2 20/ton |
| 2 | Indirect boiler efficiency gain of 5 percent | = | $1 10/ton |
| 3 | Emissions reduction benefit (at current fees) | = | $0 30/ton |
| 4 | O&M cost reductions | = | $0 20/ton |
| 5 | Ash disposal savings | = | $0 02/ton |
| 6 | Pulverizer energy savings | = | $0 10/ton |
| Total | | = | $3 92/ton |

Recognizing that this nominal economic benefit does not translate to a full financial benefit, Section 4 3's policy and economic evaluation sets forth steps required to convert an economic argument for investing in clean (or at least sorted) coal into a financially compelling argument In summary, the direct efficiency and emission benefits of clean coal are just one component of a larger stream of benefits, which nearly double the potential payback from an investment in properly prepared coal

## 4.3 Emissions Reductions Benefits and Enforcement Policy

### *4.3.1 The Value of Emissions Reductions from Prepared Coal*

The use of properly prepared coal also has been demonstrated to show significant reductions in emissions of particulate matter (PM) and toxins associated with particulate emissions These emission levels, and the impact of alternative coals on their levels in each of the tested boiler designs, are an important component of the program. Table 4-3 profiles the emission fee structure in effect in Novokuznetsk and the Kemerovo Oblast The fee structure begins with a basic fee per ton of annual emission level This basic fee is adjusted by an inflation multiple and by a regional "ecological hardship" multiple The inflation multiple (basis a value of 1 0 in 1991) is 42, and the regional adjuster is 1 44 Thus, for PMs, with a base fee of 165 rubles per ton of annual emission, the inflation multiple of 42, coupled with the regional adjustment of 1 44, places the full fee at 6,930 rubles per ton PM emissions

**Table 4-2**
**Emission Fee Structure for Novokuznetsk and the Kemerovo Oblast**
**(rubles)**

| | | PMs | SO2 | NOx | CO |
|---|---|---|---|---|---|
| Base Rate Per Annual Ton = | | 165 | 330 | 415 | 5 |
| Inflation Multiple = | 42 | 6,930 | 13,860 | 17,430 | 210 |
| Regional Adjustment = | 1 44 | 9,979 | 19,958 | 25,099 | 302 |
| Multiple for * | | | | | |
| a) Temporarily Permitted Excess = | 5 | 49,896 | 99,792 | 125,496 | 1,512 |
| b) Excess to Temporarily Permitted = | 25 | 1,247,400 | 2,494,800 | 3,137,400 | 37,800 |

* Note that the emission fee multiples for the temporarily permitted and excess to temporary levels only apply to the incremental emission tonnage in each class, not the base amount



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Beyond this basic per ton fee, two additional multiple levels exist

1 Users are given a "temporary permitted" emissions level in excess of base levels, for which a multiple of 5 0 is applied to the incremental emissions in excess of the base permitted level, up to the higher "temporarily permitted" emissions level, and

2 Beyond the temporary permitted level, a multiple of 25 applies

The temporarily permitted levels are generally set in accordance with an expected plant utilization rate multiplied by standard formulae for calculating expected emission levels These calculations take into account boiler technology and emissions control systems. However, they also assume the effective operation of the emissions control systems (notably the mechanical collector), acceptable fuel specifications, and the use of efficient combustion practice. In practice, boiler efficiency, collector efficiency, and other emissions control practices are not usually optimized, nor is coal quality Therefore, actual emission levels may exceed base and temporarily permitted levels, but without field audits or regular inspection, this goes undetected

Because Russia's emission fee levels have not kept pace with inflation[7], the penalties associated with base emission levels are quite low Even temporary permit levels, carrying an additional multiple of 5 0 (x 42 x 1 44), do not result in prohibitively high per-ton fees

The fundamental problems with the emission fee system include (1) its low base and multiplier levels, (2) the lack of field measurement and, (3) the lack of enforcement, even where measurement may occur An example of the emission fee structure build-up for particulate emissions is shown in Table 4-3, which compares emission levels recorded for the Dimitrova boiler house during the 1995 and 1996 clean coal demonstration tests The results shown compare the average of the existing coal and the sorted G-mark coal's emission performance

The particulate emissions shown in Table 4-3 are measured at the collector outlet on a kg/hour basis This figure is converted to an annual estimate based on a normalized heat input and output rate between the existing and test coals. The number of hours each boiler will run (assuming coal quality input and boiler capacity utilization rates are constant) is projected based on recent years' capacity utilization levels, then multiplied by the number of boilers (6) in the boiler house This approach assumes a constant collector efficiency rate and consistent combustion practices Field testing has shown that wide ranges in both collector efficiency and air fuel mix ratios is the norm Thus, forecasts based on optimal practice are likely to substantially understate actual emission rates

In the comparison of 1995 and 1996 tests results, note that Dimitrova's collector efficiency levels were higher both years for the existing (unsorted) fuel Despite this fact, the emissions performance of the test fuel was far superior to the existing fuel

Given the low fee structure in effect, the potential financial effect of this difference is quite small, at least until temporary and excess emission level penalty multiples are

[7] Compared to the 42 multiple, since 1991 the construction cost index for Siberia has been reported to have increased by 1,600 times, and the currency has devalued by a factor of at least 200.

reached On a per ton coal (unit) input basis, the allowed emissions fees were under 15 rubles in all four average test results shown The unit fee for the temporarily allowed emission levels, with a penalty multiple of 5, rose to a range of 159-177 rubles per ton coal input, still an insignificant level (< $0 03/ton) However, when taking account of emission levels in excess of the temporarily permitted levels, for which a multiple of 25 applies, the potential emission fee liability becomes significant

**Table 4-3**

**Particulate Emission Fee Exposure Comparison: Dimitrova Existing vs. Sorted Coal Test Results for 1995 and 1996**

| | | Existing | Sorted G | | Existing | Sorted G |
|---|---|---|---|---|---|---|
| | | 1995 | 1995 | | 1996 | 1996 |
| Variables | (Units) | | | | | |
| | | | | | | |
| Coal Input | (tons/hr ) | 2 55 | 2 18 | | 2 75 | 1 99 |
| Particulate Emission Rate (Collector ) | (kg/gcal) | 3 15 | 1 83 | | 4 70 | 3 02 |
| Boiler Heat Output | (Gcal/hr ) | 11 10 | 8 61 | | 11 50 | 10 65 |
| Heat Output Normalized | (Gcal/hr ) | 11 10 | 11 48 | | 11 50 | 12 64 |
| Normalized Emission Rate | (kg/hr) | 34 97 | 20 31 | | 54 05 | 34 73 |
| No Hours in Operation | 3800 | | | | | |
| Annual Emission Per Boiler | (tons/yr ) | 133 | 77 | | 205 | 132 |
| No Boilers | 6 | | | | | |
| Total Annual Emissions | (tons/yr ) | 797 20 | 463 14 | | 1,232 34 | 791 84 |
| Normalized Coal Volume | (tons/yr ) | 58,140 | 56,447 | | 62,700 | 60,874 |
| Collector Efficiency | ( percent/100 | 0 8925 | 0 8745 | | 0 6644 | 0 6778 |
| Collector Outlet Emissions | (kg/hr) | 35 37 | 15 59 | | 54 09 | 32 13 |
| Ratio of Emissions to Ton/hr Input | (tons) | 0 0139 | 0 0072 | | 0 0197 | 0 0161 |
| vs Reported in 1991 | | 0 0150 | | | | |
| **Allowed Emissions Eff. 1994** | (tons/yr ) | 74 9 | 74 9 | | 74 9 | 74 9 |
| Standard Fee Eff 1991 | (Rbl/ton) | 165 | 165 | | 165 | 165 |
| x Inflation Multiplier (eff 1996) | 42 | 6 930 | 6,930 | | 6,930 | 6,930 |
| x Regional Multiplier | 1 44 | 9,979 | 9,979 | | 9,979 | 9,979 |
| Fee on Allowed Emissions | (Rbl 000) | 747 | 747 | | 747 | 747 |
| Unit Fee Per Ton Coal Input | (Rbl/Gcal) | 12 86 | 13 24 | | 11 92 | 12 28 |
| **Temp. Allowed Emissions** | (tons/yr ) | 200 | 200 | | 200 | 200 |
| Standard Fee Eff 1991 | (Rbl/ton) | 825 | 825 | | 825 | 825 |
| w/ multiplier = | 5 | | | | | |
| x Inflation Multiplier (eff 1996) | 42 | 34,650 | 34,650 | | 34,650 | 34,650 |
| x Regional Multiplier | 1 44 | 49,896 | 49,896 | | 49,896 | 49,896 |
| Fee on Temp Allowed Emissions | (Rbl 000) | 9,979 | 9,979 | | 9,979 | 9,979 |
| Unit Fee Per Ton Coal Input | (Rbl/ton) | 171 64 | 176 79 | | 159 16 | 163 93 |
| **Excess Emissions** | (tons/yr ) | 522 3 | 188 2 | | 957 4 | 516 9 |
| Standard Fee Eff 1991 | (Rbl/ton) | 4,125 | 4,125 | | 4,125 | 4,125 |
| w/ multiplier = | 25 | | | | | |
| x Inflation Multiplier (eff 1996) | 42 | 173,250 | 173,250 | | 173,250 | 173,250 |
| x Regional Multiplier | 1 44 | 249,480 | 249,480 | | 249,480 | 249,480 |
| Fee on Allowed Excess Emissions | (Rbl 000) | 130,304 | 46,961 | | 238,862 | 128,967 |
| Unit Fee Per Ton Coal Input | (Rbl/ton) | 2,241 | 832 | | 3,810 | 2,119 |
| | | | | | | |
| Total Fee | (Rbl 000) | 141,031 | 57,688 | | 249,589 | 139,694 |
| Unit Fee | (Rbl/ton) | 2,426 | 1,022 | | 3,981 | 2,295 |
| **Sorted G Savings** | **(Rbl/ton)** | | **1,404** | | | **1,686** |

As seen in Table 4-3, at the Excess Emissions level, the per ton fee exposure increases to



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2,241 rubles for the 1995 existing coal, and up to 3,810 rubles/ton for the 1996 existing coal Adding in the emissions fee exposures from the base and temporarily allowed emission levels yields a total emissions liability for each set of tests The emission fee liabilities for the existing coal runs are then compared to the sorted coal total fee liabilities and the difference is taken as the potential savings from using the sorted coal As shown, this savings was 1,404 rubles/ton (about $0 25/ton) based on the 1995 tests, and 1,686 rubles (about $0 30/ton) based on the 1996 results Had collector efficiency levels been higher during the 1996 tests, a greater unit savings in emission fees would have resulted

Tables 4-4 and 4-5 present a similar particulate emission fee build-up structure for the Abashaevskaya and Laundry depot boiler houses respectively In Table 4-4 (at Abashaevskaya), the lack of reliable sorted coal test results in 1995 limits the comparison of 1995 and 1996 existing coal with sorted G and a sorted and unsorted G mix in 1996 Again, collector efficiency levels varied markedly within the 1996 test results, as they were notably lower for the sorted G-mark runs This, in turn, reflects poor air fuel mix controls during this set of runs Particulate emissions for the 1996 sorted test coals at Abashaevskaya were modestly lower than for the unsorted existing fuel, but substantially lower than 1995 existing coal test levels The savings between the 1995 existing coal and 1996 existing and sorted coal tests range from 3,340 rubles/ton to 6,690 rubles/ton, or about $0 60-$1 15/ton equivalent

Table 4-5 presents the test results for particulate emissions at the Laundry Depot and the corresponding emission fee exposures Lacking data from the City Administration, the allowed and temporary emission levels were placed at comparable levels relative to the preferred T-mark fuel's emission levels Thus, one ton was used as the base level, and four tons as a temporarily permitted level, reflecting similar ratios in effect for the larger boiler houses Particulate emission levels varied widely at the Laundry Depot The existing T-mark coal with low fines content demonstrated far lower emission levels than the sorted G-mark Surprisingly, the unsorted G-mark coal out-performed the sorted G-mark and G T mix This result is qualified by the lack of sufficient flyash data in the unsorted G-mark runs to take a full reading of boiler efficiency (hence kg/Gcal emission rates)

The particulate emission results show that the existing (sorted T-mark) coal yields emission reduction benefits of 1,755 rubles/ton in comparison to the sorted G-mark results (i e , about $0 32/ton) This result is more reliable than the lower results obtained for the mixed G T run and three unsorted G-mark test runs, owing to insufficient flyash data for these two test sets

## Table 4-4
## Particulate Emission Fee Exposure Comparison: Abashaevskaya
## Existing vs. Sorted Coals Test Results for 1995 and 1996

| | | Existing G | Existing G | Sorted G | Sorted Mix |
|---|---|---|---|---|---|
| | | 1995 | 1996 | 1996 | 1996 |
| Variables | (Units) | | | | |
| | | | | | |
| Coal Input | (tons/hr ) | 3 73 | 2 92 | 2 29 | 3 17 |
| Particulate Emission Rate | (kg/Gcal) | 8 63 | 4 23 | 3 91 | 3 66 |
| Boiler Heat Output | (Gcal/hr ) | 12 76 | 11 51 | 9 13 | 13 47 |
| Heat Output Normalized to Heat In | (Gcal/hr ) | 12 76 | 11 51 | 11 69 | 12 19 |
| Normalized Emission Rate | (kg/hr ) | 110 06 | 48 69 | 45 70 | 44 60 |
| No Hours in Operation | 3800 | | | | |
| Annual Emissions Per Boiler | (tons/yr ) | 418 | 185 | 174 | 169 |
| No Boilers | 4 | | | | |
| Total Annual Emissions | (tons/yr ) | 1,673 | 740 | 695 | 678 |
| Normalized Coal Volume | (tons/yr ) | 56,696 | 44,384 | 43,698 | 42,014 |
| Collector Efficiency | (%/100) | 0 6190 | 0 5458 | 0 1471 | 0 6778 |
| Collector Outlet Emissions | (kg/hr) | 116 00 | 48 65 | 32 24 | 32 13 |
| Ratio of Emissions to Tons/hr In | (tons) | 0 0011 | 0 0010 | 0 0007 | 0 0007 |
| vs Reported in 1991 | | | | | |
| **Allowed Emissions Eff. 1994** | (tons/yr ) | 34 6 | 34 6 | 34 6 | 34 6 |
| Standard Fee Eff 1991 | (Rbl/ton) | 165 | 165 | 165 | 165 |
| x Inflation Multiplier (eff 1996) | 42 | 6,930 | 6,930 | 6,930 | 6,930 |
| Regional Multiplier | 1 44 | 9,979 | 9,979 | 9,979 | 9,979 |
| Fee on Allowed Emissions | (Rbl 000) | 345 | 345 | 345 | 345 |
| Unit Fee | (Rbl/ton) | 6 09 | 7 78 | 7 90 | 8 22 |
| **Temp. Allowed Emissions** | (tons/yr ) | 100 6 | 100 6 | 100 6 | 100 6 |
| Standard Fee Eff 1991 | (Rbl/ton) | 825 | 825 | 825 | 825 |
| w/ multiplier = | 5 | | | | |
| x Inflation Multiplier (eff 1996) | 42 | 34,650 | 34,650 | 34,650 | 34,650 |
| Regional Multiplier | 1 44 | 49,896 | 49,896 | 49,896 | 49,896 |
| Fee on Temp Allowed Emissions | (Rbl 000) | 5,020 | 5,020 | 5,020 | 5,020 |
| Unit Fee | (Rbl/ton) | 88 53 | 113 09 | 114 87 | 119 47 |
| **Excess Emissions** | (tons/yr ) | 1537 6 | 604 8 | 559 4 | 542 7 |
| Standard Fee Eff 1991 | (Rbl/ton) | 4,125 | 4,125 | 4,125 | 4,125 |
| w/ multiplier = | 25 | | | | |
| x Inflation Multiplier (eff 1996) | 42 | 173,250 | 173,250 | 173,250 | 173,250 |
| Regional Multiplier | 1 44 | 249,480 | 249,480 | 249,480 | 249,480 |
| Fee on Allowed Excess Emissions | (Rbl 000) | 383,609 | 150,897 | 139,561 | 135,389 |
| Unit Fee | (Rbl/ton) | 6,766 | 3,400 | 3,194 | 3,222 |
| | | | | | |
| Total Fee | (Rbl 000) | 388,974 | 156,262 | 144,926 | 140,754 |
| Unit Fee | (Rbl/ton) | 6,861 | 3,521 | 3,317 | 3,350 |
| Sorted G Savings 1996 | (Rbl/ton) | | | 204 | 171 |
| Sorted G Savings 1996 vs 1995 | (Rbl/ton) | | 3,340 | 6,657 | 6,690 |



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## Table 4-5
## Particulate Emission Fee Exposure Comparison: Laundry Depot
## Existing T-Mark vs. G-Mark and Mixed G&T Coal Test Results for 1996

| | | Existing T | Sorted G | Mix | Unsorted G |
|---|---|---|---|---|---|
| | | 1996 | 1996 | 1996 | 1996 |
| Variables | (Units) | | | | |
| | | | | | |
| Coal Input | (tons/hr ) | 0 37 | 0 41 | 0 46 | 0 48 |
| Particulate Emission Rate | (kg/Gcal) | 0 17 | 3 51 | 1 4 | 1 |
| Boiler Heat Output | (Gcal/hr ) | 1 97 | 1 92 | 2 66 | 2 18 |
| Heat Output Normalized to Heat In | (Gcal/hr ) | 1 97 | 1 75 | 2 09 | 2 09 |
| Normalized Emission Rate | (kg/hr ) | 0 33 | 6 13 | 2 92 | 2 09 |
| No Hours in Operation | 3800 | | | | |
| Annual Emissions Per Boiler | (tons/yr ) | 1 | 23 | 11 | 8 |
| No Boilers | 1 | | | | |
| Total Annual Emissions | (tons/yr ) | 1 | 23 | 11 | 8 |
| Normalized Coal Volume | (tons/yr ) | 1,406 | 1,558 | 1,534 | 1,475 |
| Collector Efficiency | (%/100) | 0 6039 | 0 3978 | 0 564 | 0 3959 |
| Collector Outlet Emissions | (kg/hr) | 0 34 | 6 76 | 3 71 | 2 19 |
| Ratio of Emissions to Tons/hr In | (tons) | 0 0010 | 0 0011 | 0 0013 | 0 0010 |
| vs Reported in 1991 | | | | | |
| **Allowed Emissions Eff. 1994** | (tons/yr ) | 1 | 1 | 1 | 1 |
| Standard Fee Eff 1991 | (Rbl/ton) | 165 | 165 | 165 | 165 |
| x Inflation Multiplier (eff 1996) | 42 | 6,930 | 6,930 | 6,930 | 6,930 |
| Regional Multiplier | 1 44 | 9,979 | 9,979 | 9,979 | 9,979 |
| Fee on Allowed Emissions | (Rbl 000) | 10 | 10 | 10 | 10 |
| Unit Fee | (Rbl/ton) | 7 10 | 6 41 | 6 51 | 6 77 |
| **Temp. Allowed Emissions** | (tons/yr ) | 4 | 4 | 4 | 4 |
| Standard Fee Eff 1991 | (Rbl/ton) | 825 | 825 | 825 | 825 |
| w/ multiplier = | 5 | | | | |
| x Inflation Multiplier (eff 1996) | (Rbl/ton) | 4,125 | 4,125 | 4,125 | 4,125 |
| Regional Multiplier | 1 44 | 5,940 | 5,940 | 5,940 | 5,940 |
| Fee on Temp Allowed Emissions | (Rbl 000) | 0 | 18 | 18 | 18 |
| Unit Fee | (Rbl/ton) | 0 00 | 11 44 | 11 62 | 12 08 |
| **Excess Emissions** | (tons/yr ) | 0 0 | 18 3 | 6 1 | 3 0 |
| Standard Fee Eff 1991 | (Rbl/ton) | 4,125 | 4,125 | 4,125 | 4,125 |
| w/ multiplier = | 25 | | | | |
| x Inflation Multiplier (eff 1996) | (Rbl/ton) | 103,125 | 103,125 | 103,125 | 103,125 |
| Regional Multiplier | 1 44 | 148,500 | 148,500 | 148,500 | 148,500 |
| Fee on Allowed Excess Emissions | (Rbl 000) | 0 | 2,718 | 907 | 438 |
| Unit Fee | (Rbl/ton) | 0 | 1,745 | 591 | 297 |
| | | | | | |
| Total Fee | (Rbl 000) | 10 | 2,746 | 935 | 466 |
| Unit Fee | (Rbl/ton) | 7 | 1,763 | 610 | 316 |
| Sorted T Savings 1996 | (Rbl/ton) | | 1,755 | 603 | 309 |



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Section 5

# Conclusions and Recommendations

## 5.1 Conclusions

The analysis of the efficiency and emission reduction benefits of the Clean Coal Demonstration Program reveal the importance of policy incentives to move the economic and financial balance in favor of clean coal

The City and Oblast Administrations' policies on emission monitoring, testing, and enforcement need to be under the existing emission fee structure, significant fee liability exists only if emissions levels are measured and demonstrated to rise to excess levels, where penalty multiples apply Even then, the payback from burning cleaner coal is relatively modest The primary motivation, therefore, must be the energy efficiency gains obtainable from prepared coal

The value of the Clean Coal Demonstration Program is largely in its reliable measurement of boiler efficiency and emission levels of varying types of coal supplies and operating controls With this information, a more informed policy can be developed on which to base both enforcement procedures and emission credit decisions For example, numerous studies have been undertaken on the Russian emission fee structure and the implications of its modification on economic and environmental performance A recent study by HIID (the Harvard Institute for International Development) concluded that Russia's emission fee structure need not necessarily be subjected to a major overhaul, but instead proper signals could be sent to polluting industries by applying high emission penalty rates on all emission volumes in excess of acceptable levels As shown by the demonstration program, once these exceedence levels are reached, the 25x multiple of the base rate becomes a considerable factor

Under the terms of the restructuring of the coal industry, the City's Division of Municipal Services (and other City Administrations) recently have taken on ownership of the communal boiler houses operating in its jurisdiction (numbering 13 of the largest 30 boiler houses in Novokuznetsk). These were previously owned by Kuznetskugol, which still owns the industrial boilers in the same boiler houses This additional capacity is supplemented by the City's existing ownership of smaller municipal service boiler houses As a result, the City of Novokuznetsk and other municipalities throughout the coal producing regions of Russia find themselves in a critical "demonstration mode," whereby they must apply the same standards of emissions and energy efficiency to themselves as expected of private or other publicly-owned boiler houses The enforcement, incentives, and demonstration role must start with the City Administration's Department of Administration, supported by the City Administration and by the Oblast Administration

Itemized below are a set of potential policy incentives needed to induce both capital investment in a coal preparation facility and consumer investment in prepared coal, boiler efficiency and emission control hardware, and management procedures.

## 5.2 Recommendations

### 5.2.1 Coal Preparation Incentives

In order to seed interest on the part of potential investors in a coal preparation plant, various Government tax, emission fee credit, and low-cost loan incentives should be considered The use of an investment tax credit implies that a qualified investor must have a use for tax credits in the form of past or future income tax exposure Thus, profitable enterprises would be encouraged to invest in a preparation facility Investment tax credits could be granted according to a percent of the capital value of the investment, or be linked to eventual sales of prepared coal, subject to certain sales volume (pricing incentives) In this manner, the value of the credit would be tied to the extent of market penetration of the prepared coal This, in turn, would motivate investors to maintain a low cost plant, with a proper scale and simple initial design so as to not "over-cost" the output

The level of the investment tax credit needed to be effective could be based on income tax rates (e g , 30 percent credit, subject to a limit) Alternatively, the credit could be tied to sales levels, and set at perhaps 5,000 - 10,000 rubles per ton sold, so that a large portion of the price premium and variable production cost is covered by the credit

The credit could also be structured as a low interest loan, whereby an internationally competitive rate of 8-10 percent applies This would substantially reduce a primary cost of the plant, and enable a higher debt equity ratio to be carried, further reducing requisite project returns

An alternative to providing credits to the plant investor/owner is to offer consumers of the plant's prepared coal a credit equal to the measured emission reduction value of the fuel We estimate this to be at least equivalent to $0 30-$0 50/ton of prepared coal. Coupled with the direct and indirect efficiency benefit of 10-15 percent, this additional credit would help bridge the gap between the full efficiency benefits of prepared coal and the immediate market price of the coal Such a scheme would certainly assist the plant developer's efforts to secure a core customer base and revenue stream for prepared coal sales

This effort to establish an underlying customer base for the plant could be further supported were the City Administration willing to enter into a long term contract to purchase the prepared coal output at some pre-specified differential over the delivered price of existing (unsorted) coal Indeed, the City Administration represents the single largest independent buyer of stoker coal in the greater Novokuznetsk area, and may stand alone in its ability to underwrite a market for the prepared coal output Such a long-term commitment from a relatively reliable customer would help the plant qualify for financing at favorable interest rates

The price index and delivered cost terms of such a coal purchase agreement could remain responsive to market conditions As long as the preparation plant's run-of-mine coal feedstock is of similar quality and price to the customer's alternative coal, a basis exists for structuring such a long-term "indexed" purchase commitment From the viewpoint of the City Administration, a term purchase commitment might be advantageous, particularly if the City wishes to influence the configuration and output stream of the proposed facility The City clearly has an interest in exerting such influence, but only if the price of reliable, quality supply is competitive Indeed, the City might consider taking a

minority ownership interest in the plant This interest could be "earned in," based on actual volumes contracted and taken In this manner, the City could become a partner in the facility, but still provide incentives to the primary investor in the form of tax credits and other favorable investment terms

The City and Oblast Administration could also actively support the interests of a preparation plant via their influence over other coal consumers and their ability to establish mandatory requirements based on administrative authority and/or extreme environmental conditions For example, the City could assist in arranging sale of the preparation plant's "fines" output to local combined heat and power (TES) systems Similarly, City-owned boilers could be mandated to burn the prepared coal, and other boiler houses could be encouraged to burn prepared coal on the basis of more stringent emissions monitoring and enforcement policies

As an interested partner, the City and Oblast Administrations could work closely with potential investors, not only by structuring various investment and customer credit incentives, but also by insuring that the plant's scale and design is sensitive to cost and market realities In order to keep construction costs to a realistic level, it may be advisable to establish a phased plant development process, whereby size classifying units are constructed first, followed by basic cleaning circuits, and eventually a more sophisticated mix of cleaning and sizing lines In this manner, the core market for sized stoker coal would be established at a relatively low capital cost, and higher value markets could be pursued with subsequent investments in additional cleaning circuits, running from cyclones to large particle washing, heavy media separation, and chemical cleaning, as justified by market demand Higher value customers (e g , metallurgical and export-based) could then be approached, without necessarily relying upon these customers to cover high initial capital investment costs

### 5.2.2 Emissions and Coal Quality Enforcement Policy

A second path of policy support from the City and Oblast Administrations could focus on emissions monitoring, testing, and enforcement, even if initially only for purposes of developing a reliable emissions database Components of this policy could include the following

- Mandatory annual testing of all boiler houses in excess of 10 Gcal of output capacity, including all City-owned boilers

- Publishing emission levels and key control variables, such as collector efficiency levels, coal quality, internal emission and combustion efficiency control instruments, and/or procedures followed.

- Creating a formal emissions credit group or "pool" consisting of the top 25-30 boiler houses, whereby members can sell emission reduction credits to others in order to encourage investments beyond the individual boiler house's ability to use such credits

- Seeking greater financial support from the Oblast Government once the City demonstrates that its emissions monitoring and crediting policies and practices are effective. This support could be purely financial, in the form of more tax and/or emission fee funds returning to the City of Novokuznetsk, or it could take the form of

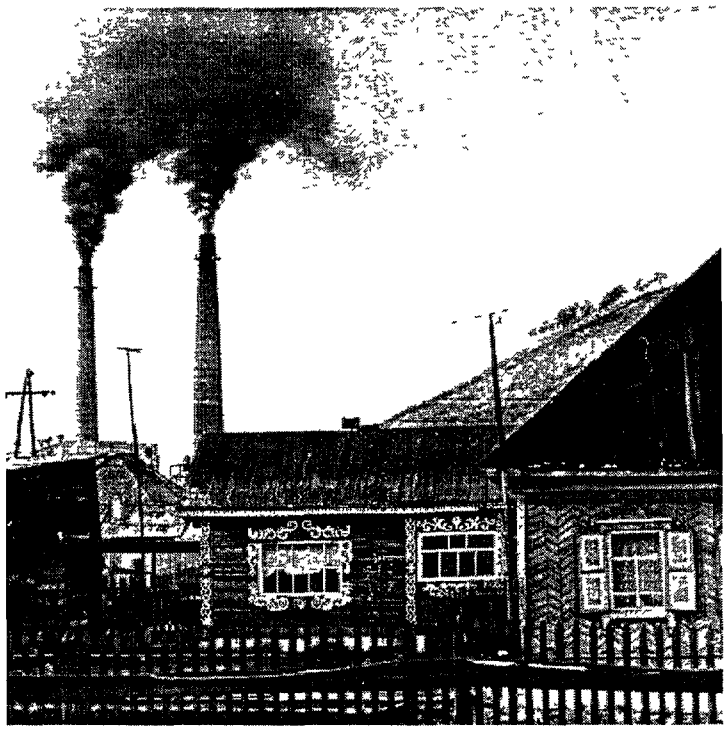
financial support for field demonstrations outside of the immediate Novokuznetsk environs

- Developing a model boiler demonstration program, serving as an example of the range of fuel, operations, and low-cost equipment investment initiatives that characterize a fully energy efficient and environmentally responsible boiler operation The Dimitrova boiler house might qualify as a potential "model," with the addition of some low-cost systems such as overfire air and hopper evacuation The City Railway had also expressed interest in re-building its boiler house to meet the full technical capabilities of a modern fuel- and emissions-efficient operation

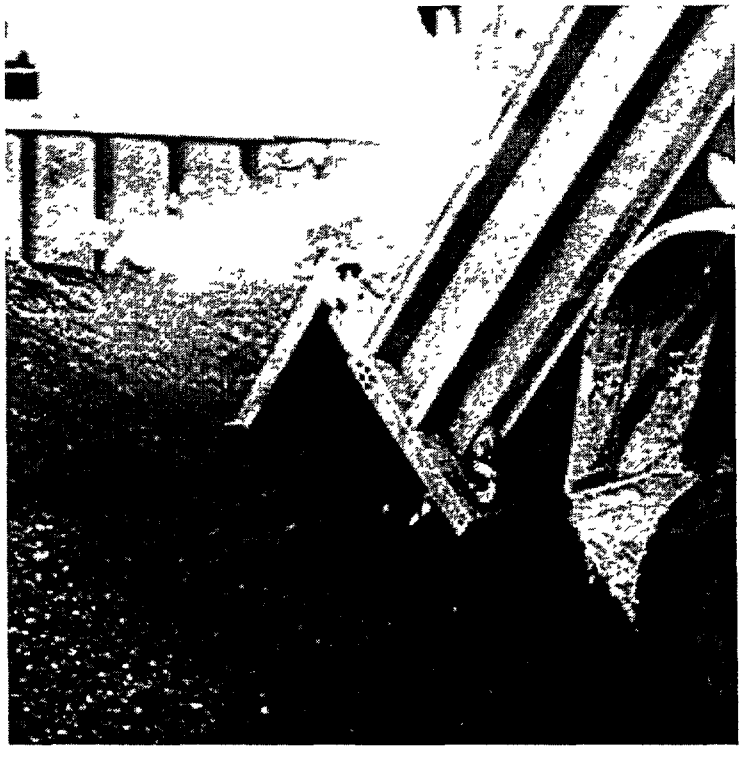
- Undertaking various "command and control" policies directed at the small boiler houses, with the backing of the Oblast Administration. Policies to consider include (1) mandatory laboratory testing of fuel stocks on the boiler house premises, coupled with mandatory covered inventory during the autumn/winter, (2) mandatory use of prepared coal during the peak 3-4 weeks of winter operation, when capacity utilization rates typically approach 100 percent and nearly one half of annual coal consumption occurs, (3) mandatory use of T-mark coal within the numerous fixed grate hand-fired boiler houses, as characterized by the Laundry Depot, at least in the winter period and potentially year-round This policy is particularly attractive if T-mark coal prices (e g., from Bungarskaya) are priced comparably to G-mark supplies

The enactment of such policies would assist the Clean Coal Demonstration Program to realize its potential By establishing and enforcing policies that make it economically, and environmentally, rewarding for boiler houses to utilize prepared coal, it becomes financially feasible for the city and local industry to invest in the construction of a coal preparation plant Given the City's increasing ownership of, and hence financial responsibility for, communal boiler houses, and the rising price of coal and maintenance services, it stands to reason that the City is in the best position to benefit from policymaking that supports an overall conversion to clean coal

## Annex A
# Pictures

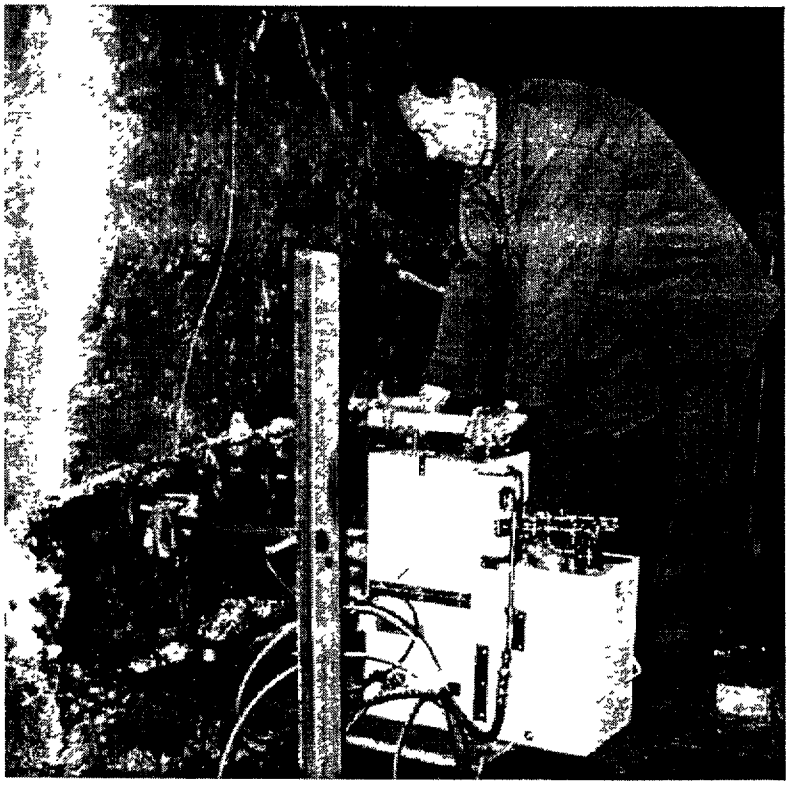


**Boiler Houses Have Low Stacks, and Are Located Near Residences**

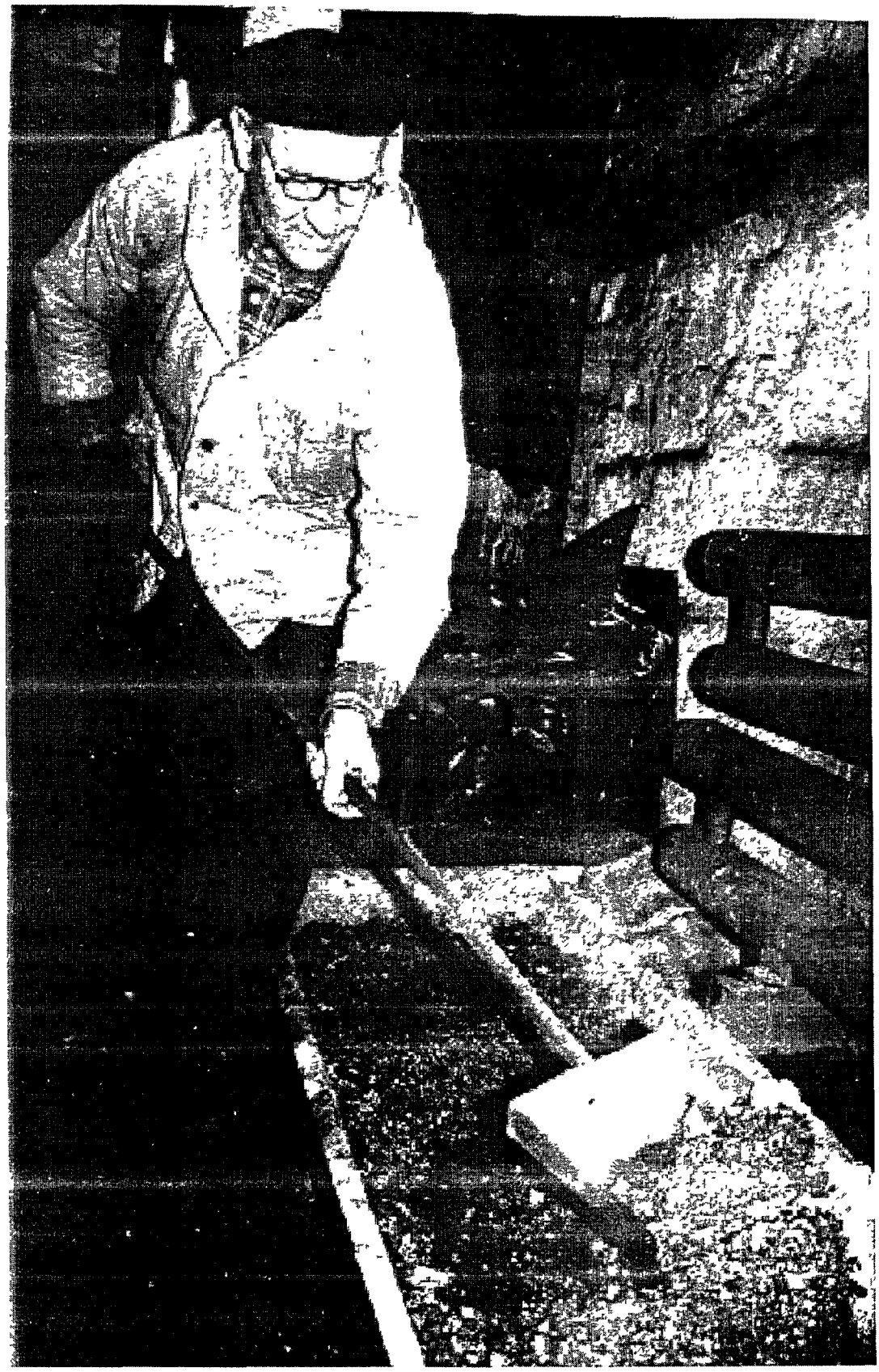


**Coal is Friable Resulting in High Portion of Small Coal Particles**

**Gas Analysis During Clean Coal Testing to Calculate Combustion Efficiency**



**Particulate Emissions Testing**



**Sampling Bottom Ash For Materials Balance**

**Recording Heat Production During Clean Coal Test**

**Boiler Undergoing Reconstruction**

Annex B-1(a)

Dimitrova Clean Coal Test Results for December, 1996 Tests

| | | Existing G Mark Coal Test Results Average | Sorted G Mark Coal Test Results Average | Sorted G Mark Coal Increase or Decrease Over Existing G |
|---|---|---|---|---|
| Pressure Corrected Steam Flow | Tons/Hr | 20 30 | 18 81 | -7 31% |
| Boiler Load | % | 81 19% | 75 25% | -7 31% |
| Steam Pressure | kg/cm2 | 7 14 | 6 45 | -9 72% |
| Feedwater Temperature | Degrees C | 94 49 | 94 20 | -0 30% |
| Steam Enthalpy | kkal/kg | 661 14 | 660 30 | -0 13% |
| Feedwater Enthalpy | kkal/kg | 94 53 | 94 24 | -0 31% |
| Boiler Outlet Oxygen (O2) | % | 12 60% | 10 97% | -12 94% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 263 38 | 270 00 | 2 51% |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 185 77 | 106 66 | -42 59% |
| Boiler Outlet Static Pressure | 100 Pascals | -2 98 | -2 41 | -19 16% |
| Collector Inlet Oxygen (O2) | % | 13 43% | 12 40% | -7 68% |
| Collector Inlet Outlet Flue Gas Temperature | Degrees C | 126 69 | 130 37 | 2 90% |
| Collector Inlet Carbon Monoxide (CO) | ppm | 170 96 | 197 29 | 15 40% |
| Collector Inlet Static Pressure | 100 Pascals | -10 84 | -8 83 | -18 56% |
| Collector Outlet Oxygen (O2) | % | 13 18% | 11 84% | -10 17% |
| Collector Outlet Flue Gas Temperature | Degrees C | 124 16 | 122 65 | -1 22% |
| Collector Outlet Carbon Monoxide (CO) | ppm | 193 04 | 203 94 | 5 65% |
| Collector Outlet Static Pressure | 100 Pascals | -25 40 | -21 49 | -15 38% |
| Coal Size Less Than 6mm (Fines) | % | 42 76% | 16 78% | -60 76% |
| Coal Ash | % | 15 47% | 7 70% | -50 24% |
| Coal Heating Value | kkal/kg | 5,896 20 | 6,875 80 | 16 61% |
| Bottom Ash Heating Value | kkal/kg | 2,290 80 | 2,287 40 | -0 15% |
| Bottom Ash Carbon | % | 28 54% | 32 08% | 12 38% |
| Bottom Ash Ash | % | 69 20% | 65 40% | -5 49% |
| Fly Ash Heating Value | kkal/kg | 5,460 60 | 6,086 40 | 11 46% |
| Fly Ash Carbon | % | 64 85% | 73 63% | 13 55% |
| Fly Ash Ash | % | 31 54% | 22 84% | -27 58% |
| Combustion Efficiency Heat Losses | | | | |
| Due to Dry Gas | % | 7 741% | 7 098% | -8 30% |
| Due to Moisture in Fuel | % | 1 182% | 0 767% | -35 09% |
| Due to Combustion of Hydrogen | % | 4 009% | 4 009% | 0 01% |
| Due to Unburned Combustibles (Carbon Loss) | % | 13 923% | 7 850% | -43 62% |
| Due to Radiation Through Boiler Skin | % | 0 770% | 0 830% | 7 79% |
| Unaccounted Losses | % | 1 500% | 1 500% | 0 00% |
| Net Efficiency | % | 70 87% | 77 95% | 9 98% |
| Heat Input | Gkal/Hr | 16 23 | 13 67 | -15 75% |
| Heat Output | Gkal/Hr | 11 50 | 10 65 | -7 35% |
| Heat Input | Tons/Hr | 2 76 | 1 99 | -27 85% |
| Collector Inlet Emissions | kg/Hr | 162 07 | 99 58 | -38 56% |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 9 99 | 7 28 | -27 07% |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 14 09 | 9 35 | -33 68% |
| Collector Outlet Emissions | kg/Hr | 54 09 | 32 13 | -40 60% |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 3 33 | 2 35 | -29 50% |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 4 70 | 3 02 | -35 89% |
| Collection Efficiency | % | 66 63% | 67 74% | 1 67% |
| Calculated Collector Inlet Flow | acmm | 983 75 | 768 25 | |
| Measured Collector Inlet Flow | acmm | 983 60 | 926 60 | -5 80% |
| Calculated Flow Deviation | % | 0 02% | -17 09% | |

Annex B-1 (b)

Dimitrova Clean Coal Test Results for December, 1996 Tests

| Date | | 04-Dec-96 | 04-Dec-96 | 05-Dec-96 | 05-Dec-96 | 05-Dec-96 | Average of |
|---|---|---|---|---|---|---|---|
| Test No | | DER1 | DER2 | DER3 | DER4 | DER5 | Existing G |
| Coal Type | | Existing G | Existing G | Existing G | Existing G | Existing G | Tests |
| Pressure Corrected Steam Flow | Tons/Hr | 18 34 | 18 25 | 21 19 | 24 75 | 18 96 | 20 30 |
| Boiler Load | % | 73 37% | 73 00% | 84 75% | 99 01% | 75 82% | 81 19% |
| Steam Pressure | kg/cm2 | 6 80 | 6 29 | 7 30 | 8 01 | 7 31 | 7 14 |
| Feedwater Temperature | Degrees C | 97 29 | 93 43 | 95 29 | 97 00 | 89 43 | 94 49 |
| Steam Enthalpy | kkal/kg | 660 75 | 660 10 | 661 34 | 662 13 | 661 35 | 661 14 |
| Feedwater Enthalpy | kkal/kg | 97 35 | 93 47 | 95 34 | 97 06 | 89 45 | 94 53 |
| Boiler Outlet Oxygen (O2) | % | 11 70% | 13 18% | 12 77% | 11 89% | 13 47% | 12 60% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 265 69 | 260 65 | 265 63 | 270 16 | 254 76 | 263 38 |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 169 50 | 186 33 | 204 86 | 139 86 | 228 29 | 185 77 |
| Boiler Outlet Static Pressure | 100 Pascals | -2 99 | -3 07 | -3 06 | -2 99 | -2 81 | -2 98 |
| Collector Inlet Oxygen (O2) | % | 13 00% | 13 60% | 13 39% | 12 86% | 14 31% | 13 43% |
| Collector Inlet Outlet Flue Gas Temperature | Degrees C | 127 22 | 126 94 | 129 21 | 128 49 | 121 59 | 126 69 |
| Collector Inlet Carbon Monoxide (CO) | ppm | 142 75 | 213 33 | 170 00 | 167 14 | 161 57 | 170 96 |
| Collector Inlet Static Pressure | 100 Pascals | -10 96 | -11 16 | -10 88 | -10 67 | -10 53 | -10 84 |
| Collector Outlet Oxygen (O2) | % | 13 15% | 13 57% | 12 80% | 12 46% | 13 91% | 13 18% |
| Collector Outlet Flue Gas Temperature | Degrees C | 124 17 | 124 35 | 126 67 | 126 43 | 119 21 | 124 16 |
| Collector Outlet Carbon Monoxide (CO) | ppm | 165 50 | 299 83 | 184 00 | 151 86 | 164 00 | 193 04 |
| Collector Outlet Static Pressure | 100 Pascals | >-25 4 | >-25 4 | >-25 4 | >-25 4 | >-25 4 | -25 40 |
| Coal Size Less Than 6mm (Fines) | % | 50 50% | 36 00% | 38 60% | 40 30% | 48 40% | 42 76% |
| Coal Ash | % | 14 68% | 15 58% | 20 95% | 11 62% | 14 54% | 15 47% |
| Coal Heating Value | kkal/kg | 6,007 00 | 5,939 00 | 5,465 00 | 6,092 00 | 5,978 00 | 5,896 20 |
| Bottom Ash Heating Value | kkal/kg | 2,026 00 | 1,773 00 | 2,608 00 | 2,504 00 | 2,543 00 | 2,290 80 |
| Bottom Ash Carbon | % | 27 07% | 23 24% | 32 01% | 30 59% | 29 81% | 28 54% |
| Bottom Ash Ash | % | 70 73% | 75 25% | 65 31% | 67 92% | 66 79% | 69 20% |
| Fly Ash Heating Value | kkal/kg | 5,424 00 | 5,480 00 | 5 282 00 | 5,503 00 | 5,614 00 | 5 460 60 |
| Fly Ash Carbon | % | 64 81% | 65 66% | 61 89% | 66 08% | 65 81% | 64 85% |
| Fly Ash Ash | % | 31 61% | 31 40% | 34 06% | 30 00% | 30 65% | 31 54% |
| Combustion Efficiency Heat Losses | | | | | | | |
| Due to Dry Gas | % | 7 202% | 8 541% | 7 474% | 7 272% | 8 215% | 7 741% |
| Due to Moisture in Fuel | % | 1 119% | 1 185% | 1 232% | 1 256% | 1 120% | 1 182% |
| Due to Combustion of Hydrogen | % | 3 875% | 4 054% | 4 054% | 4 032% | 4 032% | 4 009% |
| Due to Unburned Combustibles (Carbon Loss) | % | 13 313% | 13 313% | 18 927% | 10 809% | 13 251% | 13 923% |
| Due to Radiation Through Boiler Skin | % | 0 850% | 0 850% | 0 750% | 0 600% | 0 800% | 0 770% |
| Unaccounted Losses | % | 1 500% | 1 500% | 1 500% | 1 500% | 1 500% | 1 500% |
| Net Efficiency | % | 72 141% | 70 556% | 66 063% | 74 531% | 71 083% | 70 875% |
| Heat Input | Gkal/Hr | 14 32 | 14 66 | 18 15 | 18 77 | 15 25 | 16 23 |
| Heat Output | Gkal/Hr | 10 33 | 10 34 | 11 99 | 13 99 | 10 84 | 11 50 |
| Heat Input | Tons/Hr | 2 38 | 2 47 | 3 32 | 3 08 | 2 55 | 2 76 |
| Collector Inlet Emissions | kg/Hr | 200 14 | 144 62 | 167 51 | 161 21 | 136 86 | 162 07 |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 13 97 | 9 87 | 9 23 | 8 59 | 8 97 | 9 99 |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 19 37 | 13 98 | 13 97 | 11 53 | 12 62 | 14 09 |
| Collector Outlet Emissions | kg/Hr | 70 80 | 53 40 | **16 49** | 48 77 | 43 37 | 54 09 |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 4 94 | 3 64 | **0 91** | 2 60 | 2 84 | 3 51 |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 6 85 | 5 16 | **1 38** | 3 49 | 4 00 | 4 88 |
| Collection Efficiency | % | 64 62% | 63 08% | **90 16%** | 69 75% | 68 31% | 66 63% |
| Calculated Collector Inlet Flow | acmm | 842 07 | 933 41 | 1,020 44 | 1,094 92 | 1,027 92 | 983 75 |
| Measured Collector Inlet Flow | acmm | 998 00 | 991 00 | 986 00 | 969 00 | 974 00 | 983 60 |
| Calculated Flow Deviation | % | -15 62% | -5 81% | 3 49% | 12 99% | 5 54% | 0 02% |

Collector Outlet Emissions for test DER3 not included in averages

Annex B-1 (c)

Dimitrova Clean Coal Test Results for December, 1996 Tests

| Date | | 06-Dec-96 | 06-Dec-96 | 06-Dec-96 | 06-Dec-96 | 06-Dec-96 | Average of |
|---|---|---|---|---|---|---|---|
| Test No | | DSR1 | DSR2 | DSR3 | DSR4 | DSR5 | Sorted G |
| Coal Type | | Sorted G | Sorted G | Sorted G | Sorted G | Sorted G | Tests |
| Pressure Corrected Steam Flow | Tons/Hr | 17 96 | 16 62 | 20 54 | 21 35 | 17 59 | 18 81 |
| Boiler Load | % | 71 84% | 66 48% | 82 17% | 85 41% | 70 37% | 75 25% |
| Steam Pressure | kg/cm2 | 6 11 | 5 90 | 6 66 | 7 03 | 6 54 | 6 45 |
| Feedwater Temperature | Degrees C | 93 71 | 94 14 | 94 29 | 89 43 | 99 43 | 94 20 |
| Steam Enthalpy | kkal/kg | 659 85 | 659 55 | 660 58 | 661 05 | 660 45 | 660 30 |
| Feedwater Enthalpy | kkal/kg | 93 75 | 94 18 | 94 33 | 89 45 | 99 51 | 94 24 |
| Boiler Outlet Oxygen (O2) | % | 11 14% | 11 81% | 10 59% | 10 20% | 11 11% | 10 97% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 269 84 | 263 33 | 274 84 | 276 98 | 265 00 | 270 00 |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 111 71 | 124 86 | 106 14 | 87 00 | 103 57 | 106 66 |
| Boiler Outlet Static Pressure | 100 Pascals | -2 63 | -2 49 | -2 12 | -2 26 | -2 56 | -2 41 |
| Collector Inlet Oxygen (O2) | % | 12 44% | 13 14% | 12 04% | 11 61% | 12 76% | 12 40% |
| Collector Inlet Outlet Flue Gas Temperature | Degrees C | 124 44 | 124 05 | 135 24 | 133 25 | 134 84 | 130 37 |
| Collector Inlet Carbon Monoxide (CO) | ppm | 215 29 | 100 00 | 312 29 | 214 71 | 144 14 | 197 29 |
| Collector Inlet Static Pressure | 100 Pascals | -8 89 | -8 68 | -8 89 | -8 93 | -8 75 | -8 83 |
| Collector Outlet Oxygen (O2) | % | 12 07% | 12 64% | 11 33% | 10 84% | 12 30% | 11 84% |
| Collector Outlet Flue Gas Temperature | Degrees C | 121 03 | 121 35 | 124 29 | 122 78 | 123 81 | 122 65 |
| Collector Outlet Carbon Monoxide (CO) | ppm | 229 71 | 118 00 | 302 14 | 232 86 | 137 00 | 203 94 |
| Collector Outlet Static Pressure | 100 Pascals | -22 73 | -22 45 | -21 52 | -20 84 | -19 92 | -21 49 |
| Coal Size Less Than 6mm (Fines) | % | 16 60% | 12 80% | 18 20% | 18 90% | 17 40% | 16 78% |
| Coal Ash | % | 7 13% | 7 74% | 7 41% | 8 29% | 7 93% | 7 70% |
| Coal Heating Value | kkal/kg | 7,185 00 | 6,930 00 | 6,788 00 | 6,766 00 | 6,710 00 | 6,875 80 |
| Bottom Ash Heating Value | kkal/kg | 2 477 00 | 1,689 00 | 2,450 00 | 2,768 00 | 2,053 00 | 2,287 40 |
| Bottom Ash Carbon | % | 31 67% | 24 05% | 41 30% | 35 20% | 28 17% | 32 08% |
| Bottom Ash Ash | % | 65 21% | 74 88% | 56 96% | 63 62% | 66 34% | 65 40% |
| Fly Ash Heating Value | kkal/kg | 5,842 00 | 6,207 00 | 6,184 00 | 5,925 00 | 6,274 00 | 6,086 40 |
| Fly Ash Carbon | % | 73 15% | 73 47% | 74 85% | 70 80% | 75 90% | 73 63% |
| Fly Ash Ash | % | 23 73% | 22 84% | 21 64% | 25 74% | 20 27% | 22 84% |
| Combustion Efficiency Heat Losses | | | | | | | |
| Due to Dry Gas | % | 7 084% | 7 458% | 7 013% | 6 554% | 7 381% | 7 098% |
| Due to Moisture in Fuel | % | 0 446% | 0 691% | 0 897% | 0 848% | 0 955% | 0 767% |
| Due to Combustion of Hydrogen | % | 4 014% | 4 003% | 4 029% | 4 012% | 3 989% | 4 009% |
| Due to Unburned Combustibles (Carbon Loss) | % | 7 530% | 6 720% | 8 494% | 8 575% | 7 930% | 7 850% |
| Due to Radiation Through Boiler Skin | % | 0 850% | 0 900% | 0 750% | 0 750% | 0 900% | 0 830% |
| Unaccounted Losses | % | 1 500% | 1 500% | 1 500% | 1 500% | 1 500% | 1 500% |
| Net Efficiency | % | 78 576% | 78 728% | 77 316% | 77 761% | 77 344% | 77 945% |
| Heat Input | Gkal/Hr | 12 94 | 11 94 | 15 04 | 15 70 | 12 76 | 13 67 |
| Heat Output | Gkal/Hr | 10 17 | 9 40 | 11 63 | 12 21 | 9 87 | 10 65 |
| Heat Input | Tons/Hr | 1 80 | 1 72 | 2 22 | 2 32 | 1 90 | 1 99 |
| Collector Inlet Emissions | kg/Hr | 98 49 | 88 09 | 108 80 | 105 98 | 96 55 | 99 58 |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 7 61 | 7 38 | 7 23 | 6 75 | 7 57 | 7 28 |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 9 69 | 9 37 | 9 35 | 8 68 | 9 78 | 9 35 |
| Collector Outlet Emissions | kg/Hr | 35 64 | 28 56 | 37 46 | 32 67 | 26 30 | 32 13 |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 2 75 | 2 39 | 2 49 | 2 08 | 2 06 | 2 35 |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 3 51 | 3 04 | 3 22 | 2 68 | 2 67 | 3 02 |
| Collection Efficiency | % | 63 81% | 67 58% | 65 57% | 69 17% | 72 76% | 67 78% |
| Calculated Collector Inlet Flow | acmm | 729 01 | 739 22 | 812 59 | 812 08 | 748 37 | 768 25 |
| Measured Collector Inlet Flow | acmm | 921 00 | 926 00 | 935 00 | 932 00 | 919 00 | 926 60 |
| Calculated Flow Deviation | % | -20 85% | -20 17% | -13 09% | -12 87% | -18 57% | -17 09% |

Annex B-1 (d)

Dimitrova Clean Coal Test Results for November, 1995 Tests

| | | Existing G Mark Coal Test Results Average | Sorted G Mark Coal Test Results Average | Sorted G-T Coal Test Results Average | Sorted G Mark Coal Increase or Decrease Over Existing G | Sorted G-T Coal Increase or Decrease Over Existing G |
|---|---|---|---|---|---|---|
| Pressure Corrected Steam Flow | Tons/Hr | 19 49 | 15 09 | 18 37 | -22 54% | -5 70% |
| Boiler Load | % | 77 94% | 60 38% | 73 50% | -22 54% | -5 70% |
| Steam Pressure | kg/cm2 | 7 30 | 7 07 | 8 10 | -3 07% | 10 95% |
| Feedwater Temperature | Degrees C | 91 30 | 89 78 | 91 30 | -1 66% | 0 00% |
| Steam Enthalpy | kkal/kg | 661 27 | 661 08 | 662 19 | -0 03% | 0 14% |
| Feedwater Enthalpy | kkal/kg | 91 75 | 90 41 | 91 66 | -1 46% | -0 10% |
| Boiler Outlet Oxygen (O2) | % | 10 39% | 10 67% | 10 47% | 2 71% | 0 85% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 251 90 | 247 70 | 266 87 | -1 67% | 5 94% |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 444 40 | 204 87 | 128 03 | -53 90% | -71 19% |
| Boiler Outlet Static Pressure | 100 Pascal | -2 89 | -2 21 | -2 97 | -23 28% | 3 06% |
| Collector Inlet Oxygen (O2) | % | 11 65% | 11 50% | 11 11% | -1 22% | -4 62% |
| Collector Inlet Flue Gas Temperature | Degrees C | 139 07 | 123 37 | 132 11 | -11 29% | -5 00% |
| Collector Inlet Carbon Monoxide (CO) | ppm | 311 38 | 194 30 | 131 53 | -37 60% | -57 76% |
| Collector Inlet Static Pressure | 100 Pascal | -7 36 | -6 78 | -9 12 | -7 85% | 23 96% |
| Collector Outlet Oxygen (O2) | % | 12 18% | 12 35% | 10 99% | 1 35% | -9 83% |
| Collector Outlet Flue Gas Temperature | Degrees C | 135 18 | 124 39 | 123 97 | -7 98% | -8 29% |
| Collector Outlet Carbon Monoxide (CO) | ppm | 282 40 | 197 67 | 104 65 | -30 00% | -62 94% |
| Collector Outlet Static Pressure | 100 Pascal | -23 03 | -19 20 | -21 22 | -16 65% | -7 89% |
| Coal Size Less Than 6mm (Fines) | % | 41 60% | 13 57% | 20 07% | -67 39% | -51 76% |
| Coal Ash | % | 17 59% | 28 34% | 23 76% | 61 14% | 35 10% |
| Coal Heating Value | kkal/kg | 6,126 25 | 5,368 00 | 5,692 33 | -12 38% | -7 08% |
| Bottom Ash Heating Value | kkal/kg | 972 75 | 1,102 67 | 742 00 | 13 36% | -23 72% |
| Bottom Ash Carbon | % | 15 39% | 17 83% | 13 15% | 15 87% | -14 53% |
| Bottom Ash Ash | % | 83 03% | 81 01% | 85 72% | -2 42% | 3 25% |
| Fly Ash Heating Value | kkal/kg | 5,233 75 | 4,007 67 | 4,513 67 | -23 43% | -13 76% |
| Fly Ash Carbon | % | 64 83% | 46 86% | 57 13% | -27 71% | -11 87% |
| Fly Ash Ash | % | 29 72% | 37 96% | 36 24% | 27 73% | 21 93% |
| Combustion Efficiency Heat Losses | | | | | | |
| Due to Dry Gas | % | 7 62% | 7 77% | 8 00% | 2 03% | 4 97% |
| Due to Moisture in Fuel | % | 1 03% | 0 91% | 0 77% | -12 44% | -25 90% |
| Due to Combustion of Hydrogen | % | 4 22% | 4 24% | 3 87% | 0 55% | -8 22% |
| Due to Unburned Combustibles (Carbon Loss) | % | 13 77% | 11 34% | 9 12% | -17 60% | -33 76% |
| Due to Radiation Through Boiler Skin | % | 0 81% | 1 03% | 0 90% | 27 97% | 11 46% |
| Unaccounted Losses | % | 1 50% | 1 50% | 1 50% | | |
| Net Efficiency | % | 71 05% | 73 20% | 75 85% | 3 02% | 6 74% |
| Heat Input | Gkal/Hr | 15 58 | 11 69 | 13 78 | -24 99% | -11 58% |
| Heat Output | Gkal/Hr | 11 10 | 8 61 | 10 48 | -22 41% | -5 59% |
| Heat Input | Tons/Hr | 2 55 | 2 18 | 2 43 | -14 51% | -4 70% |
| Collector Inlet Emissions | kg/Hr | 337 66 | 127 59 | 189 46 | -62 21% | -43 89% |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 21 41 | 11 21 | 13 47 | -47 64% | -37 10% |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 30 11 | 15 55 | 17 87 | -48 37% | -40 66% |
| Collector Outlet Emissions | kg/Hr | 35 37 | 15 59 | 31 35 | -55 91% | -11 37% |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 2 24 | 1 33 | 2 27 | -40 40% | 1 66% |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 3 15 | 1 83 | 3 00 | -41 84% | -4 66% |
| Collection Efficiency | % | 89 25% | 87 45% | 82 18% | -2 02% | -7 92% |
| Calculated Collector Inlet Flow | acmm | 772 87 | 598 39 | 694 17 | -22 58% | -10 18% |
| Measured Collector Inlet Flow | acmm | 1,014 75 | 820 00 | 921 33 | -19 19% | -9 21% |
| Calculated Flow Deviation | % | -23 84% | -27 03% | -24 66% | | |

Anex B-1 (e)

Dimitrova Clean Coal Test Results for November, 1995 Tests

| Date | | 21-Nov-95 | 21-Nov-95 | 22-Nov-95 | 22-Nov-95 | Average of |
|---|---|---|---|---|---|---|
| Test No | | DE70R1 | DE70R2 | DE100R1 | DE100R2 | Existing G |
| Coal Type | | Existing G | Existing G | Existing G | Existing G | Tests |
| Pressure Corrected Steam Flow | Tons/Hr | 18 68 | 14 91 | 25 36 | 19 00 | 19 49 |
| Boiler Load | % | 74 71% | 59 62% | 101 43% | 76 00% | 77 94% |
| Steam Pressure | kg/cm2 | 7 52 | 5 96 | 8 38 | 7 33 | 7 30 |
| Feedwater Temperature | Degrees C | 90 30 | 89 40 | 90 00 | 95 50 | 91 30 |
| Steam Enthalpy | kkal/kg | 661 6089 | 659 6432 | 662 4744 | 661 3667 | 661 27 |
| Feedwater Enthalpy | kkal/kg | 90 8188 | 90 0627 | 90 5667 | 95 5542 | 91 75 |
| Boiler Outlet Oxygen (O2) | % | 9 02% | 12 80% | 8 06% | 11 66% | 10 39% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 236 1 | 227 8 | 278 5 | 265 2 | 251 90 |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 580 6 | 226 8 | 771 6 | 198 6 | 444 40 |
| Boiler Outlet Static Pressure | 100 Pascal | -3 39 | -3 34 | -2 13 | -2 68 | -2 89 |
| Collector Inlet Oxygen (O2) | % | 12 45% | 14 35% | 8 63% | 11 15% | 11 65% |
| Collector Inlet Flue Gas Temperature | Degrees C | 131 39 | 130 11 | 145 11 | 149 67 | 139 07 |
| Collector Inlet Carbon Monoxide (CO) | ppm | 173 | 171 | 669 7 | 231 8 | 311 38 |
| Collector Inlet Static Pressure | 100 Pascal | -3 15 | -10 71 | -7 14 | -8 43 | -7 36 |
| Collector Outlet Oxygen (O2) | % | 12 18% | 13 92% | 10 20% | 12 43% | 12 18% |
| Collector Outlet Flue Gas Temperature | Degrees C | 132 6 | 130 1 | 134 7 | 143 3 | 135 18 |
| Collector Outlet Carbon Monoxide (CO) | ppm | 332 2 | 167 3 | 382 0 | 248 1 | 282 40 |
| Collector Outlet Static Pressure | 100 Pascal | -25 52 | -23 70 | -20 00 | -22 91 | -23 03 |
| Coal Size Less Than 6mm (Fines) | % | 38 20% | 39 90% | 45 00% | 43 30% | 41 60% |
| Coal Ash | % | 16 93% | 16 40% | 18 40% | 18 62% | 17 59% |
| Coal Heating Value | kkal/kg | 6 243 00 | 6,147 00 | 6,015 00 | 6,100 00 | 6,126 25 |
| Bottom Ash Heating Value | kkal/kg | 747 00 | 1,762 00 | 628 00 | 754 00 | 972 75 |
| Bottom Ash Carbon | % | 11 38% | 24 33% | 11 76% | 14 07% | 15 39% |
| Bottom Ash Ash | % | 86 67% | 74 14% | 86 78% | 84 51% | 83 03% |
| Fly Ash Heating Value | kkal/kg | 5,452 00 | 4,895 00 | 5,183 00 | 5,405 00 | 5,233 75 |
| Fly Ash Carbon | % | 63 94% | 59 92% | 68 34% | 67 10% | 64 83% |
| Fly Ash Ash | % | 30 72% | 33 20% | 27 00% | 27 97% | 29 72% |
| Combustion Efficiency Heat Losses | | | | | | |
| Due to Dry Gas | % | 5 99872% | 9 21140% | 6 49541% | 8 76810% | 7 62% |
| Due to Moisture in Fuel | % | 1 03201% | 1 04681% | 1 02352% | 1 03337% | 1 03% |
| Due to Combustion of Hydrogen | % | 4 16168% | 4 22564% | 4 31860% | 4 16711% | 4 22% |
| Due to Unburned Combustibles (Carbon Loss) | % | 15 47181% | 13 01289% | 12 89590% | 13 68763% | 13 77% |
| Due to Radiation Through Boiler Skin | % | 0 80000% | 1 00000% | 0 65000% | 0 78000% | 0 81% |
| Unaccounted Losses | % | 1 50000% | 1 50000% | 1 50000% | 1 50000% | 1 50% |
| Net Efficiency | % | 71 0358% | 70 00% | 73 12% | 70 06% | 71 05% |
| Heat Input | Gkal/Hr | 15 01 | 12 13 | 19 84 | 15 34 | 15 58 |
| Heat Output | Gkal/Hr | 10 66 | 8 49 | 14 50 | 10 75 | 11 10 |
| Heat Input | Tons/Hr | 2 40 | 1 97 | 3 30 | 2 52 | 2 55 |
| Collector Inlet Emissions | kg/Hr | 385 57 | 200 37 | 434 21 | 330 5 | 337 66 |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 25 6894 | 16 5209 | 21 8910 | 21 5396 | 21 41 |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 36 1640 | 23 6002 | 29 9398 | 30 7429 | 30 11 |
| Collector Outlet Emissions | kg/Hr | 28 803 | 26 521 | 52 125 | 34 026 | 35 37 |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 1 9191 | 2 1867 | 2 6279 | 2 2176 | 2 24 |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 2 7015 | 3 1237 | 3 5941 | 3 1651 | 3 15 |
| Collection Efficiency | % | 92 53% | 86 76% | 88 00% | 89 70% | 89 25% |
| Calculated Collector Inlet Flow | acmm | 784 9 | 860 8 | 759 2 | 686 6 | 772 87 |
| Measured Collector Inlet Flow | acmm | 944 0 | 1,064 0 | 1,032 0 | 1,019 0 | 1,014 75 |
| Calculated Flow Deviation | % | -16 85% | -19 10% | -26 43% | -32 62% | -23 84% |

Annex B-1 (f)

Dimitrova Clean Coal Test Results for November, 1995 Tests

| | | | | | |
|---|---|---|---|---|---|
| Date | | 23-Nov-95 | 23-Nov-95 | 23-Nov-95 | |
| Test No | | DS70R1 | DS70R2 | DS70R3 | Average |
| Coal Type | | Sorted G | Sorted G | Sorted G | Sorted G |
| Pressure Corrected Steam Flow | Tons/Hr | 12 68 | 19 06 | 13 55 | 15 09 |
| Boiler Load | % | 50 72% | 76 22% | 54 19% | 60 38% |
| Steam Pressure | kg/cm2 | 6 81 | 7 33 | 7 08 | 7 07 |
| Feedwater Temperature | Degrees C | 85 71 | 89 75 | 93 88 | 89 78 |
| Steam Enthalpy | kkal/kg | 660 7645 | 661 3667 | 661 1135 | 661 08 |
| Feedwater Enthalpy | kkal/kg | 86 9625 | 90 3567 | 93 9204 | 90 41 |
| Boiler Outlet Oxygen (O2) | % | 13 39% | 8 40% | 10 21% | 10 67% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 247 1 | 259 6 | 236 4 | 247 70 |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 197 7 | 261 9 | 155 0 | 204 87 |
| Boiler Outlet Static Pressure | 100 Pascal | -2 81 | -1 96 | -1 87 | -2 21 |
| Collector Inlet Oxygen (O2) | % | 13 91% | 9 79% | 10 81% | 11 50% |
| Collector Inlet Flue Gas Temperature | Degrees C | 130 61 | 124 11 | 115 39 | 123 37 |
| Collector Inlet Carbon Monoxide (CO) | ppm | 179 60 | 254 70 | 148 60 | 194 30 |
| Collector Inlet Static Pressure | 100 Pascal | -8 96 | -6 76 | -4 62 | -6 78 |
| Collector Outlet Oxygen (O2) | % | 14 43% | 11 07% | 11 54% | 12 35% |
| Collector Outlet Flue Gas Temperature | Degrees C | 130 39 | 125 00 | 117 78 | 124 39 |
| Collector Outlet Carbon Monoxide (CO) | ppm | 198 70 | 234 00 | 160 30 | 197 67 |
| Collector Outlet Static Pressure | 100 Pascal | -25 36 | -19 75 | -12 48 | -19 20 |
| Coal Size Less Than 6mm (Fines) | % | 15 30% | 11 80% | 13 60% | 13 57% |
| Coal Ash | % | 27 32% | 29 20% | 28 50% | 28 34% |
| Coal Heating Value | kkal/kg | 5,448 00 | 5,359 00 | 5,297 00 | 5,368 00 |
| Bottom Ash Heating Value | kkal/kg | 850 00 | 837 00 | 1,621 00 | 1,102 67 |
| Bottom Ash Carbon | % | 15 83% | 15 04% | 22 61% | 17 83% |
| Bottom Ash Ash | % | 82 96% | 83 67% | 76 41% | 81 01% |
| Fly Ash Heating Value | kkal/kg | 4,485 00 | 3,538 00 | 4,000 00 | 4,007 67 |
| Fly Ash Carbon | % | 52 71% | 41 02% | 46 86% | 46 86% |
| Fly Ash Ash | % | 41 03% | 38 32% | 34 54% | 37 96% |
| Combustion Efficiency Heat Losses | | | | | |
| Due to Dry Gas | % | 11 00995% | 6 17513% | 6 13398% | 7 77% |
| Due to Moisture in Fuel | % | 0 96473% | 0 85295% | 0 89820% | 0 91% |
| Due to Combustion of Hydrogen | % | 4 44427% | 4 09049% | 4 18998% | 4 24% |
| Due to Unburned Combustibles (Carbon Loss) | % | 11 51538% | 8 02381% | 14 49389% | 11 34% |
| Due to Radiation Through Boiler Skin | % | 1 20000% | 0 80000% | 1 10000% | 1 03% |
| Unaccounted Losses | % | 1 50000% | 1 50000% | 1 50000% | 1 50% |
| Net Efficiency | % | 69 37% | 78 56% | 71 68% | 73 20% |
| Heat Input | Gkal/Hr | 10 49 | 13 85 | 10 72 | 11 69 |
| Heat Output | Gkal/Hr | 7 28 | 10 88 | 7 68 | 8 61 |
| Heat Input | Tons/Hr | 1 93 | 2 58 | 2 02 | 2 18 |
| Collector Inlet Emissions | kg/Hr | 167 26 | 114 82 | 100 69 | 127 59 |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 15 9458 | 8 2896 | 9 3934 | 11 21 |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 22 9880 | 10 5523 | 13 1039 | 15 55 |
| Collector Outlet Emissions | kg/Hr | 16 455 | 18 804 | 11 521 | 15 59 |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 1 5687 | 1 3576 | 1 0748 | 1 33 |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 2 2616 | 1 7281 | 1 4994 | 1 83 |
| Collection Efficiency | % | 90 16% | 83 62% | 88 56% | 87 45% |
| Calculated Collector Inlet Flow | acmm | 727 8 | 595 5 | 471 9 | 598 39 |
| Measured Collector Inlet Flow | acmm | 983 0 | 827 0 | 650 0 | 820 00 |
| Calculated Flow Deviation | % | -25 96% | -28 00% | -27 39% | -27 03% |

Annex B-1 (g)

Dimitrova Clean Coal Test Results for November, 1995 Tests

| | | | | | |
|---|---|---|---|---|---|
| Date | | 27-Nov-95 | 27-Nov-95 | 27-Nov-95 | |
| Test No | | DM70R1 | DM70R2 | DM70R3 | Average |
| Coal Type | | Sorted G-T | Sorted G-T | Sorted G-T | Sorted G-T |
| Corrected Steam Flow | Tons/Hr | 15 52 | 25 29 | 14 32 | 18 37 |
| % Boiler Load | % | 62 08% | 101 15% | 57 26% | 73 50% |
| Steam Pressure | kg/cm2 | 7 60 | 8 90 | 7 79 | 8 10 |
| Feedwater Temperature | Degrees C | 91 20 | 93 00 | 89 70 | 91 30 |
| Steam Enthalpy | kkal/kg | 661 6912 | 662 9965 | 661 8969 | 662 19 |
| Feedwater Enthalpy | kkal/kg | 91 5749 | 93 0871 | 90 3147 | 91 66 |
| Boiler Outlet Oxygen (O2) | % | 10 20% | 8 17% | 13 05% | 10 47% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 250 44 | 293 11 | 257 06 | 266 87 |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 98 90 | 93 40 | 191 80 | 128 03 |
| Boiler Outlet Static Pressure | 100 Pascal | -1 84 | -3 34 | -3 74 | -2 97 |
| Collector Inlet Oxygen (O2) | % | 11 06% | 8 96% | 13 30% | 11 11% |
| Collector Inlet Flue Gas Temperature | Degrees C | 122 39 | 139 33 | 134 61 | 132 11 |
| Collector Inlet Carbon Monoxide (CO) | ppm | 102 10 | 92 80 | 199 70 | 131 53 |
| Collector Inlet Static Pressure | 100 Pascal | -6 19 | -10 46 | -10 71 | -9 12 |
| Collector Outlet Oxygen (O2) | % | 11 70% | 10 27% | | 10 99% |
| Collector Outlet Flue Gas Temperature | Degrees C | 115 72 | 132 22 | | 123 97 |
| Collector Outlet Carbon Monoxide (CO) | ppm | 109 60 | 99 70 | | 104 65 |
| Collector Outlet Static Pressure | 100 Pascal | -15 62 | -26 81 | | -21 22 |
| Coal Size Less Than 6mm (Fines) | % | 15 50% | 31 20% | 13 50% | 20 07% |
| Coal Ash | % | 22 50% | 24 87% | 23 91% | 23 76% |
| Coal Heating Value | kkal/kg | 5,798 00 | 5,509 00 | 5,770 00 | 5,692 33 |
| Bottom Ash Heating Value | kkal/kg | 690 00 | 657 00 | 879 00 | 742 00 |
| Bottom Ash Carbon | % | 13 35% | 12 78% | 13 32% | 13 15% |
| Bottom Ash Ash | % | 85 46% | 86 08% | 85 62% | 85 72% |
| Fly Ash Heating Value | kkal/kg | 4,849 00 | 4,309 00 | 4,383 00 | 4,513 67 |
| Fly Ash Carbon | % | 57 97% | 57 90% | 55 52% | 57 13% |
| Fly Ash Ash | % | 39 47% | 39 59% | 29 66% | 36 24% |
| Combustion Efficiency Heat Losses | | | | | |
| Due to Dry Gas | % | 7 34811% | 6 71027% | 9 93312% | 8 00% |
| Due to Moisture in Fuel | % | 0 71813% | 0 82250% | 0 75779% | 0 77% |
| Due to Combustion of Hydrogen | % | 3 78110% | 3 84323% | 3 98977% | 3 87% |
| Due to Unburned Combustibles (Carbon Loss) | % | 7 38474% | 9 25332% | 10 71846% | 9 12% |
| Due to Radiation Through Boiler Skin | % | 1 00000% | 0 65000% | 1 05000% | 0 90% |
| Unaccounted Losses | % | 1 50000% | 1 50000% | 1 50000% | 1 50% |
| Net Efficiency | % | 78 27% | 77 22% | 72 05% | 75 85% |
| Heat Input | Gkal/Hr | 11 30 | 18 66 | 11 36 | 13 78 |
| Heat Output | Gkal/Hr | 8 85 | 14 41 | 8 18 | 10 48 |
| Heat Input | Tons/Hr | 1 95 | 3 32 | 2 02 | 2 43 |
| Collector Inlet Emissions | kg/Hr | 109 84 | 281 07 | 177 48 | 189 46 |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 9 7163 | 15 0594 | 15 6273 | 13 47 |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 12 4142 | 19 5018 | 21 6893 | 17 87 |
| Collector Outlet Emissions | kg/Hr | 26 841 | 42 544 | 24 658 | 31 35 |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 2 3743 | 2 2795 | 2 1712 | 2 27 |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 3 0336 | 2 9519 | 3 0134 | 3 00 |
| Collection Efficiency | % | 75 56% | 84 86% | 86 11% | 82 18% |
| Calculated Collector Inlet Flow | acmm | 573 1 | 795 2 | 714 3 | 694 17 |
| Measured Collector Inlet Flow | acmm | 756 0 | 1,000 0 | 1,008 0 | 921 33 |
| Calculated Flow Deviation | % | -24 20% | -20 48% | -29 14% | -24 66% |

Annex B-2 (a)

Abashevskaya Clean Coal Test Results for December, 1996 Tests

| Date | | 12/14/96 | 12/16/96 | 12/17/96 | Sorted G Increase or Decrease Over | Mixed G Increase or Decrease Over |
|---|---|---|---|---|---|---|
| Test No | | Three Tests | Two Tests | Three Tests | | |
| Coal Type | | Existing G | Sorted G | Mixed G | Existing G | Existing G |
| Heat Output | Gkal/Hr | 11 51 | 9 13 | 13 47 | -20 68% | 17 03% |
| Boiler Load | % | 52 33% | 41 51% | 61 24% | | |
| Water Inlet Temperature | Degrees C | 61 76 | 58 93 | 61 43 | -4 59% | -0 54% |
| Water Outlet Temperature | Degrees C | 101 76 | 90 43 | 108 48 | -11 14% | 6 60% |
| Water Inlet Enthalpy | kkal/kg | 61 74 | 58 91 | 61 40 | -4 59% | -0 54% |
| Water Outlet Enthalpy | kkal/kg | 101 86 | 90 45 | 108 65 | -11 20% | 6 66% |
| Boiler Outlet Oxygen (O2) | % | 11 63% | 13 80% | 10 50% | 18 67% | -9 71% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 292 43 | 242 42 | 293 23 | -17 10% | 0 27% |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 150 43 | 121 71 | 385 71 | -19 09% | 156 41% |
| Boiler Outlet Static Pressure | K Pascals | -0 52 | -0 53 | -0 55 | 1 49% | 6 29% |
| Collector Outlet Oxygen (O2) | % | 13 13% | 14 69% | 11 96% | 11 82% | -8 96% |
| Collector Outlet Flue Gas Temperature | Degrees C | 251 11 | 206 15 | 249 31 | -17 90% | -0 72% |
| Collector Outlet Carbon Monoxide (CO) | ppm | 110 24 | 127 29 | 228 48 | 15 46% | 107 26% |
| Collector Outlet Static Pressure | K Pascals | -1 46 | -1 61 | -1 60 | 10 41% | 9 61% |
| Coal Size Less Then 6mm (Fines) | % | 36 53% | 17 65% | 34 40% | -51 69% | -5 84% |
| Coal Ash | % | 14 15% | 13 36% | 13 92% | -5 56% | -1 58% |
| Coal Heating Value | kkal/kg | 6,077 33 | 6,032 00 | 6,173 33 | -0 75% | 1 58% |
| Bottom Ash Heating Value | kkal/kg | 1,620 00 | 513 50 | 901 67 | -68 30% | -44 34% |
| Bottom Ash Carbon | % | 23 84% | 6 30% | 11 85% | -73 59% | -50 27% |
| Bottom Ash Ash | % | 75 14% | 93 25% | 87 24% | 24 10% | 16 11% |
| Fly Ash Heating Value | kkal/kg | 2,620 00 | 3,030 00 | 3,173 33 | 15 65% | 21 12% |
| Fly Ash Carbon | % | 36 04% | 36 54% | 40 82% | 1 37% | 13 26% |
| Fly Ash Ash | % | 61 04% | 58 55% | 55 92% | -4 08% | -8 39% |
| Combustion Efficiency Heat Losses | | | | | | |
| Due to Dry Gas | % | 20 687% | 23 063% | 19 473% | 11 49% | -5 87% |
| Due to Moisture in Fuel | % | 1 323% | 1 380% | 1 230% | 4 28% | -7 00% |
| Due to Combustion of Hydrogen | % | 4 454% | 4 403% | 4 689% | -1 16% | 5 28% |
| Due to Unburned Combustibles (Carbon Loss) | % | 5 801% | 2 180% | 3 310% | -62 42% | -42 95% |
| Due to Radiation Through Boiler Skin | % | 0 983% | 1 200% | 0 867% | 22 03% | -11 86% |
| Unaccounted Losses | % | 1 500% | 1 500% | 1 500% | 0 00% | 0 00% |
| Net Efficiency | % | 65 251% | 66 274% | 68 931% | 1 57% | 5 64% |
| Heat Input | Gkal/Hr | 17 64 | 13 78 | 19 50 | -21 88% | 10 50% |
| Heat Output | Gkal/Hr | 11 51 | 9 13 | 13 47 | -20 68% | 17 03% |
| Heat Input | Tons/Hr | 2 92 | 2 28 | 3 17 | -21 80% | 8 53% |
| Collector Inlet Emissions | kg/Hr | 107 12 | 49 39 | 62 37 | -53 89% | -41 78% |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 6 07 | 3 58 | 3 20 | -40 97% | -47 31% |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 9 30 | 5 41 | 4 63 | -41 87% | -50 25% |
| Collector Outlet Emissions | kg/Hr | 48 65 | 35 70 | 49 24 | -26 63% | 1 21% |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 2 76 | 2 59 | 2 53 | -6 08% | -8 40% |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 4 23 | 3 91 | 3 66 | -7 50% | -13 51% |
| Collection Efficiency | % | 54 58% | 27 73% | 21 04% | -49 20% | -61 45% |
| Calculated Collector Inlet Flow | acmm | 1,349 74 | 1,299 77 | 1,405 60 | -3 70% | 4 14% |
| Measured Collector Inlet Flow | acmm | 1,333 00 | 1,251 00 | 1,349 00 | -6 15% | 1 20% |
| Calculated Flow Deviation | % | 1 26% | 3 90% | 4 20% | | |

Annex B-2(b)

Abashevskaya Clean Coal Test Results for December, 1996 Tests

| | | | | | |
|---|---|---|---|---|---|
| Date | | 14-Dec-96 | 14-Dec-96 | 16-Dec-96 | Average of |
| Test No | | AER1 | AER2 | AER3 | Existing G |
| Coal Type | | Existing G | Existing G | Existing G | Tests |
| Heat Output | Gkal/Hr | 11 24 | 10 91 | 12 39 | 11 51 |
| Boiler Load | % | 51 07% | 49 59% | 56 32% | 52 33% |
| Water Inlet Temperature | Degrees C | 61 14 | 62 00 | 62 14 | 61 76 |
| Water Outlet Temperature | Degrees C | 100 14 | 99 86 | 105 29 | 101 76 |
| Water Inlet Enthalpy | kkal/kg | 61 12 | 61 97 | 62 12 | 61 74 |
| Water Outlet Enthalpy | kkal/kg | 100 23 | 99 94 | 105 41 | 101 86 |
| Boiler Outlet Oxygen (O2) | % | 11 67% | 12 64% | 10 57% | 11 63% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 285 71 | 276 19 | 315 40 | 292 43 |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 198 86 | 75 71 | 176 71 | 150 43 |
| Boiler Outlet Static Pressure | K Pascals | -0 45 | -0 49 | -0 61 | -0 52 |
| Collector Outlet Oxygen (O2) | % | 13 16% | 13 71% | 12 53% | 13 13% |
| Collector Outlet Flue Gas Temperature | Degrees C | 244 21 | 241 03 | 268 10 | 251 11 |
| Collector Outlet Carbon Monoxide (CO) | ppm | 161 57 | 80 57 | 88 57 | 110 24 |
| Collector Outlet Static Pressure | K Pascals | -1 23 | -1 44 | -1 70 | -1 46 |
| Coal Size Less Then 6mm (Fines) | % | 36 90% | 35 60% | 37 10% | 36 53% |
| Coal Ash | % | 13 89% | 14 02% | 14 53% | 14 15% |
| Coal Heating Value | kkal/kg | 6,165 0 | 6,454 0 | 5,613 0 | 6,077 3 |
| Bottom Ash Heating Value | kkal/kg | 1,600 0 | 1,880 0 | 1,380 0 | 1,620 0 |
| Bottom Ash Carbon | % | 24 20% | 26 46% | 20 85% | 23 84% |
| Bottom Ash Ash | % | 74 85% | 72 37% | 78 20% | 75 14% |
| Fly Ash Heating Value | kkal/kg | 2,520 0 | 2,660 0 | 2,680 0 | 2,620 0 |
| Fly Ash Carbon | % | 33 70% | 36 67% | 37 75% | 36 04% |
| Fly Ash Ash | % | 62 73% | 60 35% | 60 04% | 61 04% |
| Combustion Efficiency Heat Losses | | | | | |
| Due to Dry Gas | % | 20 321% | 21 780% | 19 960% | 20 687% |
| Due to Moisture in Fuel | % | 1 181% | 0 673% | 2 116% | 1 323% |
| Due to Combustion of Hydrogen | % | 4 411% | 4 359% | 4 593% | 4 454% |
| Due to Unburned Combustibles (Carbon Loss) | % | 5 553% | 6 247% | 5 604% | 5 801% |
| Due to Radiation Through Boiler Skin | % | 1 000% | 1 000% | 0 950% | 0 983% |
| Unaccounted Losses | % | 1 500% | 1 500% | 1 500% | 1 500% |
| Net Efficiency | % | 66 034% | 64 441% | 65 277% | 65 251% |
| Heat Input | Gkal/Hr | 17 02 | 16 93 | 18 98 | 17 64 |
| Heat Output | Gkal/Hr | 11 24 | 10 91 | 12 39 | 11 51 |
| Heat Input | Tons/Hr | 2 76 | 2 62 | 3 38 | 2 92 |
| Collector Inlet Emissions | kg/Hr | 106 37 | 93 60 | 121 38 | 107 12 |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 6 25 | 5 53 | 6 39 | 6 07 |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 9 47 | 8 58 | 9 80 | 9 30 |
| Collector Outlet Emissions | kg/Hr | 34 23 | 33 13 | 78 60 | 48 65 |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 2 01 | 1 96 | 4 14 | 2 76 |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 3 05 | 3 04 | 6 34 | 4 23 |
| Collection Efficiency | % | 67 82% | 64 60% | 35 24% | 54 58% |
| Calculated Collector Inlet Flow | acmm | 1,283 61 | 1,382 45 | 1,383 18 | 1,349 74 |
| Measured Collector Inlet Flow | acmm | 1,258 00 | 1,264 00 | 1,477 00 | 1,333 00 |
| Calculated Flow Deviation | % | 2 04% | 9 37% | -6 35% | 1 26% |

Annex B-2 (c)

Abashevskaya Clean Coal Test Results for December, 1996 Tests

| | | | | |
|---|---|---|---|---|
| Date | | 16-Dec-96 | 16-Dec-96 | Average of |
| Test No | | ASR1 | ASR2 | Sorted G |
| Coal Type | | Sorted G | Sorted G | Tests |
| Heat Output | Gkal/Hr | 9 15 | 9 12 | 9 13 |
| Boiler Load | % | 41 57% | 41 44% | 41 51% |
| Water Inlet Temperature | Degrees C | 60 29 | 57 57 | 58 93 |
| Water Outlet Temperature | Degrees C | 91 86 | 89 00 | 90 43 |
| Water Inlet Enthalpy | kkal/kg | 60 26 | 57 55 | 58 91 |
| Water Outlet Enthalpy | kkal/kg | 91 89 | 89 02 | 90 45 |
| Boiler Outlet Oxygen (O2) | % | 13 83% | 13 77% | 13 80% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 251 90 | 232 94 | 242 42 |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 135 71 | 107 71 | 121 71 |
| Boiler Outlet Static Pressure | K Pascals | -0 55 | -0 50 | -0 53 |
| Collector Outlet Oxygen (O2) | % | 14 83% | 14 54% | 14 69% |
| Collector Outlet Flue Gas Temperature | Degrees C | 215 63 | 196 67 | 206 15 |
| Collector Outlet Carbon Monoxide (CO) | ppm | 104 00 | 150 57 | 127 29 |
| Collector Outlet Static Pressure | K Pascals | -1 60 | -1 61 | -1 61 |
| Coal Size Less Then 6mm (Fines) | % | 15 70% | 19 60% | 17 65% |
| Coal Ash | % | 14 00% | 12 72% | 13 36% |
| Coal Heating Value | kkal/kg | 6,103 0 | 5,961 0 | 6,032 00 |
| Bottom Ash Heating Value | kkal/kg | 540 0 | 487 0 | 513 50 |
| Bottom Ash Carbon | % | 6 57% | 6 02% | 6 30% |
| Bottom Ash Ash | % | 92 99% | 93 51% | 93 25% |
| Fly Ash Heating Value | kkal/kg | 2,940 0 | 3,120 0 | 3,030 00 |
| Fly Ash Carbon | % | 38 01% | 35 06% | 36 54% |
| Fly Ash Ash | % | 58 67% | 58 43% | 58 55% |
| Combustion Efficiency Heat Losses | | | | |
| Due to Dry Gas | % | 23 952% | 22 174% | 23 063% |
| Due to Moisture in Fuel | % | 1 167% | 1 593% | 1 380% |
| Due to Combustion of Hydrogen | % | 4 452% | 4 353% | 4 403% |
| Due to Unburned Combustibles (Carbon Loss) | % | 2 463% | 1 897% | 2 180% |
| Due to Radiation Through Boiler Skin | % | 1 200% | 1 200% | 1 200% |
| Unaccounted Losses | % | 1 500% | 1 500% | 1 500% |
| Net Efficiency | % | 65 265% | 67 283% | 66 274% |
| Heat Input | Gkal/Hr | 14 01 | 13 55 | 13 78 |
| Heat Output | Gkal/Hr | 9 15 | 9 12 | 9 13 |
| Heat Input | Tons/Hr | 2 30 | 2 27 | 2 28 |
| Collector Inlet Emissions | kg/Hr | 60 98 | 37 80 | 49 39 |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 4 35 | 2 79 | 3 58 |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 6 67 | 4 15 | 5 41 |
| Collector Outlet Emissions | kg/Hr | 39 15 | 32 24 | 35 70 |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 2 79 | 2 38 | 2 59 |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 4 28 | 3 54 | 3 91 |
| Collection Efficiency | % | 35 80% | 14 71% | 27 73% |
| Calculated Collector Inlet Flow | acmm | 1,343 61 | 1,255 92 | 1,299 77 |
| Measured Collector Inlet Flow | acmm | 1,260 00 | 1,242 00 | 1,251 00 |
| Calculated Flow Deviation | % | 6 64% | 1 12% | 3 90% |

Annex B-2 (d)

Abashevskaya Clean Coal Test Results for December, 1996 Tests

| | | | | | |
|---|---|---|---|---|---|
| Date | | 17-Dec-96 | 17-Dec-96 | 17-Dec-96 | Average of |
| Test No | | AMR1 | AMR2 | AMR3 | Mixed G |
| Coal Type | | Mixed G | Mixed G | Mixed G | Tests |
| Heat Output | Gkal/Hr | 14 85 | 15 04 | 10 52 | 13 47 |
| Boiler Load | % | 67 50% | 68 38% | 47 84% | 61 24% |
| Water Inlet Temperature | Degrees C | 62 00 | 62 43 | 59 86 | 61 43 |
| Water Outlet Temperature | Degrees C | 114 00 | 115 14 | 96 29 | 108 48 |
| Water Inlet Enthalpy | kkal/kg | 61 97 | 62 40 | 59 83 | 61 40 |
| Water Outlet Enthalpy | kkal/kg | 114 22 | 115 38 | 96 34 | 108 65 |
| Boiler Outlet Oxygen (O2) | % | 8 57% | 9 33% | 13 60% | 10 50% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 326 27 | 306 67 | 246 75 | 293 23 |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 977 00 | 85 71 | 94 43 | 385 71 |
| Boiler Outlet Static Pressure | K Pascals | -0 53 | -0 49 | -0 63 | -0 55 |
| Collector Outlet Oxygen (O2) | % | 10 37% | 10 83% | 14 67% | 11 96% |
| Collector Outlet Flue Gas Temperature | Degrees C | 275 79 | 262 14 | 210 00 | 249 31 |
| Collector Outlet Carbon Monoxide (CO) | ppm | 530 14 | 81 14 | 74 14 | 228 48 |
| Collector Outlet Static Pressure | K Pascals | -1 51 | -1 45 | -1 83 | -1 60 |
| Coal Size Less Then 6mm (Fines) | % | 34 70% | 23 80% | 44 70% | 34 40% |
| Coal Ash | % | 14 96% | 14 64% | 12 17% | 13 92% |
| Coal Heating Value | kkal/kg | 6,001 0 | 6,127 0 | 6,392 0 | 6,173 33 |
| Bottom Ash Heating Value | kkal/kg | 1,210 0 | 995 0 | 500 0 | 901 67 |
| Bottom Ash Carbon | % | 15 76% | 13 53% | 6 27% | 11 85% |
| Bottom Ash Ash | % | 82 53% | 85 85% | 93 35% | 87 24% |
| Fly Ash Heating Value | kkal/kg | 3,480 0 | 3,570 0 | 2,470 0 | 3,173 33 |
| Fly Ash Carbon | % | 44 20% | 45 10% | 33 16% | 40 82% |
| Fly Ash Ash | % | 52 79% | 51 34% | 63 62% | 55 92% |
| Combustion Efficiency Heat Losses | | | | | |
| Due to Dry Gas | % | 17 713% | 17 790% | 22 916% | 19 473% |
| Due to Moisture in Fuel | % | 1 432% | 1 205% | 1 055% | 1 230% |
| Due to Combustion of Hydrogen | % | 4 842% | 4 640% | 4 586% | 4 689% |
| Due to Unburned Combustibles (Carbon Loss) | % | 4 629% | 3 554% | 1 747% | 3 310% |
| Due to Radiation Through Boiler Skin | % | 0 750% | 0 750% | 1 100% | 0 867% |
| Unaccounted Losses | % | 1 500% | 1 500% | 1 500% | 1 500% |
| Net Efficiency | % | 69 134% | 70 562% | 67 096% | 68 931% |
| Heat Input | Gkal/Hr | 21 48 | 21 32 | 15 69 | 19 50 |
| Heat Output | Gkal/Hr | 14 85 | 15 04 | 10 52 | 13 47 |
| Heat Input | Tons/Hr | 3 58 | 3 48 | 2 45 | 3 17 |
| Collector Inlet Emissions | kg/Hr | 77 31 | 56 21 | 53 58 | 62 37 |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 3 60 | 2 64 | 3 42 | 3 20 |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 5 21 | 3 74 | 5 09 | 4 63 |
| Collector Outlet Emissions | kg/Hr | 58 59 | 41 09 | 48 05 | 49 24 |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 2 73 | 1 93 | 3 06 | 2 53 |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 3 95 | 2 73 | 4 57 | 3 66 |
| Collection Efficiency | % | 24 21% | 26 90% | 10 32% | 21 04% |
| Calculated Collector Inlet Flow | acmm | 1,363 51 | 1,390 87 | 1,462 43 | 1,405 60 |
| Measured Collector Inlet Flow | acmm | 1,363 00 | 1,295 00 | 1,389 00 | 1,349 00 |
| Calculated Flow Deviation | % | 0 04% | 7 40% | 5 29% | 4 20% |

Annex B-2(e)

Abashaevskaya Clean Coal Test Results for November, 1995 Tests

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | | 29-Nov-95 | 29-Nov-95 | 30-Nov-95 | 01-Dec-95 | 01-Dec-95 | |
| Test No | | TUNING | AE70R1 | | AE70R2 | | |
| Test Start Time | | 11 07 AM | 03 00 PM | 01 00 PM | 10 40 AM | 04 10 PM | Bungurskaya |
| Test End Time | | 12 30 PM | 04 10 PM | 01 20 PM | 11 50 AM | | From |
| Coal Type | | Existing G | Existing G | Sorted G | Existing G | Sorted G-T | Finnartsib |
| Heat Output | Gkal/Hr | 11 531 | 14 464 | | 10 879 | | |
| Boiler Load | % | 52 41% | 65 75% | | 49 45% | | |
| Water Inlet Temperature | Degrees C | 60 20 | 59 60 | | 54 90 | | |
| Water Outlet Temperature | Degrees C | 101 30 | 111 30 | | 95 30 | | |
| Water Inlet Enthalpy | kkal/kg | 60 17 | 59 57 | | 54 88 | | |
| Water Outlet Enthalpy | kkal/kg | 101 39 | 111 49 | | 95 35 | | |
| Boiler Outlet Oxygen (O2) | % | 14 43% | 13 94% | | 15 46% | | |
| Boiler Outlet Flue Gas Temperature | Degrees C | 256 78 | 297 33 | | 231 11 | | |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 206 30 | 817 00 | | 255 70 | | |
| Boiler Outlet Static Pressure | 100 Pascal | -8 18 | -7 67 | | -6 44 | | |
| Collector Outlet Oxygen (O2) | % | 16 04% | 16 16% | | 17 20% | | |
| Collector Outlet Flue Gas Temperature | Degrees C | 229 89 | 262 67 | | 189 00 | | |
| Collector Outlet Carbon Monoxide (CO) | ppm | 194 60 | 619 40 | | 142 50 | | |
| Collector Outlet Static Pressure | 100 Pascal | -22 31 | -19 77 | | -16 35 | | |
| Coal Size Less Then 6mm (Fines) | % | 33 50% | 49 80% | 9 40% | 49 40% | 16 80% | |
| Coal Ash | % | 22 84% | 19 68% | 29 40% | 19 33% | 21 13% | 10 15% |
| Coal Heating Value | kkal/kg | 5,530 0 | 5,729 0 | 5,329 0 | 6,224 0 | 6,084 0 | 6,999 0 |
| Bottom Ash Heating Value | kkal/kg | 618 00 | 608 00 | 457 00 | 1,687 00 | | |
| Bottom Ash Carbon | % | 10 02% | 9 01% | 6 16% | 25 22% | | |
| Bottom Ash Ash | % | 87 76% | 89 37% | 92 24% | 69 59% | | |
| Fly Ash Heating Value | kkal/kg | | 4,985 00 | | | | |
| Fly Ash Carbon | % | | 62 21% | | | | |
| Fly Ash Ash | % | | 35 36% | | | | |
| Combustion Efficiency Heat Losses | | | | | | | |
| Due to Dry Gas | % | 25 97% | 26 10% | | 24 23% | | |
| Due to Moisture in Fuel | % | 1 02% | 1 17% | | 1 15% | | |
| Due to Combustion of Hydrogen | % | 4 68% | 4 92% | | 4 38% | | |
| Due to Unburned Combustibles (Carbon Loss) | % | 2 91% | 10 13% | | 7 53% | | |
| Due to Radiation Through Boiler Skin | % | 0 90% | 0 75% | | 1 05% | | |
| Unaccounted Losses | % | 1 50% | 1 50% | | 1 50% | | |
| Net Efficiency | % | 63 02% | 55 42% | | 60 16% | | |
| Heat Input | Gkal/Hr | 18 298 | 26 099 | | 18 084 | | |
| Heat Output | Gkal/Hr | 11 531 | 14 464 | | 10 879 | | |
| Heat Input | Tons /Hr | 3 31 | 4 56 | | 2 91 | | |
| Collector Inlet Emissions | kg/Hr | | 419 55 | | 158 03 | | |
| Collector Inlet Emissions/Heat Input | kg/Gkal | | 16 08 | | 8 74 | | |
| Collector Inlet Emissions/Heat Output | kg/Gkal | | 29 01 | | 14 53 | | |
| Collector Outlet Emissions | kg/Hr | | 178 89 | | 53 06 | | |
| Collector Outlet Emissions/Heat Input | kg/Gkal | | 6 85 | | 2 93 | | |
| Collector Outlet Emissions/Heat Output | kg/Gkal | | 12 37 | | 4 88 | | |
| Collection Efficiency | % | | 57 36% | | 66 42% | | |

Anex B-3 (a)

Laundry Depot Clean Coal Test Results for December, 1996 Tests

| Date<br>Test No<br>Coal Type | | 12/10/96<br>Three Tests<br>Existing T | 12/11/96<br>Two Tests<br>Sorted G | 12/11/96<br>One Test<br>Mixed G-T | 12/12/96<br>Three Tests<br>Unsorted G | Sorted G<br>Increase or<br>Decrease<br>Over<br>Existing T | Mixed G-T Coal<br>Increase or<br>Decrease<br>Over<br>Existing T | Unsorted G<br>Increase or<br>Decrease<br>Over<br>Existing T |
|---|---|---|---|---|---|---|---|---|
| Steam Flow Calculated From Boiler Outlet Flow | Tons/Hr | 3 45 | 3 34 | 4 61 | 3 79 | 3 16% | 33 68% | 9 88% |
| Boiler Load | % | 137 96% | 133 60% | 184 42% | 151 59% | | | |
| Steam Pressure | kg/cm2 | 8 42 | 8 66 | 8 64 | 7 73 | 2 85% | 2 60% | -8 20% |
| Feedwater Temperature | Degrees C | 91 43 | 85 79 | 86 00 | 85 48 | -6 17% | -5 94% | -6 51% |
| Steam Enthalpy | kkal/kg | 662 22 | 662 12 | 662 12 | 662 12 | -0 02% | -0 02% | 0 02% |
| Feedwater Enthalpy | kkal/kg | 91 46 | 85 80 | 86 01 | 85 48 | -6 20% | -5 96% | -6 54% |
| Boiler Outlet Oxygen (O2) | % | 11 85% | 10 31% | 8 51% | 9 80% | -13 00% | -28 14% | -17 28% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 346 08 | 428 69 | 443 41 | 388 92 | 23 87% | 28 12% | 12 38% |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 173 05 | 390 14 | 1,454 57 | 817 00 | 125 45% | 740 56% | 372 12% |
| Boiler Outlet Static Pressure | 100 Pascals | -3 98 | -3 60 | -3 61 | -3 15 | 9 60% | -9 38% | -20 98% |
| Collector Inlet Oxygen (O2) | % | 14 44% | 13 06% | 11 97% | 12 59% | -9 59% | -17 11% | -12 86% |
| Collector Inlet Outlet Flue Gas Temperature | Degrees C | 205 29 | 250 44 | 270 95 | 229 81 | 21 99% | 31 98% | 11 95% |
| Collector Inlet Carbon Monoxide (CO) | ppm | 199 71 | 656 57 | 570 43 | 521 57 | 228 76% | 185 62% | 161 16% |
| Collector Inlet Static Pressure | 100 Pascals | -8 26 | -7 96 | -7 90 | -6 91 | -3 63% | -4 38% | -16 37% |
| Collector Outlet Oxygen (O2) | % | 15 38% | 14 11% | 14 77% | 14 30% | -8 24% | -3 96% | -7 06% |
| Collector Outlet Flue Gas Temperature | Degrees C | 170 82 | 200 36 | 212 94 | 185 82 | 17 29% | 24 66% | 8 78% |
| Collector Outlet Carbon Monoxide (CO) | ppm | 94 19 | 1,235 57 | 503 43 | 186 57 | 1211 78% | 434 48% | 98 08% |
| Collector Outlet Static Pressure | 100 Pascals | -23 99 | -22 50 | -22 02 | -19 88 | -6 23% | -8 23% | -17 15% |
| Coal Size Less Than 6mm (Fines) | % | 10 70% | 12 60% | 8 60% | 32 60% | 17 76% | -19 63% | 204 67% |
| Coal Ash | % | 12 41% | 6 20% | 9 21% | 15 49% | -50 09% | -25 81% | 24 79% |
| Coal Heating Value | kkal/kg | 7,083 67 | 7,129 50 | 7,241 00 | 5,746 00 | 0 65% | 2 22% | -18 88% |
| Bottom Ash Heating Value | kkal/kg | 4,096 67 | 4,815 00 | 4,800 00 | 3,713 33 | 17 53% | 17 17% | -9 36% |
| Bottom Ash Carbon | % | 52 42% | 59 69% | 58 97% | 47 02% | 13 88% | 12 50% | -10 30% |
| Bottom Ash Ash | % | 45 82% | 37 30% | 37 03% | 50 50% | -18 60% | -19 19% | 10 21% |
| Fly Ash Heating Value | kkal/kg | 5,180 00 | 7,565 00 | 0 00 | 0 00 | 46 04% | | |
| Fly Ash Carbon | % | 68 79% | 93 68% | 0 00% | 0 00% | 36 18% | | |
| Fly Ash Ash | % | 26 97% | 3 06% | 0 00% | 0 00% | -88 67% | | |
| Combustion Efficiency Heat Losses | | | | | | | | |
| Due to Dry Gas | % | 12 988% | 12 101% | 13 985% | 12 442% | -6 83% | 7 68% | -4 21% |
| Due to Moisture in Fuel | % | 0 438% | 0 823% | 0 481% | 1 536% | 87 85% | 9 80% | 250 48% |
| Due to Combustion of Hydrogen | % | 3 151% | 4 236% | 3 801% | 4 018% | 34 43% | 20 65% | 27 52% |
| Due to Unburned Combustibles (Carbon Loss) | % | 15 783% | 13 980% | 0 000% | 0 000% | -11 43% | | |
| Due to Radiation Through Boiler Skin | % | 0 850% | 0 850% | 0 850% | 0 850% | 0 00% | 0 00% | 0 00% |
| Unaccounted Losses | % | 1 500% | 1 500% | 1 500% | 1 500% | 0 00% | 0 00% | 0 00% |
| Net Efficiency | % | 65 290% | 66 510% | 0 000% | 0 000% | 1 87% | | |
| Efficiency Without Carbon Loss | % | 81 073% | 80 490% | 79 383% | 79 655% | -0 72% | -2 08% | -1 75% |
| Heat Input | Gkal/Hr | 2 63 | 2 89 | 3 35 | 2 74 | 9 90% | 27 10% | 4 22% |
| Heat Output | Gkal/Hr | 1 97 | 1 92 | 2 66 | 2 19 | -2 12% | 35 09% | 11 14% |
| Heat Input | Tons/Hr | 0 37 | 0 41 | 0 46 | 0 48 | 9 89% | 25 08% | 29 36% |
| Boiler Outlet Emissions | kg/Hr | 0 85 | 11 23 | 8 51 | 3 62 | 1220 59% | 901 18% | 325 88% |
| Boiler Outlet Emissions/Heat Input | kg/Gkal | 0 32 | 3 88 | 2 54 | 1 32 | 1101 65% | 687 73% | 308 65% |
| Boiler Outlet Emissions/Heat Output | kg/Gkal | 0 43 | 5 83 | 3 20 | 1 66 | 1249 20% | 641 11% | 283 19% |
| Collector Outlet Emissions | kg/Hr | 0 34 | 6 76 | 3 71 | 2 19 | 1907 92% | 1001 98% | 549 50% |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 0 13 | 2 34 | 1 11 | 0 80 | 1727 07% | 767 05% | 523 22% |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 0 17 | 3 51 | 1 40 | 1 00 | 1951 43% | 715 72% | 484 39% |
| Collection Efficiency | % | 60 39% | 39 78% | 56 40% | 39 59% | -34 14% | -6 60% | -34 44% |

Annex B-3 (b)

Laundry Depot Clean Coal Test Results for December, 1996 Tests

| | | | | | |
|---|---|---|---|---|---|
| Date | | 10-Dec-96 | 10-Dec-96 | 10-Dec-96 | |
| Test No | | LER1 | LER2 | LER3 | |
| Coal Type | | Existing T Large | Existing T Medium | Existing T Small | Average |
| Steam Flow Calculated From Boiler Outlet Flow | Tons/Hr | 4 34 | 3 07 | 2 93 | 3 45 |
| Boiler Load | % | 173 58% | 122 90% | 117 39% | 137 96% |
| Steam Pressure | kg/cm2 | 8 31 | 8 71 | 8 24 | 8 42 |
| Feedwater Temperature | Degrees C | 96 29 | 93 43 | 84 57 | 91 43 |
| Steam Enthalpy | kkal/kg | 662 42 | 662 12 | 662 12 | 662 22 |
| Feedwater Enthalpy | kkal/kg | 96 34 | 93 47 | 84 57 | 91 46 |
| Boiler Outlet Oxygen (O2) | % | 9 99% | 12 71% | 12 84% | 11 85% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 361 27 | 340 40 | 336 59 | 346 08 |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 391 71 | 82 43 | 45 00 | 173 05 |
| Boiler Outlet Static Pressure | 100 Pascals | -3 90 | -3 93 | -4 13 | -3 98 |
| Collector Inlet Oxygen (O2) | % | 13 69% | 15 21% | 14 43% | 14 44% |
| Collector Inlet Outlet Flue Gas Temperature | Degrees C | 205 16 | 206 03 | 204 68 | 205 29 |
| Collector Inlet Carbon Monoxide (CO) | ppm | 525 29 | 65 43 | 8 43 | 199 71 |
| Collector Inlet Static Pressure | 100 Pascals | -8 25 | -8 18 | -8 34 | -8 26 |
| Collector Outlet Oxygen (O2) | % | 14 66% | 16 20% | 15 29% | 15 38% |
| Collector Outlet Flue Gas Temperature | Degrees C | 171 11 | 171 19 | 170 16 | 170 82 |
| Collector Outlet Carbon Monoxide (CO) | ppm | 206 71 | 70 86 | 5 00 | 94 19 |
| Collector Outlet Static Pressure | 100 Pascals | -23 98 | -23 92 | -24 08 | -23 99 |
| Coal Size Less Than 6mm (Fines) | % | 0 50% | 10 20% | 21 40% | 10 70% |
| Coal Ash | % | 11 39% | 11 64% | 14 21% | 12 41% |
| Coal Heating Value | kkal/kg | 7,439 | 7,273 | 6,539 | ###### |
| Bottom Ash Heating Value | kkal/kg | 4,380 | 3,620 | 4,290 | ###### |
| Bottom Ash Carbon | % | 55 41% | 46 40% | 55 44% | 52 42% |
| Bottom Ash Ash | % | 42 75% | 51 80% | 42 92% | 45 82% |
| Fly Ash Heating Value | kkal/kg | 5,180 | | | ###### |
| Fly Ash Carbon | % | 68 79% | | | 68 79% |
| Fly Ash Ash | % | 26 97% | | | 26 97% |
| Combustion Efficiency Heat Losses | | | | | |
| Due to Dry Gas | % | 9 272% | 14 738% | 14 954% | ###### |
| Due to Moisture in Fuel | % | 0 133% | 0 272% | 0 909% | 0 438% |
| Due to Combustion of Hydrogen | % | 3 172% | 3 136% | 3 145% | 3 151% |
| Due to Unburned Combustibles (Carbon Loss) | % | 15 783% | | | ###### |
| Due to Radiation Through Boiler Skin | % | 0 850% | 0 850% | 0 850% | 0 850% |
| Unaccounted Losses | % | 1 500% | 1 500% | 1 500% | 1 500% |
| Net Efficiency | % | 69 290% | | | 65 290% |
| Efficiency Without Carbon Loss | % | 85 073% | 79 504% | 78 642% | ###### |
| Heat Input | Gkal/Hr | 3 55 | 2 20 | 2 16 | 2 63 |
| Heat Output | Gkal/Hr | 2 46 | 1 75 | 1 70 | 1 97 |
| Heat Input | Tons/Hr | 0 48 | 0 30 | 0 33 | 0 37 |
| Boiler Outlet Emissions | kg/Hr | 1 41 | 0 35 | 0 79 | 0 85 |
| Boiler Outlet Emissions/Heat Input | kg/Gkal | 0 40 | 0 16 | 0 37 | 0 32 |
| Boiler Outlet Emissions/Heat Output | kg/Gkal | 0 57 | 0 20 | 0 47 | 0 43 |
| Collector Outlet Emissions | kg/Hr | 0 35 | 0 36 | 0 3 | 0 34 |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 0 10 | 0 16 | 0 14 | 0 13 |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 0 14 | 0 21 | 0 18 | 0 17 |
| Collection Efficiency | % | 75 18% | -2 86% | 62 03% | 60 39% |

Annex B-3 (c)

Laundry Depot Clean Coal Test Results for December, 1996 Tests

| | | | | | |
|---|---|---|---|---|---|
| Date | | 12-Dec-96 | 12-Dec-96 | 12-Dec-96 | |
| Test No | | LDR1 | LDR2 | LDR3 | |
| Coal Type | | Unsorted G | Unsorted G | Unsorted G | Average |
| Steam Flow Calculated From Boiler Outlet Flow | Tons/Hr | 3 76 | 3 79 | 3 81 | 3 79 |
| Boiler Load | % | 150 57% | 151 66% | 152 55% | 151 59% |
| Steam Pressure | kg/cm2 | 7 51 | 6 99 | 8 70 | 7 73 |
| Feedwater Temperature | Degrees C | 79 86 | 87 43 | 89 14 | 85 48 |
| Steam Enthalpy | kkal/kg | 662 12 | 662 12 | 662 12 | 662 12 |
| Feedwater Enthalpy | kkal/kg | 79 85 | 87 44 | 89 16 | 85 48 |
| Boiler Outlet Oxygen (O2) | % | 10 97% | 9 14% | 9 29% | 9 80% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 381 90 | 382 30 | 402 54 | 388 92 |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 588 57 | 1,029 29 | 833 14 | 817 00 |
| Boiler Outlet Static Pressure | 100 Pascals | -3 50 | -3 04 | -2 90 | -3 15 |
| Collector Inlet Oxygen (O2) | % | 13 30% | 12 26% | 12 20% | 12 59% |
| Collector Inlet Outlet Flue Gas Temperature | Degrees C | 226 75 | 225 63 | 237 06 | 229 81 |
| Collector Inlet Carbon Monoxide (CO) | ppm | 447 29 | 998 29 | 119 14 | 521 57 |
| Collector Inlet Static Pressure | 100 Pascals | -7 77 | -6 65 | -6 30 | -6 91 |
| Collector Outlet Oxygen (O2) | % | 14 99% | 14 41% | 13 49% | 14 30% |
| Collector Outlet Flue Gas Temperature | Degrees C | 185 48 | 181 11 | 190 87 | 185 82 |
| Collector Outlet Carbon Monoxide (CO) | ppm | 28 14 | 39 43 | 492 14 | 186 57 |
| Collector Outlet Static Pressure | 100 Pascals | -22 71 | -18 82 | -18 11 | -19 88 |
| Coal Size Less Than 6mm (Fines) | % | 34 20% | 35 90% | 27 70% | 32 60% |
| Coal Ash | % | 16 17% | 16 83% | 13 47% | 15 49% |
| Coal Heating Value | kkal/kg | 5,661 | 5,603 | 5,974 | ###### |
| Bottom Ash Heating Value | kkal/kg | 3,760 | 2,670 | 4,710 | ###### |
| Bottom Ash Carbon | % | 46 65% | 35 24% | 59 17% | 47 02% |
| Bottom Ash Ash | % | 50 41% | 62 77% | 38 32% | 50 50% |
| Fly Ash Heating Value | kkal/kg | | | | |
| Fly Ash Carbon | % | | | | |
| Fly Ash Ash | % | | | | |
| Combustion Efficiency Heat Losses | | | | | |
| Due to Dry Gas | % | 13 483% | 11 640% | 12 202% | ###### |
| Due to Moisture in Fuel | % | 1 517% | 1 565% | 1 525% | 1 536% |
| Due to Combustion of Hydrogen | % | 4 064% | 4 117% | 3 873% | 4 018% |
| Due to Unburned Combustibles (Carbon Loss) | % | 0 000% | 0 000% | 0 000% | 0 000% |
| Due to Radiation Through Boiler Skin | % | 0 850% | 0 850% | 0 850% | 0 850% |
| Unaccounted Losses | % | 1 500% | 1 500% | 1 500% | 1 500% |
| Net Efficiency | % | | | | |
| Efficiency Without Carbon Loss | % | 78 586% | 80 328% | 80 050% | ###### |
| Heat Input | Gkal/Hr | 2 79 | 2 71 | 2 73 | 2 74 |
| Heat Output | Gkal/Hr | 2 19 | 2 18 | 2 19 | 2 19 |
| Heat Input | Tons/Hr | 0 49 | 0 48 | 0 46 | 0 48 |
| Boiler Outlet Emissions | kg/Hr | 2 03 | 5 | 3 83 | 3 62 |
| Boiler Outlet Emissions/Heat Input | kg/Gkal | 0 728 | 1 843 | 1 403 | 1 319 |
| Boiler Outlet Emissions/Heat Output | kg/Gkal | 0 926 | 2 295 | 1 753 | 1 656 |
| Collector Outlet Emissions | kg/Hr | 1 24 | 3 02 | 2 3 | 2 19 |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 0 445 | 1 113 | 0 843 | 0 797 |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 0 566 | 1 386 | 1 053 | 1 001 |
| Collection Efficiency | % | 38 92% | 39 60% | 39 95% | 39 59% |

Annex B-3 (d)

Laundry Depot Clean Coal Test Results for December, 1996 Tests

| | | | | | |
|---|---|---|---|---|---|
| Date | | 11-Dec-96 | 11-Dec-96 | | 11-Dec-96 |
| Test No | | LSR1 | LSR2 | | LMR1 |
| Coal Type | | Sorted G | Sorted G | Average | Mixed G-T |
| Steam Flow Calculated From Boiler Outlet Flow | Tons/Hr | 3 25 | 3 43 | 3 34 | 4 61 |
| Boiler Load | % | 129 87% | 137 33% | 133 60% | 184 42% |
| Steam Pressure | kg/cm2 | 8 97 | 8 36 | 8 66 | 8 64 |
| Feedwater Temperature | Degrees C | 81 86 | 89 71 | 85 79 | 86 00 |
| Steam Enthalpy | kkal/kg | 662 12 | 662 12 | 662 12 | 662 12 |
| Feedwater Enthalpy | kkal/kg | 81 85 | 89 74 | 85 80 | 86 01 |
| Boiler Outlet Oxygen (O2) | % | 10 64% | 9 97% | 10 31% | 8 51% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 429 92 | 427 46 | 428 69 | 443 41 |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 248 57 | 531 71 | 390 14 | 1,454 57 |
| Boiler Outlet Static Pressure | 100 Pascals | -3 63 | -3 57 | -3 60 | -3 61 |
| Collector Inlet Oxygen (O2) | % | 12 86% | 13 26% | 13 06% | 11 97% |
| Collector Inlet Outlet Flue Gas Temperature | Degrees C | 248 17 | 252 70 | 250 44 | 270 95 |
| Collector Inlet Carbon Monoxide (CO) | ppm | 584 00 | 729 14 | 656 57 | 570 43 |
| Collector Inlet Static Pressure | 100 Pascals | -7 93 | -7 99 | -7 96 | -7 90 |
| Collector Outlet Oxygen (O2) | % | 13 99% | 14 24% | 14 11% | 14 77% |
| Collector Outlet Flue Gas Temperature | Degrees C | 198 57 | 202 14 | 200 36 | 212 94 |
| Collector Outlet Carbon Monoxide (CO) | ppm | 1,485 14 | 986 00 | 1,235 57 | 503 43 |
| Collector Outlet Static Pressure | 100 Pascals | -22 62 | -22 37 | -22 50 | -22 02 |
| Coal Size Less Than 6mm (Fines) | % | 15 00% | 10 20% | 12 60% | 8 60% |
| Coal Ash | % | 6 62% | 5 77% | 6 20% | 9 21% |
| Coal Heating Value | kkal/kg | 6,962 | 7,297 | 7,129 50 | 7,241 |
| Bottom Ash Heating Value | kkal/kg | 4,560 | 5,070 | 4,815 00 | 4,800 |
| Bottom Ash Carbon | % | 58 64% | 60 74% | 59 69% | 58 97% |
| Bottom Ash Ash | % | 39 30% | 35 30% | 37 30% | 37 03% |
| Fly Ash Heating Value | kkal/kg | 7,530 | 7,600 | 7,565 00 | |
| Fly Ash Carbon | % | 94 01% | 93 35% | 93 68% | |
| Fly Ash Ash | % | 3 26% | 2 85% | 3 06% | |
| Combustion Efficiency Heat Losses | | | | | |
| Due to Dry Gas | % | 12 270% | 11 932% | 12 101% | 13 985% |
| Due to Moisture in Fuel | % | 0 988% | 0 658% | 0 823% | 0 481% |
| Due to Combustion of Hydrogen | % | 4 223% | 4 249% | 4 236% | 3 801% |
| Due to Unburned Combustibles (Carbon Loss) | % | 14 652% | 13 308% | 13 980% | 0 000% |
| Due to Radiation Through Boiler Skin | % | 0 850% | 0 850% | 0 850% | 0 850% |
| Unaccounted Losses | % | 1 500% | 1 500% | 1 500% | 1 500% |
| Net Efficiency | % | 65 518% | 67 502% | 66 510% | |
| Efficiency Without Carbon Loss | % | 80 169% | 80 810% | 80 490% | 79 383% |
| Heat Input | Gkal/Hr | 2 88 | 2 91 | 2 89 | 3 35 |
| Heat Output | Gkal/Hr | 1 88 | 1 97 | 1 92 | 2 66 |
| Heat Input | Tons/Hr | 0 41 | 0 40 | 0 41 | 0 46 |
| Boiler Outlet Emissions | kg/Hr | 14 55 | 7 9 | 11 23 | 8 51 |
| Boiler Outlet Emissions/Heat Input | kg/Gkal | 5 06 | 2 71 | 3 88 | 2 54 |
| Boiler Outlet Emissions/Heat Output | kg/Gkal | 7 72 | 4 02 | 5 83 | 3 20 |
| Collector Outlet Emissions | kg/Hr | 6 42 | 7 1 | 6 76 | 3 71 |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 2 23 | 2 44 | 2 34 | 1 11 |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 3 41 | 3 61 | 3 51 | 1 40 |
| Collection Efficiency | % | 55 88% | 10 13% | 39 78% | 56 40% |

Annex D

Abashaevskaya Clean Coal Test Results for November, 1995 Tests

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | | 29-Nov-95 | 29-Nov-95 | 30-Nov-95 | 01-Dec-95 | 01-Dec-95 | |
| Test No | | TUNING | AE70R1 | | AE70R2 | | |
| Test Start Time | | 11 07 AM | 03 00 PM | 01 00 PM | 10 40 AM | 04 10 PM | Bungurskaya |
| Test End Time | | 12 30 PM | 04 10 PM | 01 20 PM | 11 50 AM | | From |
| Coal Type | | Existing G | Existing G | Sorted G | Existing G | Sorted G-T | Finnartsib |
| Heat Output | Gkal/Hr | 11 531 | 14 464 | | 10 879 | | |
| Boiler Load | % | 52 41% | 65 75% | | 49 45% | | |
| Water Inlet Temperature | Degrees C | 60 20 | 59 60 | | 54 90 | | |
| Water Outlet Temperature | Degrees C | 101 30 | 111 30 | | 95 30 | | |
| Water Inlet Enthalpy | kkal/kg | 60 17 | 59 57 | | 54 88 | | |
| Water Outlet Enthalpy | kkal/kg | 101 39 | 111 49 | | 95 35 | | |
| Boiler Outlet Oxygen (O2) | % | 14 43% | 13 94% | | 15 46% | | |
| Boiler Outlet Flue Gas Temperature | Degrees C | 256 78 | 297 33 | | 231 11 | | |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 206 30 | 817 00 | | 255 70 | | |
| Boiler Outlet Static Pressure | 100 Pascal | -8 18 | -7 67 | | -6 44 | | |
| Collector Outlet Oxygen (O2) | % | 16 04% | 16 16% | | 17 20% | | |
| Collector Outlet Flue Gas Temperature | Degrees C | 229 89 | 262 67 | | 189 00 | | |
| Collector Outlet Carbon Monoxide (CO) | ppm | 194 60 | 619 40 | | 142 50 | | |
| Collector Outlet Static Pressure | 100 Pascal | -22 31 | -19 77 | | -16 35 | | |
| Coal Size Less Then 6mm (Fines) | % | 33 50% | 49 80% | 9 40% | 49 40% | 16 80% | |
| Coal Ash | % | 22 84% | 19 68% | 29 40% | 19 33% | 21 13% | 10 15% |
| Coal Heating Value | kkal/kg | 5,530 0 | 5,729 0 | 5,329 0 | 6,224 0 | 6,084 0 | 6,999 0 |
| Bottom Ash Heating Value | kkal/kg | 618 00 | 608 00 | 457 00 | 1,687 00 | | |
| Bottom Ash Carbon | % | 10 02% | 9 01% | 6 16% | 25 22% | | |
| Bottom Ash Ash | % | 87 76% | 89 37% | 92 24% | 69 59% | | |
| Fly Ash Heating Value | kkal/kg | | 4,985 00 | | | | |
| Fly Ash Carbon | % | | 62 21% | | | | |
| Fly Ash Ash | % | | 35 36% | | | | |
| Combustion Efficiency Heat Losses | | | | | | | |
| Due to Dry Gas | % | 25 97% | 26 10% | | 24 23% | | |
| Due to Moisture in Fuel | % | 1 02% | 1 17% | | 1 15% | | |
| Due to Combustion of Hydrogen | % | 4 68% | 4 92% | | 4 38% | | |
| Due to Unburned Combustibles (Carbon Loss) | % | 2 91% | 10 13% | | 7 53% | | |
| Due to Radiation Through Boiler Skin | % | 0 90% | 0 75% | | 1 05% | | |
| Unaccounted Losses | % | 1 50% | 1 50% | | 1 50% | | |
| Net Efficiency | % | 63 02% | 55 42% | | 60 16% | | |
| Heat Input | Gkal/Hr | 18 298 | 26 099 | | 18 084 | | |
| Heat Output | Gkal/Hr | 11 531 | 14 464 | | 10 879 | | |
| Heat Input | Tons /Hr | 3 31 | 4 56 | | 2 91 | | |
| Collector Inlet Emissions | kg/Hr | | 419 55 | | 158 03 | | |
| Collector Inlet Emissions/Heat Input | kg/Gkal | | 16 08 | | 8 74 | | |
| Collector Inlet Emissions/Heat Output | kg/Gkal | | 29 01 | | 14 53 | | |
| Collector Outlet Emissions | kg/Hr | | 178 89 | | 53 06 | | |
| Collector Outlet Emissions/Heat Input | kg/Gkal | | 6 85 | | 2 93 | | |
| Collector Outlet Emissions/Heat Output | kg/Gkal | | 12 37 | | 4 88 | | |
| Collection Efficiency | % | | 57 36% | | 66 42% | | |

Annex D

Dimitrova Clean Coal Test Results for November, 1995 Tests

| | | Existing G Mark Coal Test Results Average | Sorted G Mark Coal Test Results Average | Sorted G-T Coal Test Results Average | Sorted G Mark Coal Increase or Decrease Over Existing G | Sorted G-T Coal Increase or Decrease Over Existing G |
|---|---|---|---|---|---|---|
| Pressure Corrected Steam Flow | Tons/Hr | 19 49 | 15 09 | 18 37 | -22 54% | -5 70% |
| Boiler Load | % | 77 94% | 60 38% | 73 50% | -22 54% | -5 70% |
| Steam Pressure | kg/cm2 | 7 30 | 7 07 | 8 10 | -3 07% | 10 95% |
| Feedwater Temperature | Degrees C | 91 30 | 89 78 | 91 30 | -1 66% | 0 00% |
| Steam Enthalpy | kkal/kg | 661 27 | 661 08 | 662 19 | -0 03% | 0 14% |
| Feedwater Enthalpy | kkal/kg | 91 75 | 90 41 | 91 66 | -1 46% | -0 10% |
| Boiler Outlet Oxygen (O2) | % | 10 39% | 10 67% | 10 47% | 2 71% | 0 85% |
| Boiler Outlet Flue Gas Temperature | Degrees C | 251 90 | 247 70 | 266 87 | -1 67% | 5 94% |
| Boiler Outlet Carbon Monoxide (CO) | ppm | 444 40 | 204 87 | 128 03 | -53 90% | -71 19% |
| Boiler Outlet Static Pressure | 100 Pascal | -2 89 | -2 21 | -2 97 | -23 28% | 3 06% |
| Collector Inlet Oxygen (O2) | % | 11 65% | 11 50% | 11 11% | -1 22% | -4 62% |
| Collector Inlet Flue Gas Temperature | Degrees C | 139 07 | 123 37 | 132 11 | -11 29% | -5 00% |
| Collector Inlet Carbon Monoxide (CO) | ppm | 311 38 | 194 30 | 131 53 | -37 60% | -57 76% |
| Collector Inlet Static Pressure | 100 Pascal | -7 36 | -6 78 | -9 12 | -7 85% | 23 96% |
| Collector Outlet Oxygen (O2) | % | 12 18% | 12 35% | 10 99% | 1 35% | -9 83% |
| Collector Outlet Flue Gas Temperature | Degrees C | 135 18 | 124 39 | 123 97 | -7 98% | -8 29% |
| Collector Outlet Carbon Monoxide (CO) | ppm | 282 40 | 197 67 | 104 65 | -30 00% | -62 94% |
| Collector Outlet Static Pressure | 100 Pascal | -23 03 | -19 20 | -21 22 | -16 65% | -7 89% |
| Coal Size Less Than 6mm (Fines) | % | 41 60% | 13 57% | 20 07% | -67 39% | -51 76% |
| Coal Ash | % | 17 59% | 28 34% | 23 76% | 61 14% | 35 10% |
| Coal Heating Value | kkal/kg | 6,126 25 | 5,368 00 | 5,692 33 | -12 38% | -7 08% |
| Bottom Ash Heating Value | kkal/kg | 972 75 | 1,102 67 | 742 00 | 13 36% | -23 72% |
| Bottom Ash Carbon | % | 15 39% | 17 83% | 13 15% | 15 87% | -14 53% |
| Bottom Ash Ash | % | 83 03% | 81 01% | 85 72% | -2 42% | 3 25% |
| Fly Ash Heating Value | kkal/kg | 5,233 75 | 4,007 67 | 4,513 67 | -23 43% | -13 76% |
| Fly Ash Carbon | % | 64 83% | 46 86% | 57 13% | -27 71% | -11 87% |
| Fly Ash Ash | % | 29 72% | 37 96% | 36 24% | 27 73% | 21 93% |
| Combustion Efficiency Heat Losses | | | | | | |
| Due to Dry Gas | % | 7 62% | 7 77% | 8 00% | 2 03% | 4 97% |
| Due to Moisture in Fuel | % | 1 03% | 0 91% | 0 77% | -12 44% | -25 90% |
| Due to Combustion of Hydrogen | % | 4 22% | 4 24% | 3 87% | 0 55% | -8 22% |
| Due to Unburned Combustibles (Carbon Loss) | % | 13 77% | 11 34% | 9 12% | -17 60% | -33 76% |
| Due to Radiation Through Boiler Skin | % | 0 81% | 1 03% | 0 90% | 27 97% | 11 46% |
| Unaccounted Losses | % | 1 50% | 1 50% | 1 50% | | |
| Net Efficiency | % | 71 05% | 73 20% | 75 85% | 3 02% | 6 74% |
| Heat Input | Gkal/Hr | 15 58 | 11 69 | 13 78 | -24 99% | -11 58% |
| Heat Output | Gkal/Hr | 11 10 | 8 61 | 10 48 | -22 41% | -5 59% |
| Heat Input | Tons/Hr | 2 55 | 2 18 | 2 43 | -14 51% | -4 70% |
| Collector Inlet Emissions | kg/Hr | 337 66 | 127 59 | 189 46 | -62 21% | -43 89% |
| Collector Inlet Emissions/Heat Input | kg/Gkal | 21 41 | 11 21 | 13 47 | -47 64% | -37 10% |
| Collector Inlet Emissions/Heat Output | kg/Gkal | 30 11 | 15 55 | 17 87 | -48 37% | -40 66% |
| Collector Outlet Emissions | kg/Hr | 35 37 | 15 59 | 31 35 | -55 91% | -11 37% |
| Collector Outlet Emissions/Heat Input | kg/Gkal | 2 24 | 1 33 | 2 27 | -40 40% | 1 66% |
| Collector Outlet Emissions/Heat Output | kg/Gkal | 3 15 | 1 83 | 3 00 | -41 84% | -4 66% |
| Collection Efficiency | % | 89 25% | 87 45% | 82 18% | -2 02% | -7 92% |
| Calculated Collector Inlet Flow | acmm | 772 87 | 598 39 | 694 17 | -22 58% | -10 18% |
| Measured Collector Inlet Flow | acmm | 1,014 75 | 820 00 | 921 33 | -19 19% | -9 21% |
| Calculated Flow Deviation | % | -23 84% | -27 03% | -24 66% | | |