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KRAKOW CLEAN FOSSIL FUELS AND ENERGY EFFICIENCY PROJECT

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INTRODUCTION

In Krakow, Poland almost half of the energy used for heating is supplied by local, solid-fuel-fired boilerhouses and home stoves. These facilities are referred to as the "low emission sources" and are primary contributors of particulates and hydrocarbon air pollution in the city and secondary contributors of sulfur dioxide and carbon monoxide.

The Support for Eastern European Democracy (SEED) Act of 1989 directed the U.S. Department of Energy (DOE) to undertake an equipment assessment project aimed at developing the capability within Poland to manufacture or modify industrial-scale combustion equipment to utilize fossil fuels cleanly. This project is being implemented in Krakow as the "Krakow Clean Fossil Fuels and Energy Efficiency Project" and funding is being provided through the U.S. Agency for International Development. The Project is being conducted in a manner that can be generalized to all of Poland and to the rest of Eastern Europe.

The project details have been developed through extensive working contacts between DOE and Polish representatives. The project plan includes three phases which have been developed around five specific subprojects. In Phase I, which continues through summer of 1993, technical and economic assessments will be made of pollution reduction options for the five subprojects. Phase II plans call for public meetings in the U.S. and Poland for companies interested in forming joint ventures. Information is available in these meetings to enable companies to identify markets and select potential partners that meet with their capabilities and interests. In Phase III, as early as the Fall of 1992, DOE will issue a solicitation for Polish/American joint ventures to perform commercial feasibility studies for the supply of U.S. technology applicable to one or more of the five subprojects. The selected joint venture companies would receive assistance in the form of cooperative agreements requiring at least 50% cost-sharing to perform those activities necessary to permit them to conduct business in Poland.

The five specific subprojects which have been defined include:

Subproject 1. Extensions to the district heating system to allow elimination of smaller, local boilerhouses which are more polluting than the central sources of heat. This subproject also includes building conservation activities which can also allow elimination of some local boilerhouses.

Subproject 2. Conversion of small, hand-fired boilers to natural gas or replacement with advanced coal combustion options.

Subproject 3. Elimination of home stoves by increased use of electric heating in selected parts of the city.

Subproject 4. Modernization of boilerhouses through replacement of existing boilers with modern units or refitting existing boilers to improve operations and reduce emissions.

Subproject 5. Use of improved home stove designs and/or improved coal fuels to reduce emissions.

The Phase I studies involve efforts both on the Polish and the U.S. side. Because of the emphasis on conservation in Subproject 1, DOE/Conservation and Renewable Energy is the lead DOE office for this subproject. Subprojects 2 through 5 are being managed by DOE/Fossil Energy through Pittsburgh Energy Technology Center (PETC). Brookhaven National Laboratory (BNL) as well as Burns and Roe Services Corporation (B&RSC) are supporting PETC. Work in Krakow is being managed by the Biuro Rozwoju Krakowa (BRK or Krakow Development Office) and for Subprojects 2 through 5 BRK is working under subcontract to BNL.

OBJECTIVES

The objective of BNL's efforts are to work with PETC, BRK and B&RSC to develop the technical and economic basis needed to evaluate options for reducing air pollution due to the low emission sources within the bounds of Subprojects 2 through 5 defined above.

ACCOMPLISHMENTS AND STATUS

The subprojects each involve the following three elements:

Engineering Analysis-To develop costs for selected options

Testing-To develop baseline emissions and efficiency data as well as to provide an assessment of the emissions reduction potential of selected options

Incentives Analysis-To identify economic incentives that the city of Krakow can use to encourage the use of pollution reduction options which have been shown to be attractive. An emphasis is being placed on legal system changes which can provide opportunities for growth of industries in Poland which contribute to the clean-up.

In addition to these elements Phase I includes a public relations program which will serve to inform the residents of Krakow about the project and to obtain inputs about their views which may affect the options selected and incentives applied. This public relations activity has been started recently. The accomplishments and status of the other three elements are discussed below.

Engineering Analysis

In preparation for this project the City of Krakow conducted a detailed survey of the population of boilers which are among the low emission sources. This survey provides a basis for assessing the relative importance of each of the boiler types. From the survey, there are 2,248 boilers that consume 375,000 metric tons of solid fuels annually of which 77% is coal, the remainder coke. These include two basic types: gravity feed, travelling grate boilers and hand-fired boilers. The table below summarizes the number and fuel use of these. There is a very recent trend toward increased coke use in the hand-fired boilers and this will effect the values given in this table.

Boiler Type:	Number:	Coal Use (mt/year):	Coke use (tonnes/year):
Overfeed, travelling grate stoker	227	233224	1250
Hand-fired	2021	52023	85119

In the case of the travelling grate boilers 85% of the coal consumption is in boilers which have cyclone dust collectors. The remainder have no controls. Only 19% of the hand-fired boilers have cyclones.

Under Subproject 2 BRK has completed detailed engineering studies of the conversion of 48 local boilerhouses situated within the historic Old Town part of Krakow to natural gas. During the heating season the air quality in this part of the city is dominated by emissions from these boilerhouses as well as the home stoves in the area. Conversion to gas in Old Town is part of the city's master plan and the results of these studies are being used to encourage this through incentives as needed.

<u>Testing</u>

STOVES - A facility for studying the emissions and efficiency of the home coal stoves has been built at the Academy of Mining and Metallurgy (AGH) in Krakow under the direction of BNL and with equipment provided from the U.S. under this program. The system uses a dilution tunnel method [1,2], to determine gaseous pollutant emission rates and flue gas energy loss on a continuous basis. Particulate emissions are averaged over firing cycles.

Large "masonry" or "tile" stoves are most commonly used in Krakow. These are fired at 12 or 24 hour intervals, heating the massive structure. After the firing cycle, which lasts for about 1 1/2 hours, the room continues to be warmed by the heat stored in the masonry. Stoves of this type typically heat one room. Some Krakow residents also use newer cast iron stoves and these are included in this test program.

Coal is supplied to Krakow from the nearby Upper Silesian Basin. This is typically a very high ash, low sulfur coal. While some of the coal is washed, the fuel used in Krakow is generally run-of-mine. One approach being considered for reducing emissions from these stoves involves the use of different fuel. This may include washed and/or graded coal, briquetted coal fines, and briquettes processed to have reduced volatiles. A fuel in this last category has been supplied for this program from the nearby Institute for the Chemical Processing of Coal at Zarbze [3]. Basic properties for these briquettes as well as for the other fuels which are included in the AGH test program to date are included in the following table.

	Wujek Mine	B. Smiawy Mine	Zabrze Briquettes
Ultimate Analysis			
C	80.04	61.15	79.20
H	4.81	4.15	1.60
N	1.19	0.98	1.16
O	8.22	9.22	4.42
S	0.28*	0.65*	0.26*
Water	2.12	2.11	2.36
Ash	3.34	21.74	11.0
Heating Value:			
KJ/kg	31354	24616	27646
Btu/Lb.	13495	10595	11899
Volatiles (% as received)	32.1	30.3	8.14

*"combustible" sulfur- total sulfur is typically 0.8 to 1.0%

The data taken during a 24 hour stove test provides continuous measurement of the emission rate of gaseous pollutants, the emission rate of combustion products from the stove, and the stove internal and exit gas temperatures. Using these, the emission factors for the run as well as the stack gas losses can be calculated. The energy loss due to heating value of the filterable and condensible particulates can only be determined on an integrated basis for the run and this is needed to complete the efficiency determination.

To illustrate the general nature of stove operation Figure 1 shows the emission rate of CO and CO_2 over the 1.3 hour "burn" part of the cycle. The emission rate of CO_2 can be used as a measure of the combustion rate. Initially, the coal volatiles burn giving high combustion rates as well as high emissions of CO (based on Figure 1). After about 0.3 hours much of the volatiles are burned off, the combustion rate remains fairly high but the CO emission rate decreases. In addition to the lost volatiles it is likely the higher temperatures of the combustion chamber and the masonry flue passages also help keep the CO down from about 0.4 to 0.9 hours. At the 1 hour point the top door of the stove was closed leading to a gradual reduction in the combustion rate but a dramatic increase in the CO emission rate. A very significant part of the total CO emission rate clearly occurs after this top door has been closed. When the lower, ash pit door is finally closed at about 1.3 hours the combustion process clearly stops.

For this specific test the integrated energy loss is 33%. The emission factors for CO, NO_X, and SO_2 are 40.1, 6.5, and 5.3 g/kg coal as fired respectively. These roughly compare

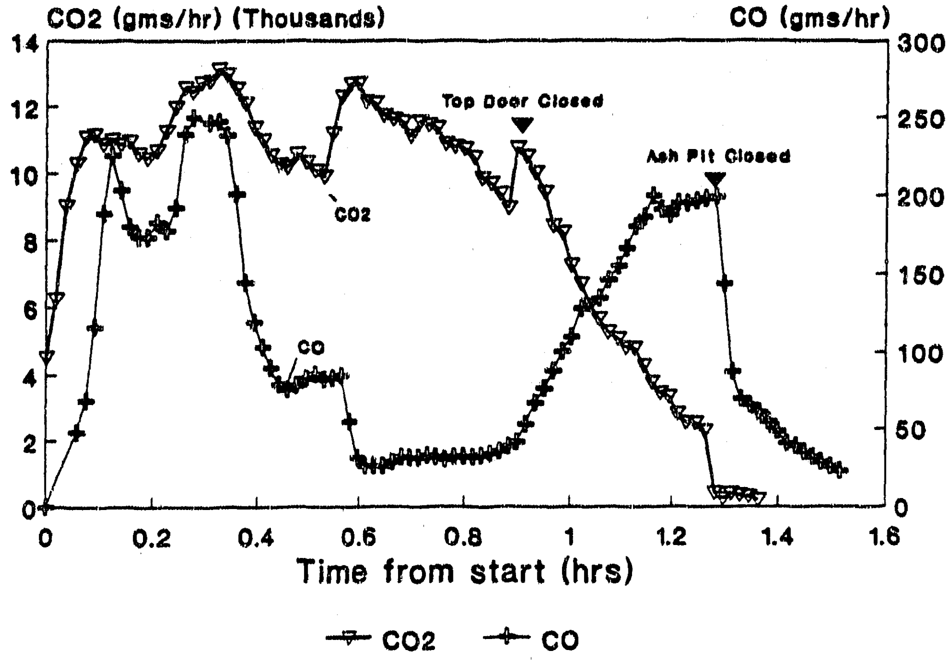

Figure 1. Illustration of stove test results. CO_2 and CO emission rates.

with prior published data for stoves. Particulate emissions for this test were on the order of 20 g/kg coal.

Test results to date indicate that the stove efficiencies are on the order of 65%. The performance is dependent on the operating procedures and some tests are in progress to quantify this. With the lower volatiles content briquettes the particulate emissions are reduced by a factor of 10 or more and this may offer a very attractive option.

BOILERS- Testing has been planned for four boilers in Krakow. This includes two which are fired with mechanical stokers and two which are hand-fired. Both of the stoker-fired units have cyclones and one has overfire air ports. One of the hand fired units will be tested with coke and the other with coal. In addition to providing baseline data these tests will serve to evaluate the general operating practices and the possible reduction in emissions using improved fuels. To date tests have been completed at one site-the Balicka boilerhouse, a mechanical stoker unit.

The unit tested at Balicka is a hot water boiler rated at 12 MW (40,000 Btu/hr) output. The unit provides heat into the district heating system and was built in 1972. The normal fuel is unwashed duf (0 X 20mm) from the Ziemowit mine in Silesia. Beyond some baseline tests done with this coal most of the testing was done with both run-of-mine and washed coal from the Stasciz mine. These coals will also be used at the other planned test sites. The properties of the Stasciz coals and a coke to be tested at other sites is listed below. The unwashed Stasciz coal is very typical of the coals used in all of the stoker fired boilers in Krakow.

	ROM Staszic	Washed Staszic	Knurow Coke
Ultimate Analysis			
C	61.33	72.03	85.92
H	3.66	4.57	0.27
N	0.93	0.95	0.89
O	7.52	9.44	2.90
S	0.47*	0.31*	0.77*
Water	2.99	5.38	1.50
Ash	23.10	7.32	7.75
Heating Value:			
kJ/kg	21918	26247	24549
Btu/Lb.	94335	11297	10566
Volatiles (% as received)	26.9	31.9	0.80

*"combustible" sulfur- total sulfur is typically 0.8 to 1.0%

Normal operating practice at Balicka calls for all air dampers to remain fixed for the entire heating season. This leads to very high excess air-to 400%- at low firing rates. Load in the tests was limited to 65% of rated output. Higher loads produced unacceptable bottom ash combustible losses. The poor condition of the air and flue gas dampers prevented the desired range of operating conditions to be reached. At the conditions tested emissions and thermal performance were very typical for units of this type.

Based upon the available information about the boiler population and the availability of at least some test data it is interesting to make a comparison of the relative contribution of the various types of low emission sources. This has been done combining the above boiler and stove data as well as emission factors published by the U.S. EPA [4] for hand fired boilers. The results are shown in Figure 2 below. Fuel use is clearly dominated by the mechanical stoker-fired boilers and these are the greatest source of SO_2 and NO_X emissions but the coal stoves and the hand fired boilers are the greatest source of CO and particulates and these certainly deserve at least equal attention.

Incentives Analysis

One objective of Phase I of the project is to examine incentives that the local government could use to promote cost-effective options for improving the air quality in Krakow. This analysis will incorporate all results from the testing and engineering analysis activities.

Increasing fuel prices will be a significant determinant of the relative costs and benefits

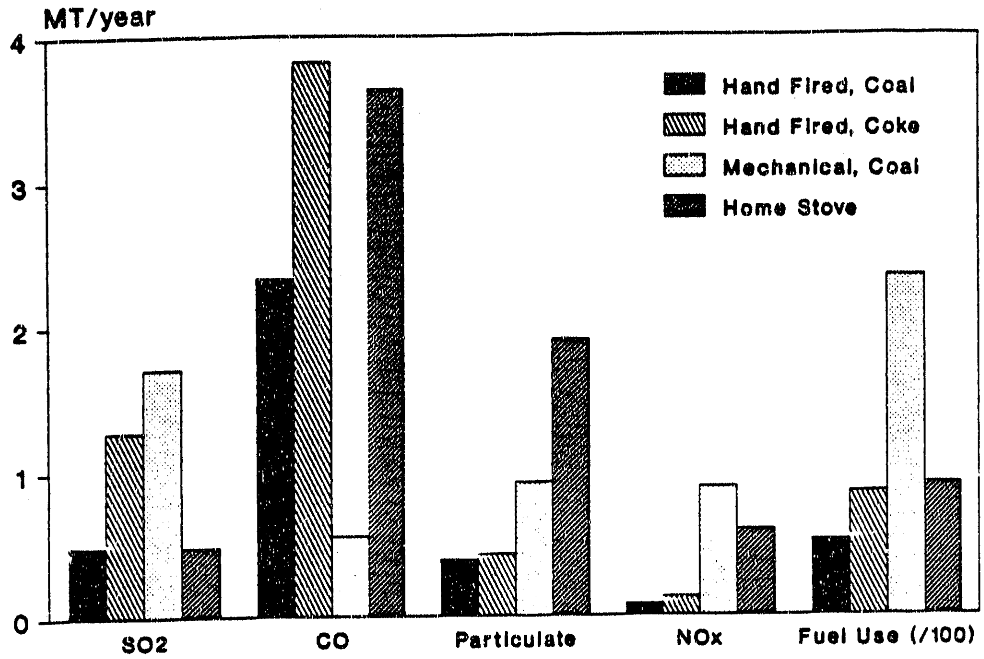

Figure 2. Comparison of fuel use and estimated emissions from low emission sources.

of the alternatives. Fuel price projections have been prepared for natural gas, coal, and electricity. Current prices are close to world levels, and coal prices are expected to grow at an annual rate of approximately 2.3 percent to 1995, and between 1 and 2 percent per year through 2010. Electricity prices are directly related to coal prices, because production of electricity is based on coal. By 1997, sector-specific electricity prices are expected to reach the desired ratio to coal prices. The forecast is similar for natural gas.

Along with fuel price projections, an analysis has been completed on the restructuring and privatization of the energy industries necessary to achieve world energy prices and local control of pricing policies. Legislative activity has started in this area.

Poland currently has a system of fines and penalties for air pollutant emissions from boilers. Allowable levels and penalties for exceeding those levels have been established for dust, SO_2, NO_x, CO, benzo-α-pyrene, and soot. An examination of the shortcomings of the current system and recommendations for improvement have been completed. The system is based on the type of boiler, including pollution control equipment, and the fuel, and provides an incentive for gas use. Proposed modifications could provide a basis for emissions trading.

PLANS

Engineering Analysis

In selected parts of the city of Krakow detailed studies will be completed of the cost of increasing the use of electric heating to reduce coal use. Costs at the room, building and grid levels will be evaluated. Conversion to electric heating, and time-of-day rates are not uncommon in Krakow buildings. Often the conversion includes the insertion of electric resistance elements into the firebox of an existing masonry stove.

Studies are planned of the cost of producing the types of improved fuels which might be used to reduce emissions from these sources. This will include consideration of preparation plant waste disposal costs. Presently the most attractive option appears to be some form of briquette with reduced volatiles content.

Detailed air quality analyses are planned to evaluate the effects of the options under consideration on the city. These are being done by a firm in Krakow, under contract to BRK.

Testing

Additional testing on stoves will include evaluation of operating effects, tests with a Polish cast iron stove, tests with additional devolatilized coal, and tests with one U.S. made stove. Boiler testing will include one additional travelling grate stoker-fired boiler, and two hand fired boilers. In one of the hand fired boilers the briquettes from Zabrze will be tested.

Incentives Analysis

Further work will incorporate all results from testing, engineering and the public relations activity, specifically fuel price elasticities, and examine incentives such as rebates or subsidies to encourage consumers to purchase efficient less-polluting equipment. Joint-venture opportunities are also being examined.

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