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**EMISSIONS REDUCTIONS IN COAL-FIRED HOME HEATING STOVES
THROUGH USE OF BRIQUETTES**

Quarterly Report:
for the period of January 1, 1995 to March 31, 1995

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DOE Project Officer
Thomas J. Feeley, III

Submitted by:

Acurex Environmental Corporation
4915 Prospectus Drive
P.O. Box 13109
Research Triangle Park, NC 27709

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Document Control Center
Pittsburgh Energy Technology Center
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EXECUTIVE SUMMARY

This period has seen additional briquette testing at Akademia Górniczo Hutnicza (AGH). In addition, Euromining has begun large-scale briquette production. The initial multi-ton batches were delivered as this period ended. Acurex Environmental Corporation has delivered a sampling crew and equipment to Kraków. Testing at INCO Veritas (INCO) has not started due to delays in the delivery of briquettes by Euromining but is expected to begin with the new quarter. Arrangements are in place for the product market testing to begin as soon as the briquettes are available.

INTRODUCTION/BACKGROUND

The work to be performed is part of the program in the Support for Eastern European Democracy (SEED) Act of 1989 (P.L. 101-179). Following the guidance of this legislation, a U.S.-Poland Bilateral Steering Committee (BSC) was established to define the program. The BSC is directing a program in Kraków, Poland that would reduce air pollution produced from about 1,300 boiler houses (that provide heat for industrial, commercial, and residential applications) and 100,000 small home heating stoves. The boiler houses and home heating stoves primarily use solid fossil fuels and have been collectively called "low emissions sources" because of their low stack heights and the consequent low-level entry of flue gases into the ambient air.

In October 1991, a Memorandum of Understanding (MOU) titled "Collaboration on the Kraków Clean Fossil Fuels and Energy Efficiency Program, A Project of Elimination of Low Emission Sources in Kraków" was signed by the U.S. Department of Energy (DOE) and the Ministry of Environmental Protection, Natural Resources and Forestry of the Republic of Poland. This MOU describes the cooperation of the governments of the United States and the Republic of Poland to accomplish this program which is funded through the Agency for International Development (AID).

The purpose of the program is to encourage the formation of commercial ventures between U.S. and Polish firms to provide equipment and/or services to reduce pollution from low emission sources in Kraków, Poland. These commercial ventures may take the form of contracts, joint ventures, partnerships, or any other commercially feasible arrangement that accomplishes the purposes of the statute.

SPECIFIC OBJECTIVES OF THE PROJECT

The objective of the work to be conducted by Acurex Environmental Corporation is to create a commercially successful venture to market a low emission coal briquette to the residential heating market in Kraków. During Phase I, small quantities of the briquetted product will be manufactured and tested. Five Polish coals and two Polish sources of binder material will be tested to determine their amenability to forming briquettes. Small-scale combustion tests will also be performed during Phase I to determine the effectiveness of the briquettes in reducing emissions. A preliminary engineering review of the plant will also be performed. Construction of a new plant in Katowice to serve the Kraków market is being considered.

APPROACH

The approach of Phase I is to develop an optimum briquette formulation using Polish raw materials. This "optimum" is determined by the physical characteristics as well as the ability of the briquette to reduce organic emissions during combustion. This work is being performed at the briquetting and combustion laboratories of Akademia Górniczo Hutnicza (AGH) in Kraków. Once the optimum formulation has been determined during these laboratory experiments, larger quantities will be manufactured at the Brikpol facility of Euromining Consulting in Bogdanka, Poland. These briquettes will be used for marketing studies of the Kraków consumer market, as well as larger-scale combustion tests at INCO Veritas (INCO) and Przedsiębiorstwo Energetyki Ciepłej (PEC) at Chrzanów. Business development will proceed in parallel with research into the Kraków residential heating market, preparations for formation of a joint venture company, and development of a business plan for the new company. Planmar Consulting, Inc. (PCI) will assist Acurex Environmental in its business development activities.

ACCOMPLISHMENTS DURING THE QUARTER

ACCOMPLISHMENTS FOR THIS QUARTER

Accomplishments for this quarter include the following:

- Project oversight trips to Poland by the Project Manager and Planmar representative
- Data review trip to AGH, Kraków, Poland
- Briquette formulation testing continued at AGH
- Combustion testing continued at AGH
- Preparation of first large-scale batches of briquettes by Euromining
- Preparations for testing at INCO Veritas completed
- Investigation of market facts completed
- Progress made on investigating briquette distribution systems
- Work on market strategies continued
- Work on sales and service alternatives started
- Negotiations with potential joint venture partners continued
- Met with the V.P. of the Kraków City Council
- Completed preparations for the home stove product market testing in Kraków
- Completed the first draft of the business plan

COMPLETED DELIVERABLES

Completed deliverables for this quarter include the following:

- Delivered Environmental Questionnaire reformatted for USAID
- Submitted third quarterly report
- Completed first draft of business plan

DISCUSSION

This quarter has been a period of both management and technical progress. Briquetting experimentation and combustion testing continues at AGH. Large-scale briquette production started at Euromining. A sampling crew and equipment has been sent to Kraków for the test programs at INCO Veritas and PEC, Chrzanów. As mentioned in the third quarterly report, a reformatted Environmental Questionnaire was submitted at the beginning of this quarter as a required preliminary to activities at Euromining and INCO.

The Project Manager traveled to Kraków in early March with Euromining the primary focus of the trip. Discussions were held regarding formation of a joint venture during Phase II of this project.

As a result of our concerns over the organic emissions reduction results presented in the third quarterly report, Mr. David Natschke was sent to perform a data review on sampling and analytical procedures at AGH. Appendix A contains the questionnaire used for this review and a trip report memorandum. We have requested that the following procedural modifications and quality assurance tests be performed:

- Requested that a blank stove run be performed. The fuel used will consist of only the kindling material.
- Requested that the use of silicone grease to seal sampling system ball joints be discontinued. Distilled water can be substituted for the grease.
- Requested that a blank filter be extracted and analyzed by the GRAV and TCO procedures.
- Requested that a blank XAD-2 cartridge be extracted and analyzed by the GRAV and TCO procedures.
- Requested that a performance sample be analyzed for the GRAV procedure.
- Requested that a performance sample be analyzed for the TCO procedure.
- Requested that they report the evaporation rate used in the extract concentration step.
- Requested the analysis of a concentration step performance sample by the GRAV and TCO procedures.

- Requested the analysis of a dichloromethane performance sample by the TCO procedure.
- Requested that all future GRAV analyses be performed in duplicate as specified in the protocol.
- Requested that the GRAV procedure be checked for "extract wicking" from the pan.
- Requested that a daily performance sample be implemented for the GRAV procedure.
- Requested that a daily performance sample be implemented for the TCO procedure.
- Requested that the fuel analysis protocols be provided.
- Requested that the cyclone's cut-point be provided.
- Requested that the cyclone and filter capture be reported as separate numbers.
- Requested that previously reported Ms values be recalculated as separate cyclone catch and filter capture numbers.
- Requested that previously reported numbers be recalculated to provide standard deviations in addition to the average value.

During this visit a video tape of the combustion sampling procedure was also obtained. While there, Mr. Natschke requested that a manual, single-point combustion bed temperature be obtained. This was performed on two days of testing while briquettes were being burned. Temperatures of 1,300 and 1,200 °C were recorded. The gauge used had a nominal top end of 1,200 °C so these numbers should not be regarded as absolutes. However, when they are compared to the Zhuang¹ paper, these temperatures are high enough to raise concerns about the probability of success in controlling SO₂ emissions through the use of calcium addition. In Figure 1 of that paper it is shown that as the combustion temperature is raised to 1,200 °C and beyond, calcium sulfate decomposes to release SO₂ captured at lower temperatures. This, of course, is in keeping with the injection of calcium sorbents into lower temperature zones in such processes as LIMB.

¹ Zhuang, Y.H., Shen, D.X., Xiao, P.L.; "Sulfur Fixation During Coal Briquet Combustion"; in *Processing and Utilization of High Sulfur Coals III Coal Science and Technology* 16; R. Markuszewski and T.D. Wheelock eds.; Elsevier Press; 1990.

The briquetting laboratories of Professor Drzymała were also visited. The drop shatter test was again demonstrated, this time for the large briquettes. During this test the number of briquettes is reduced to five and more importantly, the sieve used in the rejection step is changed to a 51 mm diameter hole which does much to explain the relatively low test results that were reported in the last quarter. It is important to note that the rejected pieces are still large enough for residential use and are unlikely to be rejected by a consumer.

The compression strength test was also demonstrated. A briquette and a mechanical force sensor, which is monitored visually, are placed in a motorized press. When the briquette cracks there is an obvious deflection of the sensor's needle. The reading prior to cracking is recorded and converted to newtons using a calibration chart. Ten briquettes are tested and averaged.

Mr. Natschke requested the compression strength tests on a set of cast briquettes that had been prepared by Acurex Environmental. Twelve batches of cast briquettes were prepared using Polish and Chinese coals with Polish and North Carolina clays. In preparing them, clay and water were slurried in a blender. The coal was then added and mixed into the slurry. This mixture was then cast into 1.5- x 1.5-in cylinders and allowed to dry under ambient conditions. It was found that 3 mL of water per gram of clay was appropriate when forming a 1:6 clay to coal briquette. For a 1:4 clay to coal briquette 2 mL of water was used. For certain briquettes a saturated calcium hydroxide solution was substituted for the water.

These results may be found in Table 1. Pressure was applied across the diameter to provide the most stringent comparison. It is encouraging to note that the test results of these small briquettes compare favorably to that of large pressed briquettes. This comparison must be viewed carefully because the results in Table 1 are for a single determination; however, the uniformly good results suggest that they are valid.

Figure 1 provides a quick comparison between the cast and pressed briquette results. The particular points chosen for this graph all contain washed Brzeszcze fines and were mixed with water

rather than the saturated calcium hydroxide solution. We recognize that this is not a fair comparison because the cast results are from a single determination; it does, however, suggest that this is a direction worth pursuing.

Based upon these results we have requested that three batches of cast briquettes be prepared for combustion testing in the ceramic stove. They will be cast as cylinders with a diameter of 30 mm and a length of 50 mm. The requested formulations are:

- Brzeszcze (0-2 mm):Chrzanów 6:1 clay to coal; water
- Brzeszcze (0-2 mm):Chrzanów 4:1 clay to coal; water
- Brzeszcze (0-2 mm):Chrzanów 6:1 clay to coal; Ca(OH)_2 solution

TABLE 1. COMPRESSION STRENGTH RESULTS FOR ACUREX ENVIRONMENTAL CAST BRIQUETTES

Coal	Clay	Ratio	Liquid	Compression Strength (N)
Hong Chong	Chrzanów	6:1	water	320
Hong Chong	Chrzanów	6:1	Ca(OH)_2	355
Hong Chong	Carrboro, N.C.	6:1	water	233
Hong Chong	Carrboro, N.C.	6:1	Ca(OH)_2	270
Hong Chong	Chrzanów	4:1	water	592
Hong Chong	Chrzanów	4:1	Ca(OH)_2	500
Hong Chong	Carrboro, N.C.	4:1	water	375
Hong Chong	Carrboro, N.C.	4:1	Ca(OH)_2	382
Brzeszcze	Chrzanów	6:1	water	462
Brzeszcze	Chrzanów	6:1	Ca(OH)_2	382
Brzeszcze	Chrzanów	4:1	water	495
Brzeszcze	Chrzanów	4:1	Ca(OH)_2	452

Figure 1. Compression strength vs. briquette volume

The requested coal fines sieve analyses have been performed and reported. Unfortunately, certain batches of fines, that were previously used in the preparation of briquette batches, have been exhausted, making size analysis data unavailable. Table 2 presents the sieve analyses results. Figures 2 through 6 present the particle distributions for the five coals. The median particle size differs significantly for these coals. For the washed Brzeszcze fines (0-4 mm) it is found within the 1.6 to 2 mm fraction. For washed Brzeszcze fines (0-2 mm), Siersza, and Janina coals it is found in the 0.63 to 1 mm fraction. For the Bogdanka coal it is found in the 0.25 to 0.4 mm fraction. A similar trend is found when we look at the finest fractions, 0-0.16 mm, where only 4.15 percent of washed Brzeszcze (0-4 mm) is found, 8.4 percent of Janina, 11.3 percent of washed Brzeszcze (0-2 mm), 13.1 percent of Siersza and 33.1 percent of Bogdanka.

TABLE 2. COAL FINES PARTICLE SIZE DISTRIBUTION DATA
PERCENTAGE FOUND

Cut (mm)	Brzeszcze 0-4 mm	Brzeszcze 0-2 mm	Siersza	Bogdanka	Washed Janina
3.15 - 4.0	8.78				
2.50 - 3.15	24.15				
2.00 - 2.50	15.51				
1.60 - 2.00	13.76	5.83	0.05	0.05	4.36
1.00 - 1.60	13.27	29.68	25.97	1.97	31.90
0.63 - 1.00	10.00	21.26	27.97	14.55	26.20
0.40 - 0.63	4.39	12.68	13.89	16.18	13.80
0.25 - 0.40	3.41	11.42	11.74	19.04	9.40
0.16 - 0.25	2.58	7.81	7.24	15.10	5.94
0.075 - 0.16	1.27	3.20	2.60	9.13	1.24
0.045 - 0.075	1.46	4.67	6.04	13.72	4.67
< 0.045	1.42	3.45	4.50	10.26	2.49

Figure 2. Particle size distribution for washed Brzeszcze fines (0-4mm).

Figure 3. Particle size distribution for washed Brzeszcze fines (0-2mm).

Figure 4. Particle size distribution for Siersza fines.

Figure 5. Particle size distribution for Bogdanka fines.

Figure 6. Particle size distribution for washed Jania fines.

During this period, the briquetting laboratory has continued to investigate briquetting formulations and to prepare large (~30 kg) batches for combustion testing. Tables 3 and 4 present the physical test data for briquettes prepared from Brzeszcze fines and a Czech graded coal sludge. Table 5 presents the large batch formulation data and is an extension of Table 11 from the third quarterly.

This Czech graded coal sludge is a material recommended by Euromining for testing. Despite the remoteness of the source from Kraków, it was worth consideration for this program due to a very low price and relatively high heat content. Comparison of Table 4 with Table 3 and previous formulation tests indicates that a relatively strong briquette which ages well can be prepared from this material.

Acurex Environmental's Program Manager provided some of these briquettes (Combustion Batch XVIII, 1100 mm press) to two consumers for informal testing. They reported poor results with these briquettes. According to the consumers, the briquettes were hard to ignite and unable to sustain combustion. When these used briquettes were broken for examination, it was found that only the exterior had burned. Coal had been consumed from approximately one cm of the surface before combustion ceased. This could indicate that better results would be obtained with small sized briquettes. No further testing has been performed with this material to date.

Table 6 presents the fuel analysis data results to date. Tables 7 and 8 present the details of sampling conditions and facility operation during all tests. As in the previous report, each fuel was burned in replicate runs. Each change in fuel was preceded by a stove cleaning and a stove conditioning run with the new fuel. Data acquired during the conditioning run is not included in any calculated averages.

In Table 8 the stove operation times presented are referenced to the time at which ignition occurred. Thus, in test 081101 a portion of the total fuel charge was used for ignition and the remainder was added 5 minutes later ($D\ 1 = 5$). The grating door was closed at the completion of this fuel addition ($GD\ 1 = 5/$). The grating door was reopened 6 minutes later to increase the air flow and

TABLE 3. BRIQUETTE FORMULATION DATA FOR BRZESZCZE FINES
WITH KRAKÓW ADDITIVE; 1100mm PRESS

Briquettes prepared from Coal and Binder						
AGH #	AEC #	Mixing	% Binder	% Water	Drop Shatter Test	
					Immediate	After 48 hr
133		wet slurry	14.3	14.2	98.6	93.1
134		wet slurry	14.3	13.3	99.0	95.3
135		wet slurry	14.3	12.6	98.5	96.2
136		wet slurry	14.3	11.3	98.1	97.4
137		wet slurry	14.3	10.4	96.2	96.9
138		wet slurry	14.3	9.5	89.8	90.9
139		wet slurry	14.3	8.9	78.7	83.2
140		wet slurry	10	13.1	86.8	81.2
141		wet slurry	10	12.3	87.3	83.5
142		wet slurry	10	11.5	85.6	82.9
143		wet slurry	10	10.4	82.1	80.7
144		wet slurry	10	9.9	78.4	74.9
145		wet slurry	10	8.8	62.0	53.5

TABLE 4. BRIQUETTE FORMULATION DATA FOR CZECH FINES
WITH KRAKÓW ADDITIVE

Briquettes prepared from Coal and Binder								
AGH #	AEC #	Mixing	% Binder	% water	Shape	Pressure (MPa)	Drop Shatter Test	
							Immediate	After 48 Hr
146		wet slurry	10	15.9	saddle	4	99.4	97.1
147		wet slurry	10	12.9	saddle	10	99.1	95.3
148		wet slurry	10	11.1	saddle	14	98.9	95.3
149		wet slurry	10	8.6	saddle	44	94.7	98.0

TABLE 5. FORMULATION AND PHYSICAL TEST DATA FOR COMBUSTION BATCHES

Batch	Coal	Fraction	Binder	Binder %	Water %	Size	Dropping resistance (%)		Compression strength (N)
							Green	Aged	Aged
IV	ground Siersza	0-2 mm	Chrzanów	20.0	27.1		98.3	93.9	65
V	ground Wujek	0-2 mm	Chrzanów	14.3	10.7		97.1	91.4	60
VI	ground Wujek	0-2 mm	Kraków	14.3	10.3		96.5	94.2	78
VII	ground Wujek	0-2 mm	Bentonit	14.3	10.5		99.2	91.4	68
VIII	washed Brzeszcze fines	0-2 mm	Kraków	14.3	12.5	small	99.1	94.9	102
IX	washed Brzeszcze fines	0-2 mm	bentonit	7.4	11	small	97.6	96.1	110
X	washed Brzeszcze fines	0-2 mm	Kraków	10	11.8	small	98.9	86.2	83
XI	washed Brzeszcze fines	0-2 mm	Kraków	10	10.7	large	82.8	80.9	335
XII	washed Brzeszcze fines	0-2 mm	glikocel	1	12.7	large	98.9	98.7	848
XIII	washed Brzeszcze fines	0-2 mm	Kraków + glikocel	11	13.5	large	98.1	96.8	314
XIV	washed Brzeszcze fines	0-2 mm	Kraków + bentonit	9.5	12.2	large	92.4	85.5	382
XV	washed Brzeszcze fines	0-2 mm	Kraków	14.3	13.0	large	99.1	95.9	478
XVI	washed Brzeszcze fines	0-4 mm	Chrzanów	14.3	9.3	large	76.1	70.7	171
XVII	washed Brzeszcze fines	0-4 mm	Kraków	14.3	9.2	large	80.5	79.4	214
XVIII	graded coal sludge		Kraków	10	13.2	large	98.2	94.8	469
XIX	washed Brzeszcze fines	0-2 mm	Chrzanów	14.3	9.5	large	94.5	76.2	262
XX	washed Janina fines	0-2 mm	Chrzanów	14.3	24.4	large	99.4	68.7	262
XXI	washed Brzeszcze fines	0-2 mm	Chrzanów	14.3	27.9	cast ¹		36.7	212
COMPARABLE TESTS WITH COAL FINES									
AGH test	Coal	Fraction	Binder	Binder %	Water %	Size	Green	Aged	Aged
87	Siersza fines		Chrzanów	20	27.3		99.4	95.1	127
77	Wujek fines		Chrzanów	14.3	10.5		95.7	94.6	117
110	washed Brzeszcze fines		Bentonit	7.4	10.7			95.7	114
115	washed Brzeszcze fines		Kraków	10	11.7			85.6	86
134	washed Brzeszcze fines	0-2 mm	Kraków	14.3	12.6	large	98.5	96.2	495
137	washed Brzeszcze fines	0-2 mm	Kraków	14.3	10.4	large	96.2	96.9	502

¹ cast size = 30 mm diameter x 50 mm length cylinder

TABLE 6. CHARACTERISTICS OF FUELS USED DURING TESTING

FUEL	Qi [kJ/kg]	St [%]	V [%]	Fuel Composition, mass %						
				C	H	S	N	O	W	A
"Wujek" coal WU-PL washed	31793	0.52	32.10	81.20	4.88	0.33	1.35	6.54	2.7	3.00
"Wujek" coal WU-PL/S chunks	32157	0.48	32.00	81.47	5.13	0.30	1.28	6.02	2.8	3.00
"Wujek" chunk coal average	31975	0.50	32.05	81.335	5.005	0.315	1.315	6.28	2.75	3.00
Briquettes I BR-IS Baranów binder dry mixed	18165	1.05	20.98	45.89	3.06	0.76	0.76	6.70	4.1	38.73
Briquettes I BR-IM Baranów binder wet mixed	18250	1.04	20.77	45.79	3.07	0.70	1.32	6.48	4.4	38.30
Briquettes II BR-IIC Chrzanów binder	20527	0.90	24.41	53.46	3.25	0.36	0.84	7.25	4.0	30.84
Briquettes III BR-IIIC ground Wujek coal Chrzanów (14.3%) binder, 10.7% water wet mixed, *small briquette	25746	0.47	27.47	64.47	4.08	0.23	1.14	7.02	8.7	14.36
Briquettes III BR-IIIK ground Wujek coal Kraków (14.3%) binder, 10.3% water wet mixed, small briquette	26608	0.50	27.36	66.95	4.18	0.29	1.24	6.56	8.2	12.58
Briquettes III BR-IIIB ground Wujek coal Bentonit (14.3%) binder, 10.5% water wet mixed, small briquette	25648	0.37	26.31	65.43	4.22	0.28	1.17	5.42	8.5	14.98
Washed Brzeszcze fines	27252	0.7	29.9	68.74	4.4	0.63	1.24	7.99	3.4	13.6
Briquettes IV BR-IVK washed Brzeszcze fines Kraków (14.3%) binder, 12.5% water wet mixed, small briquette	22628	0.62	25.31	58.13	3.92	0.45	1.19	6.05	10.0	20.26

FUEL	Qi [kJ/kg]	St [%]	V [%]	Fuel Composition, mass %						
				C	H	S	N	O	W	A
Briquettes IV BR-IVB washed Brzeszcze fines Bentonit (8%) binder, 11.0% water wet mixed, small briquette	25677	0.58	27.91	63.56	4.25	0.54	1.24	8.11	4.1	18.2
Briquettes BR-VBB washed Brzeszcze fines Kraków (10%) binder, 11.8% water small briquette	24952	0.63	27.45	62.61	3.92	0.49	1.17	6.74	6.31	18.76
Briquettes BR-VIBB washed Brzeszcze fines Kraków (10%) binder, 10.7% water large briquette	24155	0.63	27.96	64.02	4.25	0.58	1.23	7.98	4.26	17.68
Briquettes BR-VIIBG washed Brzeszcze fines Glikocel (1%) binder, 12.7% water large briquette	26542	0.64	25.76	62.98	4.18	0.61	1.18	7.75	9.09	14.21
Briquettes BR-VIIBK washed Brzeszcze fines Kraków (10%) + Glikocel (1%) binder 13.5% water large briquette	23589	0.71	27.15	62.68	4.22	0.64	1.17	6.83	5.06	19.39
Briquettes BR-VIIBK washed Brzeszcze fines Kraków (14.3%) binder 13.0% water large briquette	23385	0.75	26.21	59.54	3.94	0.6	1.11	6.71	5.55	22.55
Briquettes BR-VIIBC washed Brzeszcze fines (0-4 mm) Chrzanów (14.3%) binder 9.3% water large briquette	24034	0.73	26.18	60.59	3.71	0.3	1.05	7.16	4.66	22.53
Briquettes BR-IXBK washed Brzeszcze fines (0-4 mm) Kraków (14.3%) binder 9.2% water large briquette	24377	0.69	25.19	61.76	3.9	0.49	1.16	6.39	4.07	22.23

(continued)

FUEL	Q _i [kJ/kg]	S _t [%]	V [%]	Fuel Composition, mass %						
				C	H	S	N	O	W	A
Chunk Brzeszcze coal	29268	0.31	30.44	73.9	4.72	0.3	1.21	8.02	5.74	6.11

Where: C,H,S,N,O,W,A—respectively: carbon, hydrogen, combustible sulfur, nitrogen, oxygen, moisture content, ash

Q_i—fuel heating value

S_t—total sulfur

V—volatile content

* "small briquette" indicates preparation on the 450-mm press

‡ "large briquette" indicates preparation on the 1100-mm press

TABLE 7. MASS OF FUEL COMPONENTS, UNBURNT MATERIALS
AND AMBIENT THERMODYNAMIC PARAMETERS

FUEL	Test No.	Mass of fuel added	Kindling	Previous run unburnt fuel retained	Mass of unburnt fuel (grating)	Mass of ash pit residue generated	Atmospheric conditions		
		Mw [kg]	Md [kg]	Mk [kg]	Mkd [kg]	Ma [kg]	to [deg.C]	Po [Pa]	fio [%]
"Wujek" coal WU-PL washed	081101	4.006	0.174	0	0.424	0.360	22	98000	67
	081202	4.002	0.186	0.424	0.376	0.326	21	98300	60
	081303	4.002	0.168	0.376	0.414	0.332	21	95000	63
	081404	4.001	0.166	0.414	0.350	0.316	20	99000	46
Briquettes I BR-IS Baranów binder dry mixed	081705	5.890	0.170	0	2.270	0.768	19	98700	58
	081806	5.888	0.182	1.860	4.000	0.766	19	98100	62
	081907	5.890	0.170	2.066	4.330	0.518	18	98000	53
Briquettes I BR-IM Baranów binder wet mixed	082008	6.452	0.160	0	2.900	0.466	18	98200	62
	082109	6.456	0.172	1.388	4.160	0.564	18	99000	56
	082210	6.450	0.158	3.884	5.738	0.958	18	99100	62
Briquettes II BR-IIC Chrzanów binder	082511	5.890	0.158	0	2.174	0.822	20	98000	56
	082612	5.882	0.162	2.174	2.804	1.714	19	98000	63
	082713	5.890	0.170	2.682	3.054	1.246	19	98900	62
Briquettes III BR-IIIC ground "Wujek" Chrzanów binder	091914	4.822	0.168	0	0.514	0.756	15	99200	51
	092015	4.814	0.158	0.514	1.008	0.756	16	98000	67
	092116	4.822	0.166	1.008	1.142	0.912	17	98200	65
	092217	4.822	0.162	1.142	0.998	0.922	17	99300	64
Briquettes III BR-IIIK ground "Wujek" Kraków binder	092318	4.492	0.168	0	0.524	0.562	18	100000	62
	092419	4.492	0.166	0.524	0.484	0.598	18	99400	63
	092520	4.492	0.168	0.484	0.864	0.694	18	99000	62
Briquettes III BR-IIIB ground "Wujek" Bentonit binder	100321	4.652	0.166	0	0.932	0.556	16	97500	71
	100422	4.694	0.162	0.932	1.302	0.754	16	98600	59
	100523	4.694	0.162	1.302	1.144	0.946	16	99500	55
	100624	4.694	0.162	1.144	1.292	0.500	16	100400	47

(continued)

FUEL	Test No.	Mass of fuel added	Kindling	Previous run unburnt fuel retained	Mass of unburnt fuel (grating)	Mass of ash pit residue generated	Atmospheric conditions		
		Mw [kg]	Md [kg]	Mk [kg]	Mkd [kg]	Ma [kg]	to [deg.C]	Po [Pa]	fio [%]
Briquettes IV BR-IVK "Brzeszcze" fines Kraków binder	100725	5.266	0.164	0	0.956	0.934	15	99600	49
	100826	5.264	0.168	0.956	1.610	1.044	14	99600	53
	100926	5.264	0.164	1.610	1.940	1.174	13	99000	56
Briquettes IV BR-IVB "Brzeszcze" fines Bentonit binder	101828	5.000	0.164	0	0.624	0.900	17	99800	37
	101929	4.830	0.164	0.624	0.870	1.054	16	99700	30
	102030	4.828	0.158	0.870	1.182	1.094	16	99400	33
	102131	4.832	0.164	1.182	1.322	1.052	16	99400	36
"Wujek" coal WU-PL (repeat run)	102535	4.004	0.166	0	0.348	0.304	18	98000	57
	102636	4.006	0.162	0.348	0.664	0.358	18	98000	47
	102737	4.008	0.162	0.664	0.500	0.422	18	98700	48
Briquettes BR-VBB "Brzeszcze" fines Kraków binder small	110738	4.932	0.162	0	0.55	0.96	15	98800	40
	110839	4.96	0.162	0.55	1.088	0.992	17	98600	47
	110940	4.96	0.164	1.088	1.338	1.104	18	98600	50
	111041	3.904	0.164	1.338	1.482	0.848	18	98400	42
Briquettes BR-VIBB "Brzeszcze" fines Kraków binder large	111142	4.964	0.164	0	1.704	0.46	17	98700	39
	111243	4.932	0.164	1.704	1.826	1.062	16	99300	34
	111344	4.96	0.164	1.826	1.448	1.294	15	99600	29
Briquettes BR-VIIBG "Brzeszcze" fines Glikocel binder large	111845	4.452	0.162	0	1.016	0.498	17	98000	44
	111946	4.672	0.164	1.016	0.748	0.918	16	99100	43
	112047	4.756	0.162	0.742	0.952	0.776	15	96000	38
	112148	4.756	0.162	0.952	0.8	0.898	17	99200	45
Briquettes BR-VIIBK "Brzeszcze" fines Kraków + Glikocel binder large	112249	5.05	0.162	0	0.592	0.792	18	100000	45
	112350	5.06	0.162	0.592	0.886	1.074	16	100000	40
	112451	5.068	0.164	0.886	0.966	1.158	17	99400	43

(continued)

FUEL	Test No.	Mass of fuel added	Kindling	Previous run unburnt fuel retained	Mass of unburnt fuel (grating)	Mass of ash pit residue generated	Atmospheric conditions		
		Mw [kg]	Md [kg]	Mk [kg]	Mkd [kg]	Ma [kg]	to [deg.C]	Po [Pa]	fio [%]
Briquettes BR-VIIBK "Brzeszcze" fines Kraków binder large	010759	5.314	0.162	0	1.768	0.648	13	100100	33
	010860	5.294	0.162	1.768	2.254	1.256	13	100500	34
	010961	5.314	0.162	2.254	3.01	1.156	13	99200	32
Briquettes BR-VIIBC "Brzeszcze" fines Chrzanów binder large	012262	5.304	0.164	0	2.31	0.476	12	98400	34
	012363	5.318	0.162	2.31	1.78	1.498	14	97400	48
	012464	5.306	0.162	1.78	1.994	1.354	15	97600	44
	012565	5.318	0.16	1.994	1.88	1.482	16	97600	39
Briquettes BR-IXBK "Brzeszcze" Kraków binder large	020766	5.354	0.164	0	2.212	0.548	16	97700	46
	020867	5.296	0.168	2.212	2.722	1.294	16	97200	47
	020968	5.328	0.164	2.722	2.2	1.822	16	97400	35
	021069	5.312	0.162	2.2	2.638	1.374	15	98500	30
"Brzeszcze" chunk	030570	4.064	0.162	0	0.66	0.364	15	98000	43
	030671	4.06	0.162	0.66	0.524	0.432	15	97500	43
	030772	4.062	0.166	0.524	0.48	0.454	17	98600	40
	030873	4.064	0.162	0.48	0.246	0.408	17	98500	36

Where: to, po, fio—temperature, pressure, and relative air humidity, respectively

TABLE 8. STOVE OPERATION TIMES REFERENCED TO TIME OF IGNITION

FUEL	Test No.	Fuel additions D [min]				Agitation RU [min]						Grating door operations GD z/o [min]			Stove closure PZ [min]
		1	2	3	4	1	2	3	4	5	6	1	2	3	
"Wujek" coal WU-PL washed	081101	5	-	-	-	28	-	-	-	-	-	5/11	45/-	-	45
	081202	5	-	-	-	32	-	-	-	-	-	32/-	-	-	48
	081303	5	-	-	-	31	-	-	-	-	-	45/-	-	-	50
	081404	6	-	-	-	32	-	-	-	-	-	47/-	-	-	51
Briquettes I BR-IS Baranów binder dry mixed	081705	2	6	-	-	21	28	31	35	-	-	31/35	37/-	-	37
	081806	3	5	14	18	27	32	35	39	44	-	49/-	-	-	50
	081907	3	6	10	23	22	35	40	43	47	-	51/-	-	-	51
Briquettes I BR-IM Baranów binder wet mixed	082008	3	7	-	-	22	27	32	37	42	-	47/-	-	-	47
	082109	2	8	14	-	26	35	41	45	-	-	47/-	-	-	47
	082210	3	8	17	22	17	35	38	44	-	-	47/-	-	-	47
Briquettes II BR-IIC Chrzanów binder	082511	2	7	-	-	23	28	32	-	-	-	23/23	32/32	41/-	41
	082612	3	8	12	-	33	39	46	-	-	-	46/48	52/-	-	52
	082713	2	8	16	-	31	36	43	46	61	72	84/-	-	-	84
Briquettes III BR-IIIC ground "Wujek" Chrzanów binder	091914	2	8	-	-	22	29	32	57	-	-	37/37	57/-	-	58
	092015	2	9	-	-	23	33	-	-	-	-	43/-	-	-	53
	092116	4	10	-	-	25	36	44	-	-	-	48/-	-	-	58
	092217	4	10	-	-	28	40	49	-	-	-	55/-	-	-	65
Briquettes III BR-IIIC ground "Wujek" Kraków binder	092318	6	12	-	-	27	35	-	-	-	-	36/-	-	-	49
	092419	3	9	-	-	25	34	40	-	-	-	42/-	-	-	57
	092520	3	9	-	-	25	34	41	-	-	-	41/-	-	-	51
Briquettes III BR-IIIB ground "Wujek" Bentonit binder	100321	3	11	-	-	27	39	-	-	-	-	41/-	-	-	47
	100422	2	8	-	-	22	31	37	41	-	-	41/-	-	-	52
	100523	2	8	-	-	24	36	-	-	-	-	47/-	-	-	57
	100624	2	9	-	-	24	30	41	-	-	-	41/-	-	-	52
Briquettes IV BR-IVK "Brzeszcze" fines Kraków binder	100725	3	9	-	-	30	36	50	-	-	-	50/-	-	-	60
	100826	2	9	-	-	25	34	41	-	-	-	41/-	-	-	49
	100927	3	10	-	-	32	40	45	-	-	-	45/-	-	-	56

(continued)

FUEL	Test No.	Fuel additions D [min]				Agitation RU [min]						Grating door operations GD z/o [min]			Stove closure PZ [min]
		1	2	3	4	1	2	3	4	5	6	1	2	3	
Briquettes IV BR-IVB "Brzeszcze" fines Bentonit binder	101828	3	10	-	-	23	30	37	-	-	-	44/-	-	-	53
	101929	2	9	-	-	23	29	39	-	-	-	44/-	-	-	51
	102030	2	9	-	-	21	29	38	-	-	-	43/-	-	-	50
	102131	3	9	-	-	22	28	35	-	-	-	41/-	-	-	51
"Wujek" coal WU-PL (repeat run)	102535	5	-	-	-	33	-	-	-	-	-	44/-	-	-	49
	102636	4	-	-	-	30	-	-	-	-	-	42/-	-	-	48
	102737	5	-	-	-	31	-	-	-	-	-	42/-	-	-	49
Briquettes BR-VBB "Brzeszcze" fines Kraków binder small	110738	2	8	-	-	25	33	39	-	-	-	41/-	-	-	51
	110839	2	8	-	-	22	28	33	-	-	-	38/-	-	-	49
	110940	3	10	-	-	26	31	36	-	-	-	43/-	-	-	53
	111041	2	8	-	-	23	28	33	-	-	-	36/-	-	-	48
Briquettes BR-VIBB "Brzeszcze" fines Kraków binder large	111142	3	8	-	-	15	27	36	42	-	-	8/-	-	-	47
	111243	3	9	-	-	15	35	43	49	-	-	9/-	-	-	58
	111344	3	10	-	-	19	34	42	50	-	-	3/-	-	-	61
Briquettes BR-VIIBG "Brzeszcze" fines Glikocel binder large	111845	3	-	-	-	9	27	36	42	-	-	3/-	-	-	49
	111946	4	10	-	-	34	44	54	-	-	-	4/-	-	-	61
	112047	4	21	-	-	30	39	48	-	-	-	0/-	-	-	60
	112148	3	9	-	-	18	36	42	52	-	-	3/-	-	-	62
Briquettes BR-VIIBK "Brzeszcze" fines Kraków + Glikocel binder large	112249	3	11	-	-	25	37	44	52	-	-	3/-	-	-	55
	112350	4	11	-	-	31	40	48	56	-	-	4/-	-	-	61
	112451	3	9	-	-	31	42	51	-	-	-	3/-	-	-	60
Briquettes BR-VIIBK "Brzeszcze" fines Kraków binder large	010759	3	13	-	-	28	36	46	-	-	-	3/-	-	-	51
	010860	3	10	-	-	28	33	44	52	-	-	3/-	-	-	59
	010961	3	10	-	-	29	37	43	49	-	-	3/-	-	-	61
Briquettes BR-VIIBC "Brzeszcze" fines Chrzanów binder large	012262	3	10	-	-	17	24	27	49	-	-	3/-	-	-	62
	012363	3	9	-	-	14	23	35	42	57	-	3/-	-	-	74
	012464	3	12	23	-	16	32	41	48	57	-	3/28	31/-	-	71
	012565	4	12	-	-	12	22	34	41	48	-	4/-	-	-	68

FUEL	Test No.	Fuel additions D [min]				Agitation RU [min]						Grating door operations GD z/o [min]			Stove closure PZ [min]
		1	2	3	4	1	2	3	4	5	6	1	2	3	
Briquettes BR-IXBK "Brzeszcze" fines Krakow binder large	020766	4	9	-	-	27	35	41	49	57	66	4/15	17/-	-	77
	020867	4	12	-	-	21	29	37	49	55	66	4/-	-	-	75
	020968	4	11	-	-	36	45	58	-	-	-	4/-	-	-	75
	021069	3	10	-	-	23	35	46	-	-	-	3/-	-	-	66
"Brzeszcze" chunk	030570	5	-	-	-	36	-	-	-	-	-	5/-	-	-	52
	030671	5	-	-	-	35	-	-	-	-	-	5/-	-	-	51
	030772	5	-	-	-	35	-	-	-	-	-	5/-	-	-	51
	030873	5	-	-	-	30	-	-	-	-	-	5/-	-	-	47

where: D - fuel loading; RU - grate cleaning; GC z/o - time of closing/opening of upper stove door
PZ - time of closing of the stove (equivalent to closing ash-pit door)

left open until the end of the run (GD 1 = /11 and GD 2 = 45/). At 28 minutes past ignition (RU 1 = 28) a poker was used to disturb the accumulated ash. Combustion was discontinued at 45 minutes past ignition by closing the stove (PZ = 45 and GD 2 = 45/). For GD entries numbers preceding the / indicate a grating door closure. Note that the last GD entry always precedes the / whether it is simultaneous with stove closure or precedes it as in test 081102. Stove closure requires the shutting of the ash pit door and will also include a shutting of the grating door unless this has already occurred.

Table 9 presents the results of particulate capture and impinger sample analysis along with combustible analysis on the ash pit and grating residues. As described in the third quarterly, Meo was not performed from Test No. 091914. Table 10 presents the integrated reactive gas emissions for the individual runs along with the calculated stove efficiency for each run and the loss factors used in that calculation.

Table 11 presents reactive gas, particulate, and stove efficiencies on a per kg of fuel basis and averaged across the individual tests; whereas Table 12 presents the same data calculated on a per MJ energy basis.

Finally, Table 13 presents the available GRAV and TCO data. Table 14 summarizes the combustion tests in terms of stove efficiency and "Equivalent Emission."² Equivalent Emission (EE) is a calculated value from the Polish Ministry of Environmental Protection which is based upon particulate, CO, NO_x, and SO₂. The results in Table 14 are divided between chunk coals, glikocel-based briquettes (BR-7BG and BR-7BK), and Acurex Environmental style briquettes. The chunk coals are at the top of this table and include results for both Wujek and Brzeszcze coals. These results are quite similar with Equivalent Emissions of 3.4 g/MJ and stove efficiencies between 69 and 71 percent.

² P. Cyklis, J. Kowalski, J. Króll, A. Włodkowski, A. Zachkowski, J. Boroń, T. Butcher; "Characteristics of Kraków's Boiler Population"; pp. 111-122; Plzeň Proceedings Conference on Alternatives for Pollution Control from Coal-Fired Low Emissions Sources, Plzeň, Czech Republic; April 26-28, 1994.

TABLE 9. RESULTS OF PARTICULATE CAPTURE, IMPINGER AND COMBUSTIBLE CONTENTS ANALYSES

FUEL	Test No.	Particulate capture Ms [g]	Impingers organics Meo [g]	Impingers inorganics Men [g]	Ash pit combustibles Ca [%]	Grating residue combustibles Ck [%]
"Wujek" coal WU-PL washed	081101	-	-	-	-	88.0
	081202	62.24	6.87	4.900	57.4	
	081303	58.41	5.70	3.460	59.3	
	081404	66.60	6.39	3.400	58.8	
Briquettes I BR-IS Baranów binder dry mixed	081705	-	-	-	-	30.8
	081806	27.59	11.35	3.460	17.7	
	081907	26.46	10.87	2.930	14.6	
Briquettes I BR-IM Baranów binder wet mixed	082008	24.67	9.14		14.9	30.5
	082109	23.59	7.47		18.9	
	082210	28.07	11.89		10.9	
Briquettes II BR-IIC Chrzanów binder	082511	35.78	8.30		19.9	38.3
	082612	29.86	7.65		21.2	
	082713	29.15	8.36		22.2	
Briquettes III BR-IIIC ground "Wujek" Chrzanów binder	091914	-	-	-	-	73.0
	092015	34.28		6.032	29.1	
	092116	34.94		4.061	30.9	
	092217	42.11		5.196	29.8	
Briquettes III BR-IIIK ground "Wujek" Kraków binder	092318	51.01		4.005	24.8	78.5
	092419	52.80		5.671	20.5	
	092520	44.74		5.312	37.2	
Briquettes III BR-IIIB ground "Wujek" Bentonit binder	100321	-		-	33.0	73.5
	100422	54.35		5.792	27.0	
	100523	46.65		4.061	32.5	
	100624	55.90		2.993	29.9	

(continued)

FUEL	Test No.	Particulate capture Ms [g]	Impingers organics Meo [g]	Impingers inorganics Men [g]	Ash pit combustibles Ca [%]	Grating residue combustibles Ck [%]
Briquettes IV BR-IVK "Brzeszcze" fines Kraków binder	100725	30.50		3.881	28.7	64.5
	100826	30.76		3.763	23.9	
	100927	44.08		2.092	23.9	
Briquettes IV BR-IVB "Brzeszcze" fines Bentonit binder	101828	-			-	66.3
	101929	59.55		4.897	27.6	
	102030	49.45		6.091	25.3	
	102131	57.7		5.672	25.5	
"Wujek" coal WU-PL (repeat run)	102535	61.39		7.653	66.3	89.4
	102636	69.52		5.139	73.8	
	102737	72.99			71.7	
Briquettes BR-VBB Brzeszcze Kraków binder small	110738	-	-	-	-	63.4
	110839	45.03		4.72	27.3	
	110940	54.35		2.45	26.0	
	111041	37.45		2.75	26.9	
Briquettes BR-VIBB Brzeszcze Kraków binder large	111142	37.63		3.46	23.8	64.6
	111243	43.96		2.57	27.4	
	111344	57.70		2.93	20.9	
Briquettes BR-VIIBG Brzeszcze Glikocel binder large	111845	-		-	-	67.4
	111946	39.78		7.88	20.5	
	112047	50.77		5.25	21.4	
	112148	44.74		6.27	21.8	
Briquettes BR-VIIBK Brzeszcze Kraków + Glikocel binder large	112249	41.39		5.08	11.6	60.4
	112350	31.83		4.71	20.9	
	112451	39.90		3.28	18.4	
Briquettes BR-VIIBK Brzeszcze Kraków binder large	010759	27.71			21.7	59.2
	010860	36.25			24.5	
	010961	35.11			22.7	

(continued)

FUEL	Test No.	Particulate capture Ms [g]	Impingers organics Meo [g]	Impingers inorganics Men [g]	Ash pit combustibles Ca [%]	Grating residue combustibles Ck [%]
Briquettes BR-VIII BC Brzeszcze Chrzanów binder large	012262	-	-	-	-	60.6
	012363	35.61			21.9	
	012464	34.58			16.1	
	012565	40.49			19.7	
Briquettes BR-IX BK Brzeszcze Kraków binder large	020766	-	-	-	-	60.3
	020867	34.94			29.3	
	020968	40.14		5.61	28.1	
	021069	41.15			30.2	
Brzeszcze	030570	-			-	83.7
	030671	67.25			47.8	
	030772	64.15			51.7	
	030873	65.64			64.2	

TABLE 10. RESULTS OF GAS EMISSION CALCULATIONS, STACK LOSSES,
AND STOVE EFFICIENCY

FUEL	Test No.	CO ₂ [g]	CO [g]	CH ₄ [g]	SO ₂ [g]	NO _x [g]	Sw [%]	Su [%]	Sn [%]	et [%]
"Wujek" coal WU-PL washed	081101	9819.9	128.1	22.6	32.3	9.2	17.30	1.90	16.80	64.0
	081202	11436.8	190.8	17.8	29.3	10.1	19.10	2.00	13.80	65.1
	081303	11102.1	82.4	6.6	24.3	10.7	19.10	0.80	14.90	65.2
	081404	11442.3	136.5	15.8	35.2	9.7	20.60	1.50	13.40	64.5
Briquettes I BR-IS Baranów binder dry mixed	081705	7095.4	93.8	15.5	45.2	8.3	34.60	1.60	26.00	37.8
	081806	7254.2	109.7	20.4	42.8	8.1	16.60	1.70	36.00	45.7
	081907	7238.1	125.7	31.6	47.7	7.9	16.20	1.80	37.10	44.9
Briquettes I BR-IM Baranów binder wet mixed	082008	7486.4	81.9	14.3	52.1	8.3	17.60	1.30	27.60	53.5
	082109	7521.6	79.2	12.6	47.3	8.6	15.90	1.10	35.20	47.8
	082210	8498.5	129.6	19.8	41.3	8.2	14.30	1.40	39.80	44.5
Briquettes II BR-IIC Chrzanów binder	082511	7989.3	96.7	10.8	46.0	7.8	16.40	1.20	28.40	54.0
	082612	9441.4	81.2	12.0	53.3	9.2	16.00	0.90	32.90	50.2
	082713	10173.5	104.8	12.5	82.0	9.5	18.90	1.10	31.60	48.4
Briquettes III BR-IIIC ground "Wujek" Chrzanów binder	091914	9310.6	98.0	10.0	34.4	6.9	17.84	1.18	17.03	64.0
	092015	9356.6	59.7	6.4	32.1	8.6	17.21	0.67	24.14	58.0
	092116	10128.2	55.0	5.9	37.7	9.2	16.62	0.56	25.72	57.1
	092217	10867.2	77.7	9.5	38.0	9.0	19.23	0.82	22.88	57.1
Briquettes III BR-IIIC ground "Wujek" Kraków binder	092318	8747.6	103.8	11.0	33.5	7.9	17.22	1.31	16.71	64.8
	092419	10426.6	115.9	15.1	43.1	8.7	18.47	1.42	13.84	66.3
	092520	8750.8	76.4	8.5	32.0	8.1	19.15	0.89	24.65	55.3
Briquettes III BR-IIIB ground "Wujek" Bentonit binder	100321	8041.3	108.9	17.7	18.9	8.4	17.64	1.63	25.59	55.1
	100422	9564.9	91.6	14.0	22.6	8.7	17.79	1.12	28.2	52.9
	100523	10640.5	82.7	11.3	31.7	9.9	18.73	0.9	26.09	54.3
	100624	10357.5	107.3	13.9	30.4	9.1	22.63	1.18	25.87	50.3
Briquettes IV BR-IVK "Brzeszcze" fines Kraków binder	100725	8125.4	84.3	14.0	43.7	10.2	21.34	1.28	25.49	51.9
	100826	8910.2	88.2	14.9	48.4	9.6	18.74	1.15	31.36	48.8
	100927	9510.9	79.2	14.9	56.0	11.4	21.1	0.99	34.07	43.8

(continued)

FUEL	Test No.	CO ₂ [g]	CO [g]	CH ₄ [g]	SO ₂ [g]	NO _x [g]	Sw [%]	Su [%]	Sn [%]	et [%]
Briquettes IV BR-IVB "Brzeszcze" fines Bentonit binder	101828	9263.1	116.3	18.7	60.8	9.7	21.04	1.62	18.69	58.7
	101929	9628.1	130.0	21.8	58.4	8.6	19.14	1.71	22.37	56.8
	102030	9542.8	112.9	16.2	54.3	8.5	18.53	1.34	25.79	54.3
	102131	9982.3	90.4	12.1	50.5	8.9	17.45	0.99	26.62	54.9
"Wujek" coal WU-PL (repeat run)	102535	10076.9	75.7	7.0	26.9	10.2	21.7	0.79	14.99	62.5
	102636	9914.6	100.4	9.9	27.8	9.6	19.33	0.99	22.39	57.3
	102737	11343.8	113.5	8.3	30.4	9.7	18.73	0.96	18.59	61.7
Briquettes BR-VBB "Brzeszcze" fines Kraków binder small	110738	9185.5	74.7	12.6	51.3	10.5	20.6	1.1	17.6	60.7
	110839	9228.4	79.2	13.7	48.2	9.1	17.7	1.1	24.7	56.6
	110940	9805.3	79	10.8	49.1	9.9	18	0.9	27	54.2
	111041	7904.6	47	6.7	37.6	8.3	18.7	0.6	31.8	48.9
Briquettes BR-VIBB "Brzeszcze" fines Kraków binder large	111142	7331.1	49.1	6	36.1	11.2	22	0.7	34.6	42.8
	111243	10324.7	67.8	8.1	55.9	11	22.6	0.7	32.3	44.4
	111344	11601	63.6	7.1	56.4	11.4	22.1	0.6	26.4	50.9
Briquettes BR-VIIBG "Brzeszcze" fines Glikocel binder large	111845	7488.7	41.1	2.8	37.9	11.4	25	0.5	23.3	51.3
	111946	10876.8	27.3	6.8	54.6	11.2	22.6	0.4	16.6	60.4
	112047	9923.1	69	7.1	52.6	11.8	24.4	0.7	20	54.9
	112148	10738.1	45.2	4.9	59.2	13.1	26.8	0.5	17.6	55.1
Briquettes BR-VIIBK "Brzeszcze" fines Kraków + Glikocel binder large	112249	10040.5	53.1	7.3	47.7	12.4	29.8	0.7	13.7	55.8
	112350	10292.5	43.2	5.8	53	14	26.5	0.5	20	52.9
	112451	10799.2	46.6	5.5	58.2	12.5	29.1	0.5	20.2	50.1
Briquettes BR-VIIBK "Brzeszcze" fines Kraków binder large	010759	7397.3	76	5.3	42.7	11.2	18.4	0.8	32.5	48.3
	010860	9498.6	56.7	7.1	65.9	12.7	14.8	0.6	35.2	49.4
	010961	9123	60.8	11.3	53.4	13.2	13.4	0.7	41	44.9
Briquettes BR-VIIBC "Brzeszcze" fines Chrzanów binder large	012262	6424.5	130.8	12.8	33.7	0.5	18.1	1.5	39.9	40.5
	012363	11915.2	65.9	12.9	78.7	13.7	16.1	0.7	27.5	55.7
	012464	10639.7	71.8	12.9	59.8	10.6	16.4	0.8	29.7	53.1
	012565	11099.3	52.9	7.8	62.3	11.3	15.5	0.5	29.1	54.9

(continued)

FUEL	Test No.	CO ₂ [g]	CO [g]	CH ₄ [g]	SO ₂ [g]	NO _x [g]	Sw [%]	Su [%]	Sn [%]	et [%]
Briquettes BR-IXBK "Brzeszcze" fines Kraków binder large	020766	6761.4	126.6	16.6	36.6	10.6	18	1.5	39.1	41.4
	020867	9611.1	67.4	12.1	57.2	12.2	15.8	0.7	39.4	44.1
	020968	11446	62.3	10.6	68	12.2	15.5	0.6	33.9	50
	021069	9640.9	44.5	6.9	55.2	11.4	13.5	0.5	39.2	46.9
Chunk Brzeszcze coal	030570	8268.3	70.6	4.9	20.1	12.6	18.2	0.8	22.8	58.2
	030671	10671.4	98.8	16.6	26.5	12.3	17.9	1.3	17.3	63.5
	030772	10304	76.3	8.2	20.6	12.1	18.7	0.9	17.4	63
	030873	10759.6	76.4	10.6	14.8	10.6	19.9	1	13.4	65.8

Where: Sw—physical loss; Su—chemical loss; Sn—incomplete combustion loss;
et—stove efficiency in single test

TABLE 11. GAS AND DUST EMISSION PER 1 kg OF FUEL AND STOVE EFFICIENCY FOR ENTIRE SERIES OF TESTS

FUEL	CO ₂ [g/kg]	CO [g/kg]	CH ₄ [g/kg]	SO ₂ [g/kg]	NO _x [g/kg]	Ms [g/kg]	Meo [g/kg]	Men [g/kg]	Ma [g/kg]	e [%]
"Wujek" coal WU-PL washed	2830.6	34.13	3.35	7.40	2.54	15.59	1.58	0.98	81.1	70.4
"Wujek" coal WU-PL/S (repeat run)	2607.4	24.09	2.10	7.08	2.45	16.97			90.2	69.1
"Wujek" chunk coal average	2719.0	29.11	2.725	7.24	2.495	16.28	1.58	0.98	85.65	69.75
Briquettes I BR-IS Baranów binder dry mixed	1230.5	19.98	4.42	7.69	1.36	4.59	1.89	0.54	109.0	59.6
Briquettes I BR-IM Baranów binder wet mixed	1214.3	15.02	2.41	7.26	1.30	3.94	1.47		102.7	63.3
Briquettes II BR-IIC Chrzanów binder	1562.9	16.00	2.00	10.27	1.50	5.37	1.38		214.1	66.7
Briquettes III BR-IIIC ground "Wujek" Chrzanów binder	2099.3	13.31	1.51	7.46	1.85	7.70		1.06	179.1	71.4
Briquettes III BR-IIIK ground "Wujek" Kraków binder	2072.2	21.97	2.57	8.06	1.83	11.02		1.11	137.6	72.6
Briquettes III BR-IIIB ground "Wujek" Bentonit binder	2170.4	19.99	2.78	6.01	1.97	11.15		0.91	156.2	68.9
Briquettes IV BR-IVK "Brzeszcze" fines Kraków binder	1680.8	15.94	2.77	9.38	1.98	6.67		0.62	199.6	66.9
Briquettes IV BR-IVB "Brzeszcze" fines Bentonit binder	2011.9	23.00	1.74	5.87	2.04	11.49		1.15	220.8	69.4

(continued)

FUEL	CO ₂ [g/kg]	CO [g/kg]	CH ₄ [g/kg]	SO ₂ [g/kg]	NO _x [g/kg]	Ms [g/kg]	Meo [g/kg]	Men [g/kg]	Ma [g/kg]	e [%]
Briquettes BR-VBB "Brzeszcze" fines Kraków binder small	1948.7	14.84	2.26	9.76	1.97	9.90		0.72	212.9	69.7
Briquettes BR-VIBB "Brzeszcze" fines Kraków binder large	1969.4	12.15	1.43	9.99	2.26	9.38		0.60	189.6	64.7
Briquettes BR-VIIBG "Brzeszcze" fines Glikocel binder large	2223.5	9.98	1.33	11.73	2.55	9.54		1.37	182.7	66.7
Briquettes BR-VIIBK "Brzeszcze" fines Kraków + Glikocel binder large	2051.1	9.41	1.23	10.47	2.56	7.45		0.86	199.2	62.6
Briquettes BR-VIIBK "Brzeszcze" fines Kraków binder large	1634.1	12.15	1.49	10.17	2.33	6.22		0.79	192.2	73.4
Briquettes BR-VIIBC "Brzeszcze" fines Chrzanów binder large	2111	11.96	2.11	12.6	2.23	6.94		0.91	271.9	73
Briquettes BR-IXBK "Brzeszcze" fines Kraków binder large	1926.3	10.93	1.86	11.32	2.25	7.29			281.8	70
Chunk Brzeszcze coal	2604.2	20.64	2.9	5.08	2.87	16.17			106.2	70.7

Where: e—stove efficiency in series of tests (for particular fuel)

TABLE 12. GAS AND DUST EMISSION PER 1 MJ OF ENERGY OBTAINED
DURING ENTIRE TEST SERIES

FUEL	CO ₂ [g/MJ]	CO [g/MJ]	CH ₄ [g/MJ]	SO ₂ [g/MJ]	NO _x [g/MJ]	Ms [g/MJ]	Meo [g/MJ]	Men [g/MJ]	Ma [g/MJ]
"Wujek" coal WU-PL washed	126.479	1.525	0.150	0.331	0.113	0.697	0.071	0.044	3.624
"Wujek" coal WU-PL/S (repeat run)	118.686	1.097	0.096	0.322	0.112	0.772			4.106
"Wujek" chunk coal average	122.583	1.311	0.123	0.327	0.1125	0.7345	0.071	0.044	3.865
Briquettes I BR-IS Baranów binder dry mixed	113.620	1.845	0.408	0.710	0.126	0.424	0.175	0.050	10.065
Briquettes I BR-IM Baranów binder wet mixed	105.134	1.300	0.209	0.629	0.113	0.341	0.127		8.892
Briquettes II BR-IIC Chrzanów binder	114.164	1.169	0.146	0.750	0.110	0.392	0.101		15.639
Briquettes III BR-IIIC ground "Wujek" Chrzanów binder	114.200	0.724	0.082	0.406	0.101	0.419		0.058	9.743
Briquettes III BR-IIIK ground "Wujek" Kraków binder	107.271	1.137	0.133	0.417	0.095	0.570		.057	7.123
Briquettes III BR-IIIB ground "Wujek" Bentonit binder	122.819	1.131	0.157	0.34	0.111	0.631		0.051	8.839
Briquettes IV BR-IVK "Brzeszcze" fines Kraków binder	111.031	1.053	0.183	0.62	0.131	0.441		0.041	13.185
Briquettes IV BR-IVB "Brzeszcze" fines Bentonit binder	112.902	1.291	0.098	0.329	0.114	0.645		0.065	12.391

(continued)

FUEL	CO ₂ [g/MJ]	CO [g/MJ]	CH ₄ [g/MJ]	SO ₂ [g/MJ]	NO _x [g/MJ]	Ms [g/MJ]	Meo [g/MJ]	Men [g/MJ]	Ma [g/MJ]
Briquettes BR-VBB "Brzeszcze" fines Kraków binder small	112.049	0.853	0.13	0.561	0.113	0.569		0.041	12.242
Briquettes BR-VIBB "Brzeszcze" fines Kraków binder large	126.015	0.777	0.092	0.639	0.145	0.6		0.038	12.132
Briquettes BR-VIIBG "Brzeszcze" fines Glikocel binder large	125.597	0.564	0.075	0.663	0.144	0.539		0.077	10.32
Briquettes BR-VIIBK "Brzeszcze" fines Kraków + Glikocel binder	138.9	0.637	0.083	0.709	0.173	0.505		0.058	13.49
Briquettes BR-VIIBK "Brzeszcze" fines Kraków binder large	95.202	0.708	0.087	0.592	0.136	0.362		0.046	11.197
Briquettes BR-VIIBC "Brzeszcze" fines Chrzanów binder large	120.32	0.682	0.12	0.718	0.127	0.396		0.052	15.497
Briquettes BR-IXBK "Brzeszcze" fines Kraków binder large	112.887	0.641	0.109	0.663	0.132	0.427			16.514
Chunk Brzeszcze coal	125.853	0.997	0.14	0.245	0.139	0.781			5.132

TABLE 13. EXTRACTABLE ORGANIC MATERIAL

Test Series	XAD-2 Resin Capture				Filter and Cyclone Catch						Total			
	TCO		GRAV		TCO		GRAV		TG		TCO		GRAV	
	[g/kg]	[g/MJ]	[g/kg]	[g/MJ]	[g/kg]	[g/MJ]	[g/kg]	[g/MJ]	[g/kg]	[g/MJ]	[g/kg]	[g/MJ]	[g/kg]	[g/MJ]
BR-IIIC*	0.8645	0.047	1.9126	0.104	0.0372	0.002	1.4861	0.0808	7.9276	0.4313	0.9016	0.049	3.3987	0.1848
BR-IIIK	0.8151	0.0422	2.7434	0.142	0.3453	0.0179	2.5245	0.1307	11.0226	0.5706	1.1604	0.0601	5.2679	0.2727
BR-IIIB	1.0652	0.0603	2.675	0.1514	0.1576	0.0089	3.1402	0.1777	11.1419	0.6305	1.2228	0.0692	5.8152	0.3291
BR-IVK	0.4269	0.0282	1.9938	0.1317	0.1376	0.0091	3.9357	0.26	6.6696	0.4406	0.5646	0.0373	5.9295	0.3917
BR-IVB	1.5397	0.0864	4.8123	0.2701	0.0386	0.0022	1.6411	0.0921	11.5045	0.6456	1.5783	0.0886	6.4534	0.3622
WU-PL2	0.6515	0.0297	1.7091	0.0778	0	0	1.2523	0.057	16.9662	0.7723	0.6515	0.0297	2.9614	0.1348
BR-VBB	1.1462	0.0659	1.7108	0.0984	0.0246	0.0014	1.36	0.0782	9.898	0.5691	1.1708	0.0673	3.0708	0.1766
BR-VIBB	0.4488	0.0287	1.0218	0.0654	0.0306	0.002	0.7721	0.0494	9.376	0.5999	0.4793	0.0307	1.7939	0.1148
BR-VIIBG	0.4695	0.0265	0.8101	0.0458	0.105	0.0059	0.7156	0.0404	9.5382	0.5388	0.5746	0.0325	1.5257	0.0862
BR-VIIBK	0.5403	0.0366	0.6094	0.0413	0	0	0.535	0.0362	7.4529	0.5047	0.5403	0.0366	1.1444	0.0775
BR-VIIIBK									6.2222	0.3625				
BR-VIIIBC									6.9427	0.3957				
BR-IXBK									7.2935	0.4274				
BRZE-1									16.1694	0.7814				

Where: TG—total particulate capture determined from both the filter and cyclone catch (equivalent to Ms in Tables 11 and 12)

*Due to a laboratory error, there was a loss of a single extract. Because of this, BR-IIIC is based upon two tests (not three).

TABLE 14. EQUIVALENT EMISSIONS FOR AGH TESTS IN GRAMS PER MEGAJOULE

	Equivalent Emission	Efficiency Percentage
WU-PL1	3.4425	70.4
WU-PL2	3.4341	69.1
WU-PLav	3.4388	69.75
BRZE-1	3.4115	70.7
BR-VIIBG	2.9257	66.7
BR-VIIBK	2.9937	62.6
BR-IS	3.2275	59.6
BR-IM	2.5956	63.3
BR-IIC	2.7903	66.7
BR-IIIC	2.276	71.4
BR-IIIK	2.914	72.6
BR-IIIB	3.0573	68.9
BR-IVK	2.8053	66.9
BR-IVB	3.1756	69.4
BR-VBB	2.9653	69.7
BR-VIBB	3.188	64.7
BR-VIIBK	2.3902	73.4
BR-VIIBC	2.5757	73
BR-IXBK	2.6046	70

In comparing briquettes, then, we would hope to find efficiencies greater than 71 percent and an EE appreciably better than 3.4.

The glikocel based briquettes do not satisfy this test. While their EE values are about ten percent better than chunk coal, the stove efficiencies are well below those of chunk coal.

The four highlighted formulations among the Acurex Environmental style briquettes do satisfy both conditions of this test. Stove efficiencies reach as much as 2.7 percentage points above the best chunk coal test while EE values are from 1/7 to 1/3 less than the chunk coal values. Among these

four formulation are two prepared from ground chunk Wujek coal and two from Brzeszcze fines. Similarly, two are prepared from Kraków sourced binder and two from Chrzanów sourced binder.

Figure 7 presents the SO₂ data from Table 12 and separates them in terms of chunk coals, glikocel based briquettes, and Acurex Environmental briquettes. As expected, the best results are found with the chunk coal samples. The worst results, as a class, are found with the glikocel containing briquettes. It is encouraging to note that four of the Acurex Environmental formulations approach the chunk coal samples in terms of sulfur dioxide emission.

Presenting these results in terms of g/MJ, however, presents an incomplete story. Chunk coal samples are expected to provide the lowest SO₂ emissions in the absence of control technology since the fines used in these and other briquettes have a higher sulfur content than the corresponding chunk coals. The Brzeszcze chunk coal tested here has a total sulfur content of only 0.31 percent while the Brzeszcze fines used in the preparation of several of these formulations has 0.7 percent total sulfur. In addition to the higher sulfur content of the fines used in their preparation, some of the binders used in these experiments also contain some sulfur. Acurex Environmental has analyzed these binder materials by X-ray Fluorescence Spectroscopy. This data may be found in Table 15. As this analysis

TABLE 15. ELEMENTAL ANALYSIS OF BINDERS

Element	Elemental Concentrations in Weight Percent					
	Bonarka	Baronow	Bentonit	Chapel Hill	Chrzanow	RTP
Al	8.78	10.94	11.82	13.75	7.33	9.44
Ca	3.76	0.23	0.53	0.16	11.28	1.66
Fe	5.46	6.90	2.06	9.17	4.01	6.50
K	2.52	2.02	2.03	0.89	2.28	2.41
Mg	1.48	0.54	0.24	0.27	1.12	1.53
Mn	.038	.027	.0072	0.475	0.400	.093
Na	0.825	0.115	1.51	0.169	0.208	11.09
Si	27.77	25.74	32.88	18.86	23.71	22.21
S	0.422	0.017	0.038	0.024	0.236	0.015
Ti	0.361	0.575	0.131	0.727	0.262	0.447

Sulfur content was quantified using SRM 2691 as the standard. (0.83 %)

Figure 7. Sulfur dioxide emissions vs. stove efficiency.

shows, the Bonarka and Chrzanów sourced binders do have more sulfur content than the Bentonit sourced material. Their sulfur content is equivalent to that found in a cleaned coal. Referring back to Figure 7, the 2 best briquettes, in terms of sulfur dioxide emissions, BR-IIIB and BR-IVB, were formulated with the Bentonit binder. The high calcium content of the Chrzanów binder should also be noted. We have attempted to calculate a mass balance on sulfur using the total sulfur, St, from Table 6, the fuel mass, Mw, from Table 7, and the mass of sulfur dioxide emitted from Table 10. This is presented in Table 16. Theoretical SO_2 in grams is simply $1000 \cdot \text{Mw} \cdot \text{St} / 100 \cdot 64.06 / 32.06$ where $64.06 / 32.06$ is the gravimetric factor between sulfur dioxide and sulfur.

Looking at the data in terms of the ratio of actual to theoretical SO_2 , Table 16 and Figure 8, we find that in most cases the Acurex Environmental briquettes do not differ to a great extent from the chunk coals. No importance is assigned to briquette formulations BR-1S, BR-1M, and BR-IIC. These were the earliest Acurex Environmental briquettes tested and the primary characteristics of these combustion tests were of incomplete combustion and large quantities of unburnt residue. It is interesting to note BR-IVB at 99 percent, suggesting that absolutely all of the sulfur content was converted to sulfur dioxide. BR-IVB has the lowest binder content (eight percent) tested among the Acurex Environmental formulations. This result could also represent an error in the reported St value for this briquette. When these four formulations are set aside we find that chunk coal and briquettes are quite comparable. It is also worth noting those formulations containing the Chrzanów binder with its high calcium content; BR-IIC, BR-IIIC, and BR-VIIIC. These samples do not form a special cluster with a lower percentage of their sulfur content emitted as sulfur dioxide. They are indistinguishable from the rest of the samples in this respect. This suggests that this binder calcium is either unavailable for sulfure dioxide capture or that the combustion temperature is high enough to decompose any calcium sulfate which forms.

TABLE 16. COMPARISON OF SULFUR CONTENT TO SULFUR DIOXIDE FOUND

	Fuel Burnt (kg)	Total Sulfur (%)	Theoretical SO ₂ (g)	Actual SO ₂ (g)	<u>Actual SO₂</u> Theoretical SO ₂ (%)	Stove Efficiency (%)
WU/PL	16.011	0.52	166.4	121.1	73	70.4
WU-PL/S	12.018	0.48	115.3	85.1	74	69.1
BRZE-1	16.25	0.31	100.7	82	81	70.7
BR-VIIBG	18.636	0.64	238.3	204.3	86	66.7
BR-VIIBK	15.178	0.71	215.3	158.9	74	62.6
BR-IS	17.668	1.05	370.7	135.7	37	59.6
BR-IM	19.358	1.04	402.3	140.7	35	63.3
BR-IIC	17.662	0.9	317.6	181.3	57	66.7
BR-IIIC	19.28	0.47	181.1	142.2	79	71.4
BR-IIIK	13.476	0.5	134.6	108.6	81	72.6
BR-IIIB	18.734	0.37	138.5	103.6	75	68.9
BR-IVK	15.794	0.62	195.7	148.1	76	66.9
BR-IVB	19.49	0.58	225.9	224	99	69.4
BR-VBB	18.756	0.63	236.1	186.2	79	69.7
BR-VIBB	14.856	0.63	187.0	148.1	79	64.7
BR-VIIBK	15.922	0.75	238.6	162	68	73.4
BR-VIIIBC	21.246	0.73	309.9	234.5	76	73
BR-IXBK	21.29	0.69	293.5	217	74	70

It may not be clear why these calculations were performed using total sulfur rather than combustible sulfur. In fact, the initial iteration was done using combustible sulfur. What we found was that the ratio of actual to theoretical sulfur dioxide, in many cases, was greater than 100 percent. This is a clear indication that these combustion conditions are sufficient to break down the sulfates and other species which represent the difference between combustible and total sulfur content of the fuels.

Figure 9 presents the scatter plot of stove efficiency vs. sulfur dioxide emissions. It is easy to discern that this graph contains two clusters. Seven samples cluster in the lower right corner (increased efficiency and lower SO₂ emission). This cluster consists of the three chunk coal samples, the BR-III series, and sample BR-IVB. These four briquette samples are the same ones which were best in Figure 7. The rest of the samples form a group of 0.55 to 0.75 g/MJ that appears to be

Comparison of Briquettes to Chunk Coal

Figure 8. Comparison of briquettes to chunk coal for sulfur mass balance.

Figure 9. Sulfur dioxide emissions vs. stove efficiency.

independent of stove efficiency or, perhaps, has a slight downward trend.

In conclusion, this data shows that the Acurex Environmental briquette can approach chunk coal in terms of SO_2 emissions. The higher SO_2 emissions for several of the formulations can be attributed to the higher sulfur content of the fines and binder materials used in their preparation. The Acurex Environmental briquette does not actively reduce SO_2 . This is exactly in keeping with our predictions on this subject in the proposal. It also suggests that lime addition to the briquettes will not be effective in reducing this emission. This is supported by the combustion bed temperatures mentioned earlier in this report. All of the above leads to the conclusion that commercialization of this briquette will require coal washing to reduce SO_2 emissions. This is also in line with our proposed approach.

Acurex Environmental's sampling team arrived in Kraków on March 20. After the lengthy customs clearance was completed the next day, the sampling equipment was immediately transported to INCO Veritas. Setup and verification began on March 22 and was essentially completed on the next day although certain critical pieces of laboratory equipment had not been received. Arrangements were made for AGH to supply clean XAD-2 resin and to perform the analyses of the filter and XAD-2 samples. Initiation of sampling was planned for March 29.

Boilers #1 and #2 at INCO Veritas (used for process steam and space heating) are batch units whose firing rates are controlled by varying the combustion air available through the fuel loading door. Combustion gases are exhausted into a common stack on the roof of the plant. Access to a single boiler's exhaust gas is not possible due to obstructions and high gas temperatures prior to the point at which the two boiler exhausts enter the common stack. The boilers will be operated simultaneously at identical firing rates, first on coke and then on briquettes. High and low loads will be attempted for each fuel by adjustment of the front fuel loading door gaps. Success here will depend upon the level of control available by this means and the plants' demand for steam. Three test runs will be performed at each boiler condition. Table 17 presents the sampling protocol while Table 18 presents

TABLE 17. SAMPLING PROTOCOL

Parameter	Method	Equipment
Sampling Location Selection	EPA Method 1	N/A
Stack Gas Flow	EPA Method 2	s-type pitot
Stack Gas Composition (oxygen/carbon dioxide)	EPA Method 3	ECOM SG-Plus gas analyzer/Fuji Model ZRH gas analyzer
Moisture Concentration	EPA Method 4	EPA Modified Method 5 Sampling Train
Particulate Concentration	EPA Modified Method 5	EPA Modified Method 5 Sampling Train
Semivolatile Organics Concentration	EPA Modified Method 5	EPA Modified Method 5 Sampling Train
Sulfur Dioxide Concentration	EPA Method 6C	ECOM SG-Plus Gas Analyzer
Nitrogen Oxides Concentration	EPA Method 7E	ECOM SG-Plus Gas Analyzer
Carbon Monoxide Concentration	EPA Method 10	ECOM SG-Plus Gas Analyzer
Total Hydrocarbons Concentration	EPA Method 25A	TECO Model 51 THC Analyzer

TABLE 18. TEST MATRIX

Test Day	Fuel	Boiler Load	# of Runs	Test Methods
1	coke	high	2	all *
2	coke	high	1	all
2	coke	low	1	all
3	coke	low	2	all
4	briquettes	high	2	all
5	briquettes	high	1	all
5	briquettes	low	1	all
6	briquettes	low	2	all

* see Table 17

the proposed test matrix. Because INCO's switch to coke will make briquette comparisons more difficult than anticipated, we hope to make use of previous DOE coal/coke comparisons for this analysis.

Large-scale production of briquettes is underway at Euromining's Brikpol facility. There was an initial delay when the promised supply of washed Brzeszcze fines was not available from the

supplier until near the end of the quarter. An additional delay occurred when the mixer shaft sheared under the stress of dealing with chunk clay. Euromining repaired the shaft and arrangements were made to purchase ground clay as a raw material for this process. Euromining also purchased and installed drying equipment to complete the production of these briquettes. The first multi-ton quantities of briquettes were delivered to Kraków as the period ended.

Business activities continued with progress on tasks IC1-9. All pertinent production, use, and demographic data were acquired. This data is found in the draft Business Plan attached to this Quarterly Report as Appendix B. Table 1 of the Business Plan presents the data for the city of Kraków. These numbers are significantly lower than DOE's 1993 estimates. Our research indicates that many illegal conversions to electrical resistive heat have occurred in Kraków. In summary, our estimate of the total Kraków LES coal market is currently 150,000 tons per year.

Since 50 percent of a 150,000 ton per year (75,000 tons per year) market is insufficient to support a new venture, Table 2 looks beyond the city of Kraków and neighboring Katowice. Within these two voivodships we find a total market of 1,040,000 tons of coal per year. The urban portion of this market, the city of Kraków and 13 others, comprises a relative market of 855,000 tons of coal per year (columns A + C of Table 2, Business Plan). Fifty-percent of this urban market comprises a business target of 428,000 tons of coal per year. Since the rural market would be much more difficult to serve, this business plan has targeted the urban LES coal market.

Further investigation of the distribution system has served only to confirm the information reported in the previous quarterly. These were bulk delivery, small quantity delivery, and customer pickup. We plan to approach only privately owned distributors and offer each exclusive areas of operation for our product.

Market strategy development will continue into the next quarter with an emphasis upon product identification. For example, the product logo will be displayed on distributors' trucks. Also, contests and a promotional print and TV campaign will begin.

We plan to diminish our business risks by using a major coal user as our raw material supplier. This eliminates the need to deal directly with the coal mines that may view our product as unwanted competition.

Work on sales and service alternatives also began during this period. Placing the actual sales responsibility in the hands of the participating distributors is considered the most logical sales method. The company's marketing department could provide training in sales service and encourage the offering of extra services (such as moving briquettes to storage areas) for modest extra fees. Another advertising tool being considered is a pamphlet describing efficient stove operation.

Negotiations continued during this quarter in several directions. Potential cash investors and fixed asset investors were contacted regarding their potential roles in the new venture. Others were contacted for their expertise in such areas as operations and technical assistance.

We plan to have the new company founded by the end of the next quarter. Chapter II of the Draft Business Plan outlines the key assumptions of the new company. The bulk of legal and accounting issues will occur in June as we seek to actually found the new company.

Contacts with government agencies continued this quarter, including a meeting with the Vice President of the Kraków City Council. He encouraged commercialization of our product and offered little hope for subsidies.

The city council was also advised on environmental matters by the Environmental Committee. There were no new developments here. They advised the council that the best solution to environmental protection is offered by installing natural gas for residential heating. This is a commonly accepted conclusion; though how that objective can be achieved in the near term is not obvious.

Meetings were also held with statistical agencies and other government offices to obtain the data used in the market forecast.

As this period ended, we were still awaiting briquettes from Euromining to be used for the product market tests. All the necessary preliminary activities were completed during this quarter such as developing a database of potential participants, preparing initial contact and concluding participant questionnaires, developing the data analysis program, and training AGH students to introduce the product to the participants and to fill out the questionnaire.

The first draft business plan was prepared during this quarter and will be revised during the next quarter to fill the remaining gaps and to reflect new data.

DELAYED TASKS

Because Euromining briquette preparation is behind schedule, INCO testing is behind schedule.

For similar reasons, product market testing is also behind schedule.

PLANS FOR NEXT QUARTER

The following activities are planned for next quarter:

- Additional testing at AGH
- Prepare test batches of briquettes at Bogdanka
- Perform sampling at INCO Veritas
- Perform sampling at PEC; Chrzanów
- Complete PAH analyses
- Compare the Kraków distribution system with that in Katowice
- Finalize the corporate and marketing strategies
- Prepare a cohesive set of proposed sales and service alternatives and present to potential distributors
- Complete negotiations to form a briquetting company
- Prepare draft articles of incorporation
- Prepare and audit the forecast financial statement for this new company
- Complete the product market survey, including the data analysis
- Revise the draft business plan

APPENDIX A

QUESTIONS FOR DATA REVISION

TRIP REPORT MEMORANDUM

Questions for Data Evaluation

Sampling in Combustion Laboratory

Probe Temperature

Filter Box Temperature

Quality Control Samples

Has a blank XAD-2 cartridge been analyzed?

Has a blank filter been analyzed?

Has an impinger blank been analyzed?

Has a blank run (no fuel) been performed

Standards

Dates of the standard gases

Sources of the standard gases

Concentrations of the standard gases

Calibration

Instruments used for reactive gas
measurement

Calibrated at what frequency?

Daily check at beginning of run?

Daily check at end of run?

Calibration range

Linearity

Thermocouples

Last calibrated when?

Types of thermocouples

Error! Bookmark not defined.Error! Bookmark not defined.

Balance

Brand and model

Capacity and resolution

Calibrated at what frequency

Standard weight is checked periodically?

Calculations

Obtain copies of spreadsheet files

How is CEM data transferred to file?

How is thermocouple data transferred to file?

Determine relationship between a data source and column locations in spreadsheets

Is data transferred in physical units ($^{\circ}\text{C}$, ppm CO, etc.) or is that calculation performed in the spreadsheet?

Protocols

Glass ware cleaning protocol

Dilution tunnel factor determination

Once per run or continuously?

Sampling glassware breakdown

What solvent is used?

What happens to probe rinse?

What happens to filter front half?

What happens to filter back half and condenser?

Stack gas volume measurement

Calculated as time * flow rate?

Determined once per run or continuously?

Protocols for ultimate analysis

How many replicates are analyzed?

Obtain copies or citations to equivalent ASTM methods

Discuss total sulfur vs. combustible sulfur

Impinger sample collection and determination

Four impingers in series

Filled with distilled or de-ionized water

Maintained in ice bath

Composited for analysis?

Volume measurement?

Evaporated with heat?

Gravimetric determination?

Other analyses?

Sample Preparation

Filter samples

Weighed immediately after collection?

Dessicated before weighing?

Dessicated before taring?

Filter source and type

Filter extraction

Is extract dried after extraction or after
concentration?

Calcium sulfate?

Solvent used

Supplier and grade

Procedure

Soxhlet

Ultrasonic shaking

Amount of solvent

Concentration procedure

Method

Kuderna-Danish

Boil in open beaker

Evaporation under flowing nitrogen

At what volume is the concentration stopped?

Is there precipitated material?

Did any of them go dry?

Made up to what final volume?

Have the extracted filters been archived?

XAD-2 samples

Extraction

Is extract dried after extraction or after concentration?

Calcium sulfate?

Solvent used

Supplier and grade

Procedure

Soxhlet

Pump through elution

Ultrasonic shaking

Amount of solvent

Concentration procedure

Method

Kuderna-Danish

Boil in open beaker

Evaporation under flowing nitrogen

At what volume is the concentration stopped?

Is there precipitated material?

Did any of them go dry?

Made up to what final volume?

Cyclone samples

No sample preparation

Not composited with any other fraction

Probe rinse

Rinsed after each run?

Rinsed with what solvent?

Discarded?

Added to what other sample?

Evaporated and determined gravimetricly?

Filter front half glassware

Rinsed after each run?

Rinsed with what solvent?

Discarded?

Added to filter extract?

Filter back half glassware and condenser

Rinsed after each run?

Rinsed with what solvent?

Discarded?

Added to XAD-2 extract?

Analysis

GRAV

Balance make and model used for this work

Balance resolution

Date of last calibration

Daily standard weight check?

Performed as per AEERL/ROP

Examine GRAV pans

Number of replicates performed per sample

Quality control sample analyzed with each run?

Solvent blank sample analyzed with each run?

Concentrated solvent blank sample analyzed?

Extract volume analyzed with each pan?

Method of dispensing extract into pan?

Total extract volume as analyzed for each sample?

Obtain copies of weighing records

TCO

Obtain copies of chromatograms and peak printouts

Review calibration regressions

Performed as per AEERL/ROP

Source and preparation of standards

Number of replicates per sample
Quality control samples for each run
Was a concentrated solvent blank analyzed?
Final volumes of extracted samples
Dilutions performed on each sample
Background method used for this analysis

PAHs

Performed as per AEC description
Obtain copies of chromatograms and peak printouts
Source and preparation of calibration standards
Number of replicates per sample
Review calibration regressions
Final volumes of extracted samples
Dilutions performed on each sample
Peak height or peak area
Background method used for each analyte

Fuel composition analysis

Obtain protocols or equivalent citations
Number of replicates performed for each sample

Compression strength test

Protocol
Equipment make and model

Force range and resolution

Number of replicates performed for each determination

Acurex Environmental Corporation Memorandum

To: Wojciech Jozewicz
From: Mr. David F. Natschke
Date: Friday, January 27, 1995
Subject: Most Recent Poland trip

This memo discusses my most recent trip to Kraków. The primary purpose of this trip was to perform a data review at AGH. In addition, I also went to INCO Veritas to collect information relative to Gene's upcoming sampling trip, discussed the preparation and testing of cast briquettes with Professor Drzymala and Dr. Szewczyk, and visited with Piotr Zamkotowicz of the Larive-Kraków office. In summary, many of my goals for the trip were achieved - though an obvious answer to the organic analysis data was not found. In the near term, I will be sending out letters to AGH requesting the preparation and analysis of certain quality control samples and some changes of procedure. The following summarizes my contacts and the information generated.

Briquetting laboratory

- I have requested that this group prepare cast briquettes in quantities sufficient for combustion testing. These briquettes are to be prepared from washed Brzeszcze fines (0 to 2 mm) and Chrzanów clay. Three batches were requested in the ratio 1:4, 1:6, and 1:6 using saturated calcium hydroxide solution rather than water. They have agreed to this and are already working on it. We agreed to a 30 mm by 50 mm diameter cylinder form. Alexander very promptly arranged for the manufacture of the necessary forms so that they could proceed with this. I believe more forms will be required to perform this efficiently and Alexander plans to have more made. Prof. Drzymala tried to argue for reversing these dimensions based upon a density gradient during the settling process. However, I felt that such a "coin-like" shape would tend to form a combustion bed with overlapping flat surfaces from which oxygen would be excluded. For better or worse, my recommendations are being followed.
- I requested a demonstration of the compression strength test. This was accomplished.
- I requested that compression strength be performed on the cast briquettes prepared by Jarek (ours are a 37.5 by 37.5 mm cylinder) and carried by me on this trip. This was also accomplished. The person performing this test and Dr. Hryniewicz appeared to be surprised by the strength exhibited by these samples. Dr. Hryniewicz provided a conversion graphs for going from dial readings to newtons.
- A demonstration of the drop shatter test on the 1:6::Chrzanów clay:Brzeszcze fines (0-2 mm) prepared on the 1100 mm press was performed for me. They make certain modifications to the drop shatter test when performing it on the large briquettes; 5 briquettes are tested rather than 10 and the sieve used for rejection of fragments has 51 mm holes. This latter has "philosophical" implications which we need to think

about since the rejected pieces are of a quite useable size. Therefore, the low results obtained with these (73 % when I watched) and other Chrzanów:Brzeszcze briquettes may not be important to us.

- Alexander has supplied washed Janina fines for briquette experimentation. Prof. Drzymala is the driving force behind this. He explained that there is some German research which seeks to define the critical parameters between a coal source and its briquetting potential. On this basis, Janina should be a "good" briquetting coal. I have no opinion on this direction of research.
- Dr. Hryniewicz provided the next report which I have carried with me. It will need to be translated, of course. This report includes combustion testing of the 1:6::Chrzanów clay:Brzeszcze fines large briquettes. It also includes some of the coal fines sieve analysis which I had requested. This data is interesting and will be supplied separately. Unfortunately, the supply of Wujek fines used in so many of the experiments was exhausted. Sieve analysis will not be available for these experiments.

Tawimex

- Discussed the sulfur dioxide results with Dr. Szewczyk. I presented him with the calculations regarding the percentage released and a proceedings paper regarding SO₂ vs. combustion temperature. They had no significant comments to make on this subject. They noted that the so-called combustible sulfur test should really be done under conditions closer to test stove conditions but are instead done under the Polish standard to provide comparability. When pressed to note that the briquettes, according to these calculations, are more efficiently generating SO₂ they had no comment. When pressed about temperature differences as a possible explanation, the comment was made that he thought the briquettes would be burning at a lower temperature than chunk coal. On this subject see below.
- Requested copies of the fuel testing protocols. These were provided. They will need to be translated.
- Requested combustion testing of cast briquettes. They are agreeable.
- Going back to the SO₂ data, Dr. Szewczyk expressed some concerns about the accuracy of the electrochemical analyzer. Apparently, it does not perfectly zero and they have to apply a correction factor.

Combustion Lab

- Requested copies of data files. These were provided in 3 different formats. Many of the missing figures from previous reports will now be available. Other correlations which they have not considered may now be checked.

- Video taped the sampling process. This is in 8 mm format and will have to be converted.
- Noted the use of silicone grease on the ball joints of the sample train glassware. This is a potential contamination problem. This was discussed afterwards with Stasiek who explained that this procedure was worked out with Tom Butcher 2 years ago when they encountered difficulty getting the system to leak-check. I have discussed this with Gene Stephenson and Mike Bowling. They use 2 techniques to seal ball joints without the use of silicone or other greases. Gene uses de-ionized water in place of grease. Mike also mentioned that there is a Teflon[®] sleeve made for ball joints. He estimates these to be around \$15 apiece.
- Discussed the sampling train breakdown. The sampling probe is brushed out rather than solvent rinsed. This material is added to the cyclone catch and filter for the extraction process. Due to the presence of silicone grease, a small amount of material trapped at the junction of the cyclone and its trap is ignored. The filter back-half glassware and the condenser are rinsed with dichloromethane. This solvent rinse is added to the XAD-2 extract. This is proper procedure. However, due to the presence of the silicone grease it is also a source of contamination. Since returning I have discussed this with Gene Stephenson. His technique is to use de-ionized water rather than grease on the ball joints. I will request that the combustion lab make this procedural change.
- The sampling probe and filter box are both operated at 120 °C.
- Discussed the method by which Dr. Szewczyk determines the end of the test. This is determined solely by him based upon his observations of the stack gas temperature (channel 25) and the carbon monoxide data. When channel 25 makes a permanent decrease and CO makes an irreversible increase, the stove is shut down.
- Requested that the cyclone cut-point value be provided.
- Determined from Stasiek that the cyclone and filter are weighed separately before extraction. Verbally requested of Dr. Szewczyk that Ms and TG be reported as separate cyclone and filter catches. I will follow this up with a written request.
- During my visit they were performing combustion tests on a Bonarka clay/Brzeszcze fines briquette. I took the opportunity to request combustion bed temperature readings. This was done on 2 separate days, once each day with a hand-held meter, with an indicated top end of 1200 °C. The thermocouple was brought up into the fuel bed through the ash pit. On the first day we measured 1300 ° and on the second day we measured 1200.
- They are requesting more filters. They will be out in just a few more days of sampling. They are requesting more of the syringe filters. They are requesting a replacement syringe.

- A background run on the sampling train and test stove has not been performed.

TCO Analysis

- Reviewed procedures with Dr. Porada and his assistant. The samples are already extracted and concentrated at the time they are received by Dr. Porada. This group performs the final filtration through the 0.45 μ syringe filter, makes the sample up to a total volume of 10 mL, measures out an exact 5 mL to another vial and transfers this to Stasiak for the GRAV analysis, and performs the TCO analysis. Manual injections are performed, 3-5 replicates as necessary to achieve satisfactory data. No additional dilution has been required for any sample.
- Standards are prepared from the materials provided by Alexander (Sigma).
- Inspected sample chromatograms. Everything looks quite satisfactory.
- One quality control sample has been presented to them for analysis. This was a concentrated solvent blank. This sample was analyzed with a small but detectable value. In performing their calculations on analyzed samples, this concentrated sample blank is subtracted out. This is perfectly appropriate procedure.
- A quality control standard is analyzed periodically, though if I understood them correctly it is not performed daily. This is performed only to track and adjust for any shifts in the retention times. This is particularly important when using manual injections since the integrator must also be started manually. They do not calculate a mass for this QC standard and use that value to maintain a QC chart. This would be an improvement in their QC procedures.

Sample Extractions

- Probe brushings, cyclone catch, and filter are combined and extracted by ultrasonic shaking with dichloromethane. This is performed until no color is visible in the latest extract and all extracts are combined. They have constructed some nice stands out of glass which support the folded filter in the extraction beaker. Some particulate matter does escape the sample and is found in the unconcentrated extract. The unconcentrated extract is dried by filtration through a bed of sodium sulfate supported by filter paper in a funnel. The dried extract is concentrated to approximately 5-6 mL in a Kuderna-Danish apparatus using a 3-ball Snyder. The concentrated extract is transferred to Dr. Porada's group for final filtration and making up to volume. These procedures are in line with those provided to them.
- XAD-2 cartridges are extracted and concentrated as per our flow through extraction procedure. Again, the concentrated extract is transferred to Dr. Porada's group for final extraction and making up to volume.

- They have acknowledged that some concentrated extracts do show solid material. It is the opinion of Stasiek and Dr. Porada's assistant, Janina, that this appears to be particulate matter which has somehow passed through the before concentration filtration steps. It is difficult to understand how the particulate would get past filtration through a bed of sodium sulfate and a filter. I requested that they check their logbooks for indications of exactly which samples had solid material. If it turns out to be only filter samples that would be indirect evidence that it was simple particulate. I have some concerns that this is evidence of over-concentration; that the solid material is organic material which has fallen out of solution when it became saturated or is polymerized material. At the same time, an experienced eye should be able to recognize particulate as opposed to organic material.
- They have modified the Kuderna-Danish apparatus to incorporate an additional condenser. This has been done to capture the evaporated dichloromethane solvent. This solvent is distilled through use of a RotoVap™ and is reused for additional sample extractions.
This procedure has the potential for contamination and is not one that we have found beneficial in the past. A RotoVap does not have the separation capacity of more stringent distillation techniques; it does have the advantage of being quite rapid. They have prepared and analyzed a concentrated solvent blank which is the appropriate quality control measure when using redistilled solvent.
There is one additional concern. Stored dichloromethane has a tendency to break down slowly generating chlorine radicals which can react with the analytes and modify them. The manufacturers address this by adding a low concentration of a free radical "getter" compound such as cyclopentene. Redistilled dichloromethane should have such a compound added if it will be stored before use. Stasiek informs me that they do not add such a getter compound. Instead, they use the redistilled solvent within hours of the distillation step. This appears to be satisfactory.
- Blank filter and XAD-2 samples have not been prepared and analyzed.

GRAV Analysis

- This is not being performed according to procedure.
- They are using a 0.1 mg resolution balance rather than the 0.01 mg specified in the AEERL protocol. At the same time, these are combustion samples rather than ambient samples and, according to Stasiek, they are weighing milligrams of material. This is probably an allowable deviance under these conditions and, in our last meeting, I told Stasiek he did not need to locate a different balance at this time.
- They are performing this analysis as a singlet determination rather than the duplicate determination specified in the protocol. Dr. Porada supplies Stasiek with a measured 5 mL in a sealed vial. Stasiek and his co-worker transfer this entire volume (plus rinses of the vial) to a single weighing pan by upending the vial in the center of the

pan.

I have concerns about several aspects of this. As a singlet determination, there is not a standard deviation by which to judge the quality of the results. I also have concerns about putting 5 mL in a weighing pan. The style they are using has a fairly large diameter with a very short wall. It is quite possible for capillary action to wick some of this liquid out of the pan. Additionally, the upending into the pan probably results in some material being lost to the outside of the vial. This latter is probably a minor loss compared to the 5 mL sample volume. On the other hand, attempting to recover this by solvent rinsing the exterior of the vial could result in significant contamination. There are better approaches to the sample transfer which I shall be writing AGH to recommend. I shall also be requesting that certain Quality assurance samples be prepared and run to validate what they are currently doing. In my last meeting with Stasiek we agreed that he would obtain a greater portion of the total extract for the GRAV procedure and perform it in duplicate.

Larive-Kraków

- Met with Piotr Zamkowitz on Wednesday.
- He is requesting that we tabulate data in a neat table rather than expect the business people to pore through reports. This seems reasonable.
- It is his strong opinion that the residential market in Kraków is too small to support a new venture by itself. He feels that the residential market is much smaller than DOE's research would indicate. He bases this upon his research into the distribution system and upon the prevalence of illegal electrical resistance conversions.. He feels that we must be able to penetrate the small boiler house market also to have a successful venture - and/or to move beyond Kraków
- He is one of those who feel that we do not have to depend upon the "Acurex" briquette to begin a new venture.
- He provided some information on a product called Sadpal which is being marketed as a catalytic material to be added to a coal bed to reduce particulate emissions. This is something else which has to be translated. Jack provided me with a sample of this stuff upon his return.
- He also expressed his reservations about the relevance of the combustion testing since it is not being done to common practice. In other words, residential users have no means to determine the optimum shutdown point in a burn as it is described above. On this point I suggested that we could perhaps provide a service to customers which would give them such a capability. I mentioned that the simplest approach would be to offer those magnetic stack thermometers which are sold to woodstove users in this country.

Dr. Ewa Wisla-Walsh

- Met with Ewa on several occasions. Delivered to her some reprints
- Discussed with her the question of sulfur dioxide generation. Her opinion is that the primary variable affecting SO₂ generation is coal preparation techniques. This includes coal washing to remove sulfur sources, of course, but she meant it in terms of mesh size. As we discussed this, it made a lot of sense. On this basis, we would expect any briquette to transform a higher percentage of its sulfur content into SO₂. This may be the real answer to Feeley's questions on this matter. The secondary variable is combustion conditions. Combustion bed temperature is part of this and is undoubtedly also tied to mesh size.
- As I mentioned to you already, she is interested in co-authoring 2 papers on the subjects of SO₂ generation and coal agglomeration techniques.

cc: project file 8611.001

Libby Beach

Alexander Pantak

APPENDIX B

BUSINESS PLAN

DRAFT
KRAKÓW BRIQUETTE PROJECT
POLISH - AMERICAN
JOINT VENTURE COMPANY

FOR
ACUREX ENVIRONMENTAL
CORPORATION

FIRST DRAFT ISSUED 7/4/95

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II. Company Description

A. Mission:

Operate a profitable privately financed and owned joint venture company in Poland to provide at affordable prices uniform quality coal based briquettes for the home heating market (both coal stoves and small boiler houses) while reducing, by significant amounts, the air pollution normally associated with the burning of the coal.

B. Company Form:

The company will be formed as a limited liability Polish corporation having four initial investors with equity as follows:

SHAREHOLDER	DIRECTOR NAME	EQUITY SHARE
Investor Group		
Technical Advisor		
ACUREX Evironmental		
Corp		
Planmar Consulting, Inc.		
Euromining Corp.		
Przedstawicielstwo Energetyki		
Ciepłej w Chrzanowie		

C. Company Name:

The company will be identified with the name _____.

It will own product trade names that include: _____.

It will make use of a corporate logotype as in the following design:

Company officers:

President (CEO)

Financial officers (CEO) and treasurers

Vice President Operations and secretary

Vice President Marketing and Sales

D. Corporate Objectives:

1. Market share:

Obtain a 50 percent market share of the solid fossil fuel home heating market (coal stoves and small boiler houses) within two years of initial product launch. The market the Voivodship (states) of Krakówskie and Katowickie in southern Poland (see exhibits II.E.A)

NB: Exhibited are a map of Poland with a box around the two voivodships and a detail map of the two voivodships on the right side, and demographic data concerning population by city of less than 100,000 inhabitants on the left.

2. A profit level of seven percent on sales after year two

3. A return on invested capital of 13 percent after year two

E. Product Position

1. Appeals to citizens as a contribution to pollution reduction through:

- a. Billboards
- b. Radio
- c. TV
- d. Advertorials

2. Lobbying and appeals to (directly and through influencing persons) city council members to support an environment friendly solid fuel by:

- a. Creating helpful legislation: for example, only license solid fuels resellers/distributors to sell low sulfur, high-quality coal.
- b. Offering publicity support for briquettes that cause less pollution, using the argument that gas or electric heating is better even than briquettes but until money is available for infrastructure development and/ or building conversion, the briquettes offer a sound solution.

3. Creative product launch program including

- a. Advertising series leading to "grand opening"
- b. Give-away items to first buyers
- c. Introductory coupons
- d. Lottery for a trip
- e. Easy to follow cartoon instruction manual
- f. Easier fuel handling than coal

4. Use of high-quality /low sulfur coal, but purchased at lower than chunk coal prices.

5. Provide a home heating service rather than just delivering a fuel through:

- a. Increased combustion efficiency instructions
- b. Finding a use for the combustion residue (revenue stream)

6. Use existing solid fuel distributors and their customer bases
7. Through production efficiency provide the product at the price that is $\pm$ 25 percent lower than high-quality chunk coal.
 - a. So why buy chunk coal?
 - b. No other environmentally friendly briquette is even near this price.

F. Market Position

1. As the only producer in Poland , the company wants to establish subsidiary production operations in other parts of Poland and neighboring countries.
2. Create a trade mark and trade name and maintain it universally in all manufacturing and marketing locations
3. Special services and incentives will be used to encourage boiler houses to switch to the briquette including:
 - a. Finding a soot (particulate) reducing catalyst allowing a mixture of briquettes and ordinary fines to be used to keep pollution and cost down.
 - b. Create a temperature/day method of calculations leading to automatic delivery of the desired "mix" to the boiler house operator.
4. Create a word of mouth publicity system with a special; number to call to sign up and get a gift
5. Establish a "help" number at each distributor to handle users' inquiries
6. Publicity and advertising will make use of results of studies on how much emissions are reduced using the briquette vs the coal from which briquette is made. There is an official statement on record at the environment protection agency in the voivodship.
7. Promotion material will be prepared for distribution through:
 - a. Boiler house/coal stove equipment dealers
 - b. Boiler house/coal stove equipment repair shops
 - c. Local home and garden shows
 - d. Camping and mountain vacation resort operators

G. Competitive Position - Product (details after test)

1. Boiler House Fuel (Cost, benefits, heat value, pollutants) non forced air.
 - a. Coke
 - b. Coke plus fines - high-quality
 - c. Small chunks - high-quality
 - d. B & C with low price coal
 - e. Big chunks (ever used?)
2. Coal stove fuel (cost, benefits, heat value, pollutants)
 - a. Coke
 - b. Medium chunks
 - c. Big chunks
 - d. B & C with low price coal
3. Briquettes - any source. Briquette manufacturer - competition
 - a. Poland
 1. BBM
 2. Zabrze
 - b. Czech Republic
 - c. Germany
 - d. France.
 - e. Great Britain

III. THE SOLID FUEL INDUSTRY

A. The Law Regarding Air Protection

1. Our product must compete successfully in the marketplace on price/heat value while meeting standards issued by the Polish Ministry of Environmental Protection.
2. The ordinance to be followed was issued on March 21, 1994, and contains the following provisions to be implemented by Jan 1, 1998. (Calculations are based on emission particles, SO₂, NO_x, CO, and so called equivalent emissions.)
 - a. The amount of emissions (concentrations of pollutants) are related to annual standards values, i.e. 32 micrograms/m³ for SO₂ and 50 micrograms/m³ for particles. The Minister Of Environment Protection recognizes only nature sanctuaries and hospital areas as special environmentally protected areas, thus excluding the general city of Kraków from this classification. The city now falls under general national environment protection law.
 - b. The primary cause of low ambient air quality in Krakow is suspended particles and SO₂ emissions. Most SO₂ pollution (47 percent) is generated in the neighboring Upper Silesian Industrial Region while the balance comes from Kraków industry and power sectors (some 18 percent) and low emission sources (35 percent). Low emission sources are almost entirely responsible for suspended particulate matter in the ambient Kraków air. By definition "suspended particles" are referred to as particles of dust with a size less than 10 micrometers in diameter that do not fall to the ground from the force of gravity .
 - c. The Department of Environment Protection at the Kraków Voivod Council limits allowable emissions for combustion sources. The limits are set individually for a given emitter.
 - d. Kraków air is measured by a network of Automatic Ambient Air Monitoring Stations. The instantaneous/real time of concentration of SO₂, CO, Suspended dust, and NO₂ is monitored constantly. The 30-minute (D30) and daily (D24) average concentrations of each pollutant are plotted and tabulated.
 - e. Allowable Concentrations of Pollutants in Ambient Air Protected Areas of Poland (Applies to Kraków):

Pollutant	30-minute concentration $\mu\text{g}/\text{m}^3$	Daily average concentration $\mu\text{g}/\text{m}^3$
SO ₂ up to 1998	600	200
starting 1999	440	150
NO ₂	500	150
CO	5000	1000
Suspended particles		120

f. Air pollution in 1993 in thousand of tons *

	City of Kraków	Kraków Voivodship	Katowice Voivodship	Poland
Total emission	217.6	242.0	2953.4	
Total particles emission	20.0	23.8	114.9	1500
- Includes pollution from burning fuel	10.7	14.1	91.3	
Total gas emission	197.6	218.2	2 838.5	
- Includes SO ₂	33.4	49.5	334.1	2740
- Includes CO	141.3	141.2	155.2	
- Includes NO ₂	18.4	22.1		
Industrial waste in		2733.0	60995.8	
Industrial waste per 1 sq km in tons		20777	118078	
Area in sq km	468.3	3254.1	6650	312685

* Information sources:

Main Statistics Office

Polish Law Ordinance, Act of March 21, 1994

Kraków Voivodship, Department of Environment Protection

B. BACKGROUND ON THE FURNACES AND STOVES IN POLAND

In Kraków there are six stove manufacturers with stove manufacture licenses listed as members of the Manufacturer Chamber. After industry restrictions were by law suspended, small manufacturers proliferated. No data is available on the actual number of such manufacturers.

It cost approximately 1100 z³ to build the average tile coal stove. Reconstruction or remodeling a stove costs about 400 z³.

Before 1989 the stove businesses were doing very well. One manufacturer could build or remodel between 300 - 350 stoves in one year.

Today, they build or remodel no more than 30-40 stoves in a year. The stoves are of ceramic construction with an ornate glazed tile exterior. Many of them are of historical value because of the artistically manufactured tiles.

Many Kraków buildings are classified by the Office of Kraków Monument Protection as historical monuments. They fall under the supervision of the City Conservator which means that any reconstruction or remodeling has to be approved by the City Conservator's Office. If a coal furnace is located in a building classified as a historical monument, removing the furnace or remodeling it has to meet the approval of the Conservator.

IV. THE TECHNOLOGY (As Originally Planned)

A. Coal to be Used

Plans call for the use of low-grade coal fines that can be obtained and transported to the briquetting plant in a cost-effective manner. They will be high-ash, low-heat quality fines with the potential to be improved in a cost-effective manner through the coal washing process to lower the ash and pyritic sulfur and improve the heating quality. The minimum size for the fines will depend on what can be effectively washed with high-coal recovery through a water-only washing operation. The high end of size distribution will be primarily driven by economics. Plans for the briquetting plant include screening and grinding operations. If larger fines are available at an attractive price, they will be sieved, ground, and washed.

An appropriate size distribution for washed coal entering the slurring operation is believed to be between 2 mm and 1/4 inches. This is based on a 1992 study that used a mixture of these two cuts. The 1987 study used coal that would have graded even finer than this.

B. Coal Washing

Coal fines will go through a washing operation before mixing with the inorganic binder slurry. This provides a separation based on specific gravity differences to reduce inorganic sulfur in the briquette, and therefore, reduce SO₂ emissions during their use. This operation will also improve the heating value of the coal feed stream by eliminating inorganic constituencies. Coal washing can be a significant improvement when the fines originate directly from the mining operation rather than the grinding operation.

Incorporation of the coal washing step should also reduce any potential CHI emissions from the product. CHI emissions from coal combustion are associated with certain mines that have a high salt content from sea water. Indication are that several Polish mines fall into this category. Any salt will be washed out by this step.

C. Inorganic Binder to be Used

The inorganic binder component of the Acurex briquette is intended for two purposes- acting as the binder for the briquette and also being the active agent in the reduction of particulate and organic matter emission during combustion. The quality of the inorganic binder is not of critical importance.

The inorganic binder imparts an important characteristic to this briquette. Unlike coal or other briquettes, the Acurex briquette maintains its original size and structure as combustion proceeds. Other solid fuels are known to volatilize in the immediate vicinity of the combustion zone. Residues are continuously flaking off exposing fresh fuel to maintain this intimate relationship. However, this briquette does not flake off or break up in any manner as the combustion process proceeds. Thus, particulate matter is physically trapped within this matrix and cannot become part of the exhaust.

The actual mechanism by which organic emissions are reduced is not known. There are three possible mechanisms of action- adsorption, catalysis, and cracking.

These binders being members of the zeolite class, suggests adsorption as a possible mechanism. However, transition metals such as iron are associated with these binders and could provide a catalytic effect.

Another possibility is a hydrocarbon cracking process due to a long residence time in a hot matrix. Once combustion has consumed the surface coal, volatilized coal must move by diffusion into the combustion zone via the narrow and tortuous passages developing within the hot matrix. No significant amount of oxygen will enter this matrix, forcing the combustion zone to remain at the exterior of the briquette. Because coal gas diffusion should be driven only by consumption of the evolved gases in the combustion zone residence time within the hot matrix may be expected to be much longer than that in the ordinary fuel situation.

Under these conditions, decomposition to simpler molecular fragments could occur. This cracking process associated with a long residence time in the hot inorganic binder matrix seems to be the most probable mechanism.

D. Mixing

Typically, the coal fines are added to a dispersed slurry. Upon mixing, a homogeneous mixture is obtained that ensures that large coal occlusions do not occur in the finished product and that the inorganic binder is in intimate contact with all the coal. Once all the coal is added, the amount of water used to prepare the slurry is adjusted to provide easy mixing with the crushed coal and a plastic mix.

E. Drying

Drying will be performed at low temperatures ($< 100\text{ }^{\circ}\text{C}$), for a long period. The drying process is strictly for removing water. Open air drying for several days, when weather conditions permit, is sufficient to produce a quality briquette. However, a low temperature oven will be used in production mode.

F. Manufacturing

(See exhibit II E. 2 of the Acurex Business Plan submitted to DOE)

V. THE PRODUCT

A. The Product as Described in the DOE Proposal Dated July 7, 1993

The Acurex Environmental fuel is a low-cost technology briquette in which the binder is the active agent for the reduction of emissions. On a per mass of coal basis, this product reduces particulate emissions by 70 percent and total hydrocarbons by 75 percent with no loss in produced energy. Sulfur dioxide emissions will be reduced by incorporating a coal washing step as a preliminary phase of the briquetting operation. Acurex Environmental has been granted a patent for this pollution reduction process. Coal briquetting is an established technology that utilizes coal fines and thereby offers an environmentally sound way of reducing this ongoing "waste" and draining settling ponds. Further, coal briquettes are relatively dust-free and, therefore, are suitable for firing in home heating stoves. Because of the similarities between home stove and small hand-fed boiler combustion practices, briquettes are suitable for small, hand-fed boiler firing.

B. The Product as Described in the U.S. Patent

Based upon U.S. Patent number 5,368,616, the Acurex Environmental Corporation's (AEC) product is a briquette prepared from coal fines and an inorganic binder. This inorganic binder is what differentiates this briquette from many others which have been proposed. During combustion, this binder forms a non-combustible matrix that entraps much of the particulate which is one of the most important constituents of the pollution from coal combustion. This briquette also reduces carbon monoxide and total hydrocarbons by improving combustion efficiency. Manufacturing costs are quite modest for this product. It may be manufactured using casting, extrusion, or briquetting press techniques.

C. The Product - As Described in the Test Results Conducted by AGH (Kraków Academy of Mining and Metallurgy)

(not yet available)

D. The Product - As Described in the Test Results Conducted on Customers' Premises

(not available yet)

VI. The Market

(some assumptions)

The approval for the use of briquettes as solid fuel has been granted by the appropriate environmental protection and regulatory agencies in the states of Katowickie and Krakowskie as well as the capital cities of Katowice and Kraków.

Endorsements from the city councils have also been obtained. Documented tests results from laboratories of AGH signed by Department Chiefs provides clear evidence for the product claims regarding heat efficiency, residue and reduction of air pollution.

A strong marketing program will support the launch of the product and the market penetration followup. The marketing plan provides the details of this program.

There are two categories of solid fuel competition described below that will be encountered and must be overcome in the market place.

1. Coal

The product is made from good coal which has a delivered sulfur content of less than one percent by volume. Only chunk coal can be burned in the target market appliances and chunk coal represents a small percentage of coal mined. It is also quite expensive (\$ 84 per ton). This is the fuel of choice for 90 percent of those who use coal.

Poor coal is a coal that has a delivered sulfur content of two percent or more by volume. This coal was once banned from the market but has made a return. It is believed the product will continue in use unless proposed legislation outlaws it once again. The briquette product will not be indirect competition with this material.

The market share target will be users of good chunk coal. The briquette product uses fines costing \$32 per ton. The briquettes will be sold to the consumer for \$ 70 per ton including manufacturing cost and distributors' margin which means the briquettes will cost less than high-quality chunk coal.

2. Other Briquettes

Rival briquettes (EMC briquettes) made from coal and other ingredients do little to reduce pollution. They cost only about half that of good coal but are approved for sale only in the poor regions of eastern Poland.

Another competing briquette made from hydrocarbonated coal does an excellent job of reducing pollution. This product is very expensive, priced approximately 30 to 40 percent more than that of good coal. At present it is not offered for sale.

C. MARKET SHARE

1. Calculating market share has been approached in a cautious manner.

2. There is an estimated relative* market size of 855,000 tons of briquettes per year.
3. To reach a 50 percent market share will require production of 428, 000 tons annually. The Bogdanka plant operating two presses for three shifts, five days per week, 12 months per year will produce only 380,000 tons.
4. The estimates therefore, appear reasonably safe.
5. Table 1, "Assessment of Coal Market Size in Krakow City," provides a set of data showing the rationale for coal use in the relative* market.
6. Table 2, "Build Up of Coal Volume," shows the relative* market size in the cities of Kraków and Katowice.
7. Table 3, "Build Down of Coal Market," is a reality check for table 2. Table 2 uses data from the Polish Department of Statistics (GUS), and indicates a residential usage of coal considerably greater than the calculated build up. This is a reality check to be sure that the calculated build up is not overstated.

* Home/ residence coal stove and hand-fired heating boilers.

ASSESSMENT OF COAL MARKET SIZE IN KRAKÓW CITY (1995)

Table 1

	ITEM	NO.	SOURCE OF INFORMATION
A	Residential units with coal stoves	30,000 units	GUS, BRK analyses and research
B	Single residential units coal stoves	75,000 units	Based on BRK, chimney services and ceramic stove builders
C	Annual coal usage in single stove	1.3 ton	BRK
D	Annual coal usage in Kraków stoves	98,000 tons	B x C
E	Annual usage of coal in small boiler houses (mostly single family houses)	52 000 tons	BRK, Cracow Politechnic, District Heating Plant
F	Coal market size in Kraków City	150,000 tons	D + E

BUILD UP OF COAL MARKET (in tons)

Table 2	A	B	C	D
Annual usage of coal in single stoves and small boiler houses (ratio base) <i>Extrapolation thru No. of residential units (GUS)</i>	Kraków City	Kraków Voivodship	Cities in Katowice Voivodship	Katowice Voivodship
150,000	150,000	235,000	705,000	815,000

BUILD DOWN OF COAL MARKET (in tons) - REALITY CHECK

Table 3				
Annual usage of coal in single residential unit stoves and boiler houses - whole country of Poland. <i>Build down thru No. of residential units (GUS)</i>	Kraków City	Kraków Voivodship	Cities in Katowice Voivodship	Katowice Voivodship
13,000,000 tons	267,000	417,000	1,255,000	1,455,000

Columns A and C of Table 2 represent total relative market size of 855,000 tons.

E. Product Launch:

A pre-product launch exercise, gathering information regarding specific strategies and tactics for marketing, sales, and distribution, will be conducted in April 1995. Topics of the pre-launch exercise will include:

1. Product acceptability
2. Price acceptability
3. Percentage of coal users likely to convert to briquettes in the 1995- 96 heating season

We used a newspaper advertisement to find volunteers willing to test a solid fuel that significantly reduces pollution. The response indicates a desire of the population to reduce pollution.

Planned Product Acceptability

The product has been designed to appeal to the average user of good quality, low-sulfur chunk coal. A few of the product features are as follows:

1. Use of the briquette requires no conversion of existing coal stoves and small boiler houses (coal burning furnaces for private homes and small apartment buildings). Therefore, there is no homeowner investment cost.

2. The briquette is ignited in the same way as coal and the damper adjustment is the same as when burning coal so there is no habit to change. (A leaflet enclosed with the briquettes will help consumers set their damper settings to achieve maximum heat efficiency.)

3. The product will be available from the same distribution channel as coal local coal distributors who buy in large quantities directly from the mining companies.

4. The customer will be informed that due to the inclusion of non-combustible materials in the briquette, 22 percent more of the briquette material must be used to equal the expected coal usage.

5. Removal of residue is simpler and cleaner than with coal. There is very little ash and the unburned residue is in small easily disposable fragments.

6. During the first year the marketing program will include contests and prizes to publicize the product and win the customers.

7. The distributor who worked on the pre-launched product is strongly customer oriented and has an option for exclusive distribution in the city of Kraków. This privately owned firm covers the entire city through two distribution concepts and has over 2,000 small boiler houses as customers that consume 35 to 500 kg (77 to 1,100 lbs) of coal per day.

8. The product launch plan will be developed in detail following company formation. Basic elements of the product launch plan are as follows:

- a. The briquette's physical appearance will help the consumer recognize the product as different from all others. The shape of the briquettes is rather standard so in order to stand out from the competition the briquettes will be colored at the end of the production process using neutral dyes or threads (e.g. gold or red). The briquettes will be available in two different sized bags and in bulk. Once the briquette receives positive acceptance, a public service campaign on improving stove operation will be implemented.

- b. Primary market: Kraków's home stove and small hand-fed boiler owners.

Secondary market: Owners or purchase managers of Kraków's solid fuel combustion boilers (e.g. mix of the briquette with coal fines).

Tertiary market: Same two types of consumers as mentioned above but in Katowice cities.

The primary customer will be middle-aged or older with a below average to average income and a low to intermediate level education. He will be very sensitive to the offer of free promotional gifts and a lottery program.

Sixty-eight percent of the inhabitants of the province of Kraków and 87 percent of the inhabitants of the province of Katowice are city dwellers.

c. Pricing

The maximum price will be based upon market acceptance. The current target price is \$65 per ton which is about a 20 percent below the cost of the most expensive coal.

d. Distribution

Well established, independent local fuel distributors in each city of more than 10,000 (There are four such cities in the province of Kraków and 41 in the province of Katowice.) will obtain the exclusive rights for their areas.

All distributors will receive strong know-how support from the American - Polish joint venture in such areas as staff training, sales and marketing, and accounting.

There is a desire to be known for high-quality delivery service within 24 hours of receiving the order.

Small quantity purchase requirements may be instituted.

e. Promotion

A public relations/ advertising agency will be selected to handle the media campaign.

A strong public relations campaign in the local media supported by government officials and other influential people will create a positive perception of the product.

There will be a limerick contest advertised for the briquette.

Free briquette samples will be offered to anyone who calls during a designated time. This will build the customer data base.

Extensive advertising and direct mailing will inform the public where and how to purchase the product.

There will be incentive programs for first-time buyers.

Primary advertising efforts will concentrate on the local daily paper and the radio.

Volume discounts on bulk purchases are planned.

Much attention will be focused on attracting the adult children and other relatives of stove owners.

After the product has established itself in the marketplace, newspaper advertising space will be purchased for a city official's letter commending the citizens of Kraków for choosing to reduce pollution in their city by using the Acurex briquette.

The names of all customers will appear in the letter in alphabetical order.

VII. OPERATIONS

A. Capital Equipment Investment

1. To start up a completely self-sufficient green field plant may require an investment of \$15 million or more.
2. There is the possibility of bringing into the company some or all of the used equipment owned by of the partners- Euromining.
 - a. The estimated market value of this equipment:
-
-
-
 - b. The estimated actual investment value to be credited as a cash equivalent to the new company:
-
-
-
3. Two investment groups have shown interest in providing capital for company development.

B. Suppliers

1. Coal is the main raw material to be purchased.
2. Both the cost and quality of the coal are important.
3. Plans call for the purchase of washed high-grade coal.
4. Because briquettes are a functional competitor of chunk coal, mine operators will have a tendency to overcharge, delay shipments, and/or substitute lower quality raw material.
5. To avoid this and to obtain the lowest volume price, coal will be purchased through the District Heating Plant that is a part of the current feasibility study.
6. Binder material will be purchased from the supplier with low prices and high quality.

C. Staffing Requirements

1. Management of the Business at the Earliest Stage
 - a. General Manager/Plant Manager

- b. Factory Foreman/ Maintenance Engineer
- 2. Plant Operations
 - a. Lead (skilled) Worker per Shift
 - b. Two to Three Unskilled Workers per Shift
- 3. Administration
 - a. Bookkeeping
 - b. One Skilled Worker

VIII. CORPORATE DEVELOPMENT

C. Expansion Alternatives

Create from the business development exercise in the southern Poland area, alone or in joint venture operations with local companies, additional briquetting operations with coal heating practices similar to those of the Kraków and Katowice areas.

1. The assumption is made that the initial product launch is successful and the market penetration reaches the rate of 25 percent by the end of the first 12 months of operation.

2. Assuming the rate of market penetration will reach the 50 percent target within the second 12 months and considering the potential cash revenue during the second 12 months, expansion options should be examined during the same same period.

3. Alternatives that should be reviewed:

- a. Increasing production for shipment to other markets.
- b. Arranging for other briquette manufacturers to act as contract manufacturers of the Acurex briquette.
- c. Creating alone or in cooperation with other companies, subsidiary manufacturing operations. Possible partners are coal mines, solid fuel distributors and building material distributors.
- d. A mix of alternatives a, b, and c is possible based upon the principal "minimize the risk and maximize the opportunity."

4. The basic aspects included in the review and selection process:

-
-

D. Proprietary Data and Protection.

1. There is a patent issued to Acurex Environmental Corp. from the U.S. Patent Office and covers the following specific claims:

a.

- b.
- c.
- d.
- 2. A patent application has been filed in Poland and Acurex has received confirmation from the Polish Patent Office of its receipt.
- 3. Information kept within the business development team include information relative to the following:
 - a. Product Specifications
 - b. Production Methods and Equipment
 - c. Corporate Strategy
 - d. Marketing Plans
 - e. Product Pricing

VIII. CORPORATE DEVELOPMENT

E. Organization Assumptions

- 1. As in any business start up, the current mix of resources must be brought together to create a successful enterprise. Symbiosis can be the key and in this case seems appropriate.
- 2. The mix of firms currently involved is quite varied in their competencies, therefore, there is a greater number of operating companies than would normally be good for a start up business.
- 3. It is assumed that some firms will be primarily interested in collecting fees, others in collecting royalties, and still others in gaining dividends.
 - a. In any case, considerably strong margins will be needed to satisfy all players.
 - b. High margins can only be attained when costs are kept to a minimum.
 - c. Therefore, the assumptions below are critical.

F. Manufacturing Assumptions

- 1. A manufacturing site in the Katowice area will be leased.
- 2. The site will be on an operating coal mine's property to eliminate possible environmental impact issues. Raw coal will be delivered pre-washed (no coal washing on site).
- 3. The site will have a manufacturing hall of at least 1,000 m²
- 4. The building will have a sufficient power supply.
- 5. The building is already heated or can have heating installed, using waste briquettes as fuel in the boiler.

6. The building will have or can be adapted for heavy footings to support a 10 ton rotating press.
7. The minimum equipment needed:
 - a. Coal quality testing unit
 - b. Material handling equipment from rail siding to manufacturing hall
 - c. Coal crushing to reduce coal to the correct size
 - d. Under cover raw material and finished product storage as a part of the manufacturing hall
 - e. Raw material mixing unit
 - f. One press with rated production of 40 tons per hour (Assume 30 tons per hour after two to three months of production.)
 - g. Under cover air drying to create hard, ignitable product
 - h. Bagging station for 25 and 50 kg bags
8. Such a plant should be able to produce:
 - a. 792 tons of finished product per 24 hour day (three shifts per day, five days per week)
 - b. 127,000 tons per year based upon an eight month production cycle
 - c. 190,000 tons per year based upon a twelve month production cycle
 - d. A three shift operation offers maximum production efficiency.
9. The value of the availability of used presses owned by Euromining:
 - a. Briquetting presses are built to last
 - b. The new company should acquire at least two of these used presses.
10. Euromining will "invest" in the new briquetting company the market value of the purchased equipment.

IX. FINANCIAL PROJECTIONS

A. BALANCE SHEET

Operating year	Start up	Commercial year one	Commercial year two
ASSETS			
Current Assets:			
Cash	(283,524)	(338,941)	122,907
Accounts Receivable	133,737	519,678	1,039,356
Inventories:			
Raw Malt and Supplies	5,833	163,021	326,042
Finished Goods	81,446	316,848	632,968
Total Current Assets	62,509	660,242	2,121,272
Plant and Equipment	1,500,000	2,500,000	3,500,000
Less: Accumulated	300,000	1,100,000	1,800,000
Depr			
Net Plant & Equipment	1,200,000	1,400,000	1,700,000
Deferred Charges	0	0	0
Other Assets	0	0	0
Total Assets	<u>1,137,491</u>	<u>2,060,242</u>	<u>3,821,272</u>

LIABILITIES AND INVESTOR EQUITY

Current Liabilities:			
Accounts Payable	163,083	271,713	500,093
Notes Payable	0	0	0
Accrued Expenses			
	0	0	0
State & Local taxes	0	0	106,530
Other	0	0	0
Total Current Liabilities	163,083	271,713	606,623
Long Term Liabilities:			
Long Term Notes	0	0	0
Other Liabilities	0	0	0
Investor's Equity			
Common Stock	30,000	30,000	30,000
Capital Surplus	1,500,000	2,500,000	3,500,000
Retained Earnings	(555,592)	(741,471)	(315,351)
Total Investor's Equity	<u>974,408</u>	<u>1,788,529</u>	<u>3,214,649</u>
Total Liabilities and	<u>1,137,491</u>	<u>2,060,242</u>	<u>3,821,272</u>
Inv. Equity			

B. PROFIT & LOSS

Operating Year	Start Up	I Commercial Year	II Commercial Year
Market Share	0.0%	25%	50%
Gross Sales	802,420	3,118,067	6,236,134
Sales Deductions	0	0	0
Value Added Tax	0	406,704	813,409
Net Sales	<u>802,420</u>	<u>2,711,363</u>	<u>5,422,725</u>
Variable Materials	35,000	978,125	1,956,250
Variable Labor	20,000	49,298	98,595
Variable Overhead	10,000	24,649	49,298
External Engineering Services	501,820	0	0
Extraordinary Manuf. Loss	0	19,563	39,125
Variable Cost of Sales	<u>566,820</u>	<u>1,071,634</u>	<u>2,143,268</u>
Fixed Overhead	0	195,625	391,250
Other Cost of Sales	0	0	0
Total Cost of Sales	<u>566,820</u>	<u>1,267,259</u>	<u>2,543,518</u>
Gross Profit	<u>235,600</u>	<u>1,444,104</u>	<u>2,888,208</u>
Advertising	50,000	77,114	54,227
Promotions	25,000	52,114	54,227
Deals	25,000	52,114	54,227
External Marketing Services	300,680	60,000	60,000
Sales Freight	500	391,250	782,500
Other Distribution Expense	30,500	19,563	39,125
Service Fees	<u>10,000</u>	0	0
Total Direct Expense	<u>441,680</u>	<u>652,153</u>	<u>1,044,307</u>
Product Contribution	(206,080)	791,950	1,843,901
Sales Costs	10,000	54,227	108,455
Marketing	10,000	54,227	108,455
Administration			
Provision for Bad Debt.	<u>4,012</u>	<u>13,557</u>	<u>27,114</u>
Total Sales Expense	<u>24,012</u>	<u>122,011</u>	<u>244,023</u>
Net Product Contribution	<u>(230,092)</u>	<u>669,939</u>	<u>1,599,878</u>

Other Functional Expense	0	0	0
Other Expenses	3,000	13,557	27,114
Royalty/Service Fee Expense	0	156,500	313,000
Contributions	2,500	13,557	27,114
Total Other Expenses	<u>5,500</u>	<u>183,614</u>	<u>367,227</u>
Operating Profit (Cash Flow)	<u>(235,592)</u>	<u>486,325</u>	<u>1,232,651</u>
Depreciation	300,000	500,000	700,000
Debt. Service	0	0	0
Other Before Tax Expense	<u>20,000</u>	<u>0</u>	<u>0</u>
Charges to Operating Profit	<u>320,000</u>	<u>500,000</u>	<u>700,000</u>
Profit before tax	<u>(555,592)</u>	<u>(13,675)</u>	<u>532,651</u>
Income Tax	0	0	213,060
Tax Credits	0	0	106,530
Net profit	<u>(555,592)</u>	<u>(13,675)</u>	<u>426,121</u>
CUM Product Contribution	(206,080)	897,041	2,740,941
CUM Operating Profit	(235,592)	378,529	1,611,179
CUM Net Profit	(555,592)	(741,471)	(315,351)

C. CASH FLOW

Operating Year	Start Up	Commercial Year One	Commercial Year-Two
Net Income	(555,592)	(13,675)	426,121
Plus: Depreciation	<u>300,000</u>	<u>500,000</u>	<u>700,000</u>
	(255,592)	486,325	1,126,121
Sources & Uses From Operations:			
Change in A/R	(133,737)	(207,871)	(519,678)
Change in Inventories	(57,2779)	(191,802)	(479,505)
Change in A/P	163,083	81,352	228,380
Change in N/P	0	0	0
Change in Taxes Payable	<u>0</u>	<u>0</u>	<u>106,530</u>
	(27,932)	(318, 321)	(664,273)
Sources & Uses From Investing			
Purchases of Fixed Assets	0	(1,000,000)	(1,000,000)
		(1,000,000)	(1,000,000)
Sources & Uses From Financing:			
Financing Activities:	0	<u>1,000,000</u>	<u>1,000,000</u>
	0	1,000,000	1,000,000
Net Change in Cash	(283,524)	168,004	461,848
Beginning Cash Balance	<u>0</u>	<u>(506,945)</u>	<u>(338,941)</u>
Ending Cash Balance	<u>(283,524)</u>	<u>(338,941)</u>	<u>122,907</u>

D. KEY RATIOS

Operating year	Start Up	Commercial Year One	Commercial Year Two
PROFIT LIABILITY RATIOS			
Return in Equity	- 36.3%	-0.7%	14.1%
Cumulative Return on Equity	-36.3%	-36.5%	-12.5%
Return on Assets	- 41.7%	-0.9%	14.5%
Profit Margin on Sales	-69.2%	-0.5%	7.9%
LIQUIDITY RATIOS			
Current Ratio	-0.38	2.43	3.50
Acid Test Ratio	-0.92	0.67	1.92
ACTIVITY RATIO			
Receivable Turnover:	12.00	6.52	6.96
Days to Turnover	30.42	55.97	52.47
Inventory Turnover:	5.88	2.75	2.90
Days to Turnover	62.11	132.59	125.68
Asset Turnover:	0.60	1.78	1.84
Net PV Future Money	\$3,019,272	\$ 3,476,611	\$3,755,460

E. P&L LINE EXPLANATIONS

PARAMETERS:

Depreciation; Straight Line; 5 year

All Numbers Quoted in 1992 US \$ (No Inflation)

End Users Price of Coal Per Ton	84.00
End User Price of Briquettes Per Ton	69.30
Value Added Tax	15%
Variable Material Costs Per Ton	25.00
Manufacturing Labor (Hrs Per Ton)	1
Cost of Labor Per Hour	1.26

Market Share Bases:

No of Stoves	100,000
Efficiency Diff - Coal v. Briquettes	17%
Briquette Consumption in Home Stoves (Tons)	156,500
Coal Consumption in Home Stoves (Tons)	130,000

Variable Overhead As % of Labor Cost Per Ton	50%
Extraordinary Manuf. Loss Per Ton	0.50
Fixed Overhead Per Ton	5.00
Other Cost of Sales Per Ton	0.00
Advertising As % of Net Sales	1%
Promotion As % of Net Sales	1%
Deals As % of Net Sales	1%
External Marketing Service Per Month	5,000
Distribution (Sales Freight) Per Ton	10.00
Other Distribution Expenses Per Ton	0.50
Service Fees As % of Net Sales	0%
Service Costs As % of Net Sales	2%
Marketing Administration	2%
Provision For Bad Debt As % of Net Sales	0.5%
Other Expenses (Phone, etc.) As % of Net Sales	0.5%
Royalty Fee (License) Per Ton	4.00
Contribution As % of Net Sales	0.5%
Tax Rate	40%
Tax Credits As % of Income Tax	50%
Discount Rate	7%