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Accomplishments of the American-Polish Program for Elimination of Low Emissions in Kraków

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INTRODUCTION

Since 1990 the U.S. Department of Energy (USDOE) has been involved in a program aimed at reducing air pollution caused by small, coal-fired sources in Poland. The activity is focused on the city of Cracow, Poland with the intention that results will be applicable and extendable to the entire region.

Formal basis for the U.S. assistance to Poland in this area was provided by the Support for Eastern European Democracy (SEED) Act of 1989. Part of this legislation directed the U.S. Department of Energy to cooperate with U.S. and Polish experts to undertake an assessment program in Poland to use fossil fuels cleanly in small-scale combustion equipment. This program became specifically directed toward the emissions problems of low emissions sources in Cracow.

Funding for this program has been provided to DOE by the U.S. Agency for International Development (USAID). In 1991, USAID and USDOE signed an interagency agreement to conduct the project. Representatives from both organizations worked with Polish officials to establish an eight-member Bilateral Steering Committee (BSC) to plan and oversee the Program. The BSC includes representatives of:

- Office of the President of the City of Cracow
- Department of Environmental Protection, Cracow Province
- Polish Ministry of Environmental Protection
- U.S. Agency for International Development
- U.S. Department of Energy

In 1991, U.S. and Polish officials signed a Memorandum of Understanding formally initiating and directing the Cracow Clean Fossil Fuels and Energy Efficiency Program.

Developing a program approach for the most effective use of the available funds required considerable effort on the part of all project participants. The team recognized early that the cost of solving the low emissions problem even in only one city far exceeded the amount of available U.S. funds. Economic conditions in Poland limited availability of local capital funds for environmental projects. Imposing environmental costs on struggling companies or city residents under difficult conditions of the early 1990's required careful consideration of the economic and political impacts. For all of these reasons the program sought to identify technologies for achieving air quality goals which, through improved efficiency and/or reduced fuel cost, could be so attractive economically as to lead to self-sustaining activities beyond the end of the formal project.

The effort under this program has been focused into 5 main areas of interest as follows:

1) Energy Conservation and Extension of Central Station District Heating.

2) Replacement of Coal- and Coke-Fired Boilers with Natural Gas-Fired Boilers.

3) Replacement of Coal-Fired Home Stoves with Electric Heating Appliances.

4) Reduction of Emissions from Stoker-Fired Boiler Houses.

5) Reduction of Emissions from Coal-Fired Home Heating Stoves.

In addition the BSC defined three major phases for the work. Phase I consisted of information gathering and analysis of technical alternatives. In this phase various technological alternatives for pollution reduction were identified. Combustion tests were performed to measure the emissions reduction performance of each technology, and economic analyses were performed to determine the cost of implementing these alternatives. Regulatory and financial incentives were identified to encourage the implementation of these technological alternatives. Phase I was conducted cooperatively by numerous organizations, under DOE direction including: Biuro Rozwoju Krakowa (BRK), Brookhaven National Laboratory, Pacific Northwest National Laboratory, Electrotek Concepts, Inc., Cracow Polytechnic University, and the Academy of Mining and Metallurgy. Phase I studies including an energy conservation demonstration, air quality impact studies, public opinion studies, source test results, and option analyses are all described in the Phase I report [1].

Phase II consisted of three public meetings designed to inform U.S. and Polish businesses about the the program and its opportunities. The meetings were held in Chicago, Illinois and Washington, D.C. in June 1992 and in Cracow in November, 1992.

Phase III consists primarily of projects conducted cooperatively by U.S. and Polish companies to introduce U.S. technologies and services to reduce emissions in Cracow. Projects were selected through a solicitation issued by the U.S. DOE in September, 1992. The solicitation requested proposals from U.S. firms for cost shared Cooperative Agreements. U.S. firms that proposed were strongly encouraged to include Polish firms as team members. The minimum cost sharing was 50% to be provided by the U.S. firm, its Polish team members, or third party investors.

Following the evaluation process a total of nine firms were selected for awards of Cooperative Agreements in the Cracow Program. The scope of work for each of these programs has been described earlier [2,3]. Some of the projects terminated before completing the full planned scope for various reasons. This paper provides a summary of some of the achievements which have been realized to date by work under Phase III of the program.

In parallel with the Phase III Cooperative Agreement projects, the BSC has commissioned some additional work to be done in Cracow. Generally this work addresses needs of the City of Cracow in planning for the long term changes in energy use and also addresses some aspects of the LES problem for which no Phase III proposals were received. This work includes: development of an updated source database, preparation of an energy plan for specific city districts, economic and incentives studies, information dissemination, and assistance in the conversion of hand-fired boilers in the central part of the City.

PHASE III ACCOMPLISHMENTS

The companies and projects selected for Phase III cost-sharing had two major goals - to help reduce pollution in Cracow and to establish joint-venture companies that would continue to thrive in Poland

and Eastern Europe after DOE cost-sharing ended. Each company's unique characteristics and strengths helped it meet the challenges of finding suitable Polish partners and implementing its project. The projects met with varying degrees of success, but all have expanded U. S. presence in Poland and have contributed demonstrable improvements to the air quality in Cracow.

Control Techtronics International, Inc.

Control Techtronics International, Inc. (CTII) is a controls manufacturing firm based in Harrisburg, Pennsylvania. The company, established in 1984, specializes in the design, development, manufacture, and application of advanced combustion and process control systems. CTII is very active in the U.S. market as well as in specific growth markets worldwide.

Under this project, the CTII team sought to introduce to the Polish market their advanced control technology for stoker-fired boilers. Controls were installed on five stoker-fired coal boilers at the Balicka boiler house. This plant is owned by MPEC, Cracow's district heating company, and supplies heat to a nearby housing development and process steam to local industry. Three hot water and two steam boilers were fitted with the automatic controls. The project also included operator training.

Partners in the project included two Polish companies, Energoaparatura (ENAP) and Naftokrak-Naftobudowa (NK-NB). ENAP was responsible for the control panel fabrication and NK-NB for the controls installation. The controls and inverters were manufactured in the U.S. by CTII. Pennsylvania State University and Cracow's Polytechnic University worked together to translate technical manuals and provide operator training. Cracow Polytechnic also provided performance testing of the boilers.

Automated Boiler Controls

Stoker-fired boilers are commonly used throughout Central and Eastern Europe. Small and mid-sized coal-fired power plants utilize traveling grate stokers to produce steam or hot water that is used by district heating systems and industries. Advantages of stokers include fuel flexibility and relatively modest requirements for fuel preparation.

In Cracow one approach to address the air pollution emissions from the existing stoker boiler population is simply to replace the stoker plants. However there are some points in favor of keeping the existing stoker plants. Beyond conversion investment and low operating cost the performance of these plants may be improved through improved operations. Dramatic improvements can be made to the efficiency and emissions level of these existing plants for significantly less money than replacement cost. This has essentially been the motivation behind the Control Techtronics project.

Stoker-fired boilers were tested as part of Phase I of this program to provide baseline performance and emissions data. The boilers were in very typical condition - furnace pressure, firing rate, and excess air were all manually controlled, allowing operators limited regulation of the combustion process. Testing was done at three load levels. Efficiencies were 51% at minimum load, 63% at average load, and 74% at maximum load for the WR-10 boilers. In normal operations combustion

air flow was not reduced as firing rate decreased in response to normal load changes. The result is very high excess air levels - to 500% - at low load. This testing was done with a coal duf that was normally used in the stoker boilers. Testing was also performed with different coals and with greater attention to optimizing grate speed and controlling combustion air flow during the tests. In these tests, efficiencies were about 73% at all load levels.

Similar baseline testing was done on a PLM 2.5 boiler at a different site again in cooperation with MPEC. Efficiencies under normal operating conditions were around 53%, and increased to around 70% with different fuels and great effort put into adjusting excess air. Greater technical detail on pre-conversion boiler operation and testing can be found in the previous chapter and in the Phase I Report [1].

As discussed in the previous chapter, Phase I of the Program included a comparison of the costs and benefits of a wide range of options for addressing the low emission sources. With the analysis tool developed for the program, the Control Techtronics project specifically was shown to provide emission reductions with a net cost savings for the boiler house owners [1].

Another important aspect of the CTII project is operator training. Even with advanced controls and proper fuel, efficiency and emissions benefits can be realized through proper operating procedures. The basis for the operator training program was educational material developed by the Pennsylvania State Facilities Engineering Institute in the U.S. Team members worked closely with faculty members at Cracow Polytechnic University to translate this educational material and adapt it to Polish conditions. Training sessions were implemented in Cracow, by the Polytechnic University. These training materials will serve as one of the enduring tools for improving performance of these boilers.

Installation of Controls at the Balicka Boiler House

The Balicka boiler house was built over the 1968-1972 time frame and has three Polish WR 10 boilers and two WLM 2.5 hot water boilers supplying heat to the residential buildings of the Widok housing development and two PLM 2.5 steam boilers supplying process steam to nearby industries. Two complete automatic control systems were installed - one managing the operation of the three WR 10 boilers, and the second managing two PLM 2.5 steam boilers. The measured control parameters are: water flow and outlet temperature for water boilers or steam flow and pressure for steam boilers, combustion chamber pressure, and flue gas oxygen content as a measure of excess air. On each of the boilers the automatic system controls three parameters: stoker grate speed (to adjust firing rate), forced draft fan speed, and induced draft fan speed. After the installation, one of the WR 10 and one of the PLM 2.5 boilers at Balicka were tested for efficiency and emissions. Results show that use of controls reduced particulate emissions by 85 percent and resulted in energy savings of 25 percent. Figure 1 illustrates these dramatic results.

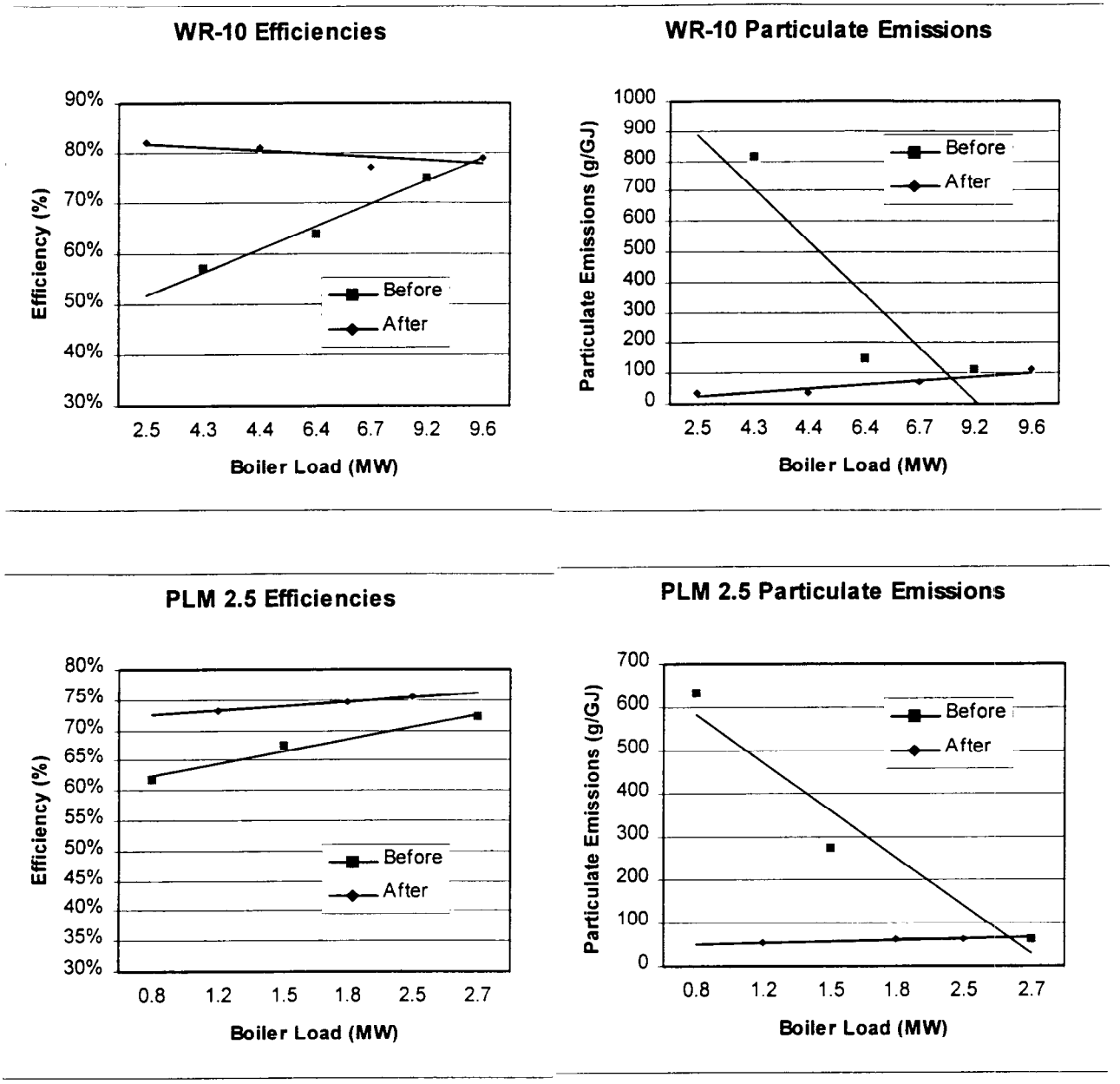

Figure 1. Results of installation of CTII controls at Balicka boiler house.

Project Impact

During the 1995-1996 winter, the Balicka boiler house accounted for 8 percent of the coal burned in Cracow's stokers and 8 percent of the particulate emissions from stoker boilers. Reducing particulate emissions by 85.5 percent at Balicka also reduced overall stoker emissions in Cracow by 7 percent. If all stokers were similarly upgraded, total LES particulate emissions in Cracow would be reduced by 31 percent. In addition to the energy and emissions reductions, the boilers can now be operated at lower loads than previously. With the fuel reduction due to improved efficiency, this

project has a payback of about 2 years. Clearly, automated controls on the stoker-fired boilers is a viable, cost-effective approach to reducing particulate emissions for Cracow.

Activities Beyond the Project

CTII has formed a joint-venture subsidiary, CTI-Polska, to continue its presence in Poland and Eastern Europe. CTI-Polska is now well established in the Polish and Eastern European markets to represent CTII sales and local engineering/field service objectives. From Poland, CTII has gone east to the middle of Siberia for its largest job to date, in conjunction with an informal joint venture with a Polish subsidiary, Neko-CTI. The city of Novokuznetsk has nine CTII control systems installed in five boiler houses around the city. Poland and Russia combine to form the largest market in the world for these control systems and CTI-Polska and Neko-CTI have been established to service this market.

Honeywell Inc.

Honeywell is a major worldwide controls manufacturer, established in Minneapolis in 1885. It's first European subsidiary began in 1934; now Honeywell operates in 95 countries.

Honeywell's project produced very significant accomplishments in enhancement of district heating and reduction of pollution from local coal-fired boilers. While their work reached many different project sites, the main area was the Balicka District Heating Network. This local network is isolated from Cracow's main district heating network and is supplied with heat from the Balicka boiler house on Lindego Street. This is the same boiler house where CTII installed combustion controls and Honeywell and CTII cooperated in the area of control interface. The following table provides a breakdown of the load served by the MPEC Balicka boiler house:

Consumer Group	% of Consumption
WIDOK Housing Cooperative	46.0
Industry	39.0
Widok Zarzecze Estate - single family houses	10.0
Detached single family houses	5.0

The Widok Housing Cooperative includes 22 buildings with 2,750 apartments, and houses 7,500 residents. Prior to the program, each building had hydroelevator nodes in the basement which mix return water with very hot district heat system water for distribution to radiators. In the apartments there was no possibility for individual room temperature control.

Beyond the Balicka District Heating System the Honeywell project involved the Bienczyce Housing Estate --another coop with 47 residential buildings and 16,000 inhabitants, Jana Pawla II Hospital, Narutowicza Hospital, and many other sites. Specific accomplishments of this project include:

- Installation of controls at the Balicka boiler house covering the internal mixing node, the water purification system, supervision of the entire Balicka District, and measurement of flue gas composition, and flow.

- Installation of 50 heat exchangers replacing hydroelevators in buildings of the Widok housing estate (installed capacity 14.05 MW)

- Installation of 14 heat exchanger stations and connection to the Balicka network of the Academy of Agriculture and several public buildings.

- Upgrading controls at an existing heat exchanger serving the Widok Zarzecze housing estate.

- Complete reconstruction of heat exchangers and heat distribution at Jana Pawla II and Narotowicza hospitals. Central control systems were installed at both of these sites.

- Installation of a separate supervisory and data collection system for heat meters located in the Balicka area.

- Installation of 80 building heat meters for the Widok Zarzecze housing estate.

- Upgrading internal building heating systems in: Widok housing estate (25 buildings), Widok Zarzecze Housing estate (25 buildings) and the Bienczyce Housing Estate (8 multistory residential buildings). This work included removing, cleaning, and reinstalling radiators, installation of Thermostatic Radiator Valves (TRVs), testing and restarting of the system, and training of the residents. In the Balicka area alone (excluding Bienczyce) 13,525 TRVs were installed.

- Removal of 4 large local boiler houses and replacement with 4 heat exchanger installations (11.8 MW capacity). These boilers were located on the main network and Honeywell cooperated with ECKSA in this case. ECKSA is the company which operates Łeg - the cogeneration plant that supplies the city's main district heating network.

- Cooperation with ECKSA on the installation of 85 additional heat exchanger substations allowing the elimination of local coal-fired boiler houses (41.0 MW capacity). These sites were again connected to the main network. Honeywell's role at these sites was limited to delivery of instrumentation and control and related project services such as project management, engineering, installation and start-up.

Project Impacts

At the Widok Housing Estate two methods were used to estimate the impact of replacement of hydroelevators with controlled heat exchangers, installation of TRVs in apartments and general overhaul of internal heating systems. In the first method, energy use in modernized buildings was compared to that in very similar buildings that had not been modernized. In the second method, energy use in specific buildings was compared before and after modernization. Modernized buildings used 7-17% less energy --although, in some cases, savings over 25% were determined. Considering all of the data analyzed, Honeywell estimates an average energy savings in buildings of 15%. Honeywell further estimates that energy use will be reduced an additional 5% in the future as residents become more experienced with the TRVs.

The improvements made to the district heating network supplied by Balicka resulted in significant benefits in addition to those achieved by CTII's project to modernize the boiler's controls. Overall, the fuel reduction at the Balicka boiler house is estimated to be about 33 percent, or 5,500 Mg per year. Also, the Honeywell project resulted in a reduction in electricity consumption at Balicka of 29 percent. The work with ECKSA which eliminated boiler houses by connecting them to Cracow's main district system resulted in an additional reduction of 690 Mg of particulate emissions per year.

Emissions for the entire city of Cracow have been significantly reduced by these projects. Percentage reductions for the city are:

Particulates:	9.7%
SO_2:	10.4%
CO:	5.3%
NO_x:	6.9%

Continued Presence in Poland and Eastern Europe

Honeywell used this project to strengthen its position in the Polish and Eastern European markets. Honeywell's presence in Poland has evolved from an entrepreneurial unit in an emerging market to an established ISO-certified affiliate. By developing local resources during the course of this project, Honeywell's affiliate in Poland has grown, formed local partnerships with subcontractors, and developed an understanding of the political, legal, financial and economic factors that shape the energy conservation market in Poland. To extend its capabilities, Honeywell created Honeywell Poland ESCO. This will not only help provide financing, but assists customers in assessing their requirements, provides comprehensive technical solutions, and manages cash flows and entire projects.

In addition, Honeywell set up a TRV assembly facility in Cracow in cooperation with the Polish firm Dempan. Honeywell expects to capture a significant share of the growing TRV market in Poland as well as Eastern Europe. It is estimated that the market in Poland for TRVs will be 1.5 -2 million units per year over the next five years - the largest in Eastern Europe.

Shooshanian Engineering Associates, Inc.

Shooshanian Engineering is a mechanical and electrical engineering firm specializing in study, design, and construction services for commercial, industrial and institutional clients. Shooshanian is based in Boston, Massachusetts. Shooshanian teamed up with MPEC and Polinvest, Ltd., a Polish economic and legal consulting firm, to extend and improve Cracow's central station district heating system. Shooshanian also provided marketing and customer service training to MPEC.

Five major tasks comprised the scope of the project. These are:

- identification and evaluation of potential district heating clients, development of client offering (including engineering and economic analyses), and negotiation of binding agreements;

- engineering design of new client connections;

- construction activities including hot water distribution enhancement and connection of clients;

- training of MPEC personnel in:
  - marketing, customer services, and strategic planning practices, including assistance in establishing a Marketing Department and a Customer Service Office,
  - energy conservation studies, and
  - project management and financing techniques; and

- joint venture formulation including market research, investigation of potential clients and projects, joint services proposal development, financial planning and legal issues analyses.

Thirty-three facilities at 26 sites within Cracow were identified, negotiated with, and connected to the main district heating network. Infrastructure improvements included not only the distribution piping, but also all required pumps, heat exchangers, metering, controls, and other items needed to make the system functional, reliable and efficient.

As a result of site connection to the central heating network, a total of approximately 40.8 MW of coal-fired boilers have been retired, abandoned, or demolished. The peak heating capacity shifted to the central network is 28.4 MW. Emission reductions associated with the load shift are:

- particulates - 265.6 metric tons/year
- sulfur oxides - 258.3 metric tons/year
- nitrogen oxides - 45.1 metric tons/year
- carbon monoxide - 388.8 metric tons/year.

Marketing Development and Training

MPEC has only recently been forced to compete for customers in a marketplace that has dramatically changed as Poland has moved away from a centrally planned economy. The issues of marketing, public relations, negotiation, research, and customer service all play important roles in expanding the district heating network. The development of a marketing strategy for MPEC was critical to the success of this project.

Shooshanian developed a *Marketing and Customer Service Training Manual* for MPEC to assist the company in defining the services which should be provided in a competitive marketplace. In addition, marketing and customer service training was provided. Because there was no clear means by which even existing customers could communicate questions or concerns, MPEC was encouraged to establish a Customer Service office. Training was also provided in strategic planning and in how to conduct an energy conservation study. MPEC is now well-positioned to provide customers with value added services and to develop strategies and techniques to succeed in a competitive marketplace.

Future Activities

Discussions of future cooperation among the three companies - Shooshanian, MPEC, and Polinvest - have been ongoing throughout the project. Continued cooperation is deemed highly compatible with the strategic goals of each firm. Several scenarios for future cooperation have been identified and evaluated; creation of a formal joint venture is not feasible at this time. Nonetheless, the companies are continuing discussions and intend to continue working on potential future joint projects in the area of energy efficiency and environmental protection.

LSR Technologies, Inc.

LSR Technologies, Inc. of Acton, Massachusetts is a small company specializing in the development of advanced technology for physical and chemical separations. Beginning in 1989 and with support from the U.S. Department of Energy and the U.S. Environmental Protection Agency, LSR developed a new concept for mechanical dust collection - the Core Separator. The LSR work in Poland has involved the refit of Core Separators to existing, coal-fired boilers.

In Poland mechanical particulate collectors have traditionally been used over more efficient control devices in industrial applications due to lower initial and operating costs. The Core Separator is more efficient than conventional mechanical collectors. Dust emissions from this device are typically 3-6 times lower than from even the best cyclone collectors. Its performance approaches that of fabric filters and electrostatic precipitators (ESP), but at much lower cost.

A simplified schematic of the Core Separator system is shown in Figure 2. The system includes two conventional components, a cyclone collector for extracting solids and a fan for flow recirculation.

A Core Separator component usually includes a multitude of cylindrical units. Each unit has a single inlet for the stream to be treated and two outlets, one for the cleaned gas stream on the other containing a highly concentrated recirculation stream. The dust-laden recirculation stream is fed to the cyclone and then returns again by means of the fan. The processes of separation and collection are accomplished separately in different components. The Core Separator cleans the inlet stream and detains dust particles in the system. Since its efficiency is quite high, the dust particles cannot leave the system. They recirculate again and again until collected in the cyclone. Historically, conventional cyclone dust collectors have been ineffective in removing dust particles with diameters below 10 microns. In comparison, the Core Separator is able to remove a high percentage of particles even at 2-3 microns. In Poland, the cyclone dust collectors commonly used on coal-fired stoker boilers typically have an efficiency for particulate capture of 75-80%. Applied to the same boilers, the Core Separator achieves 94-98% capture [4].

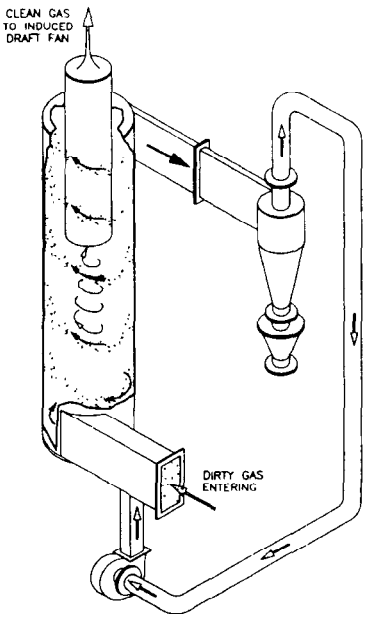

Figure 2. Simple illustration of the LSR Core Separator system

The Core Separator system can actually be arranged in a variety of configurations depending on process conditions, required performance, inlet dust concentration, abrasiveness of solids, etc. A typical arrangement is shown in Figure 3.

In Poland, LSR has cooperated primarily with two organizations: FEWE - the Polish Foundation for Energy Efficiency based in Katowice, Poland and EcoInstal - an equipment manufacturing firm in Poznan. FEWE is an independent and non-profit organization formed at the end of 1990. The organizer of the Foundation has been Pacific Northwest Laboratories from the U.S. FEWE is involved in projects throughout Poland with three regional centers in: Warsaw, Cracow, and Katowice. As part of their cooperation with LSR, FEWE provided industry knowledge and contacts and marketing support.

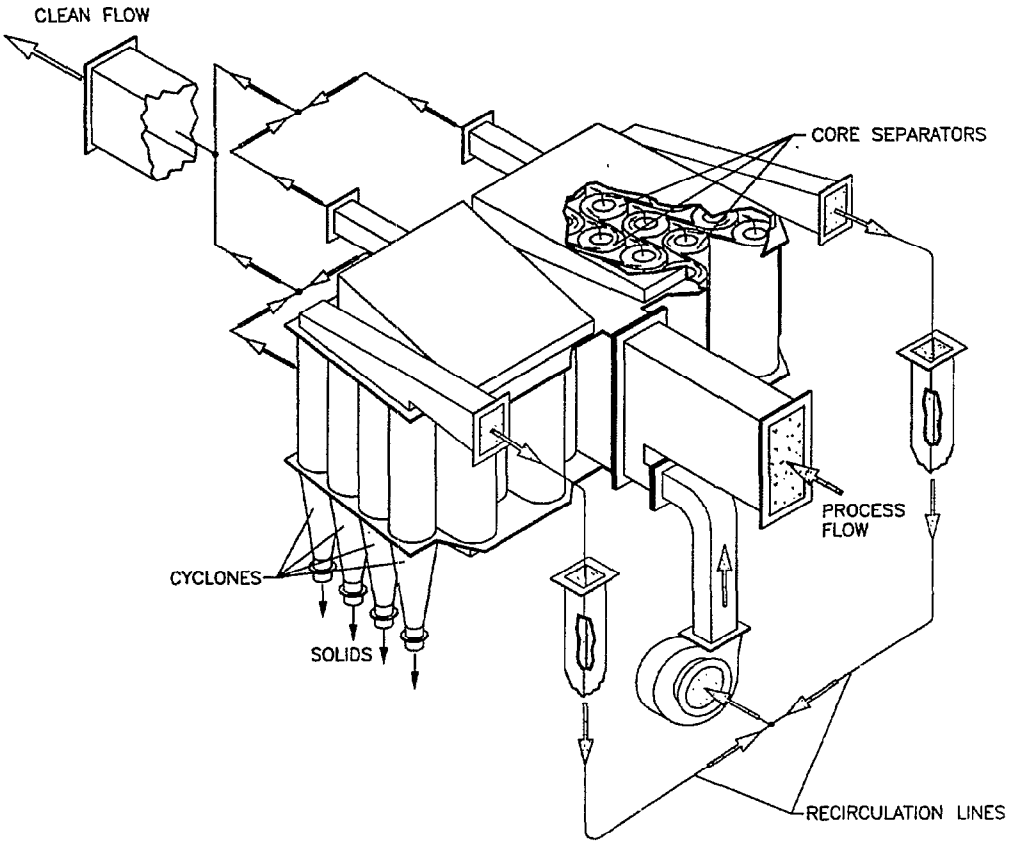

Figure 3. Typical Core Separator arrangement

As a formal part of this program, the LSR team completed the installation of a Core Separator particulate removal systems at two sites in Cracow. This includes one stoker fired boiler located at the plant of a motor manufacturing company - Armatura - and three stoker-fired boilers located in a service facility of the national bus company - MPK. At each of these sites testing was done to document actual performance. At Armatura the boiler has a nominal capacity of 6 MW and measured particulate removal efficiency was 95.4%. At MPK the total boiler capacity is 1.5 M W. Two of the three boilers were tested at MPK and measured particulate removal efficiency was 91.4% and 96.0%.

Beyond the formal scope of this program, Eco-Instal has completed 36 additional Core Separator installations and 16 additional installations are in progress. Total coal consumption at these sites is estimated at 557,000 metric tons per year. The growth rate of the Core Separator business of Eco-Instal has been very impressive. Figure 4 shows the trend in Core Separator total installed capacity

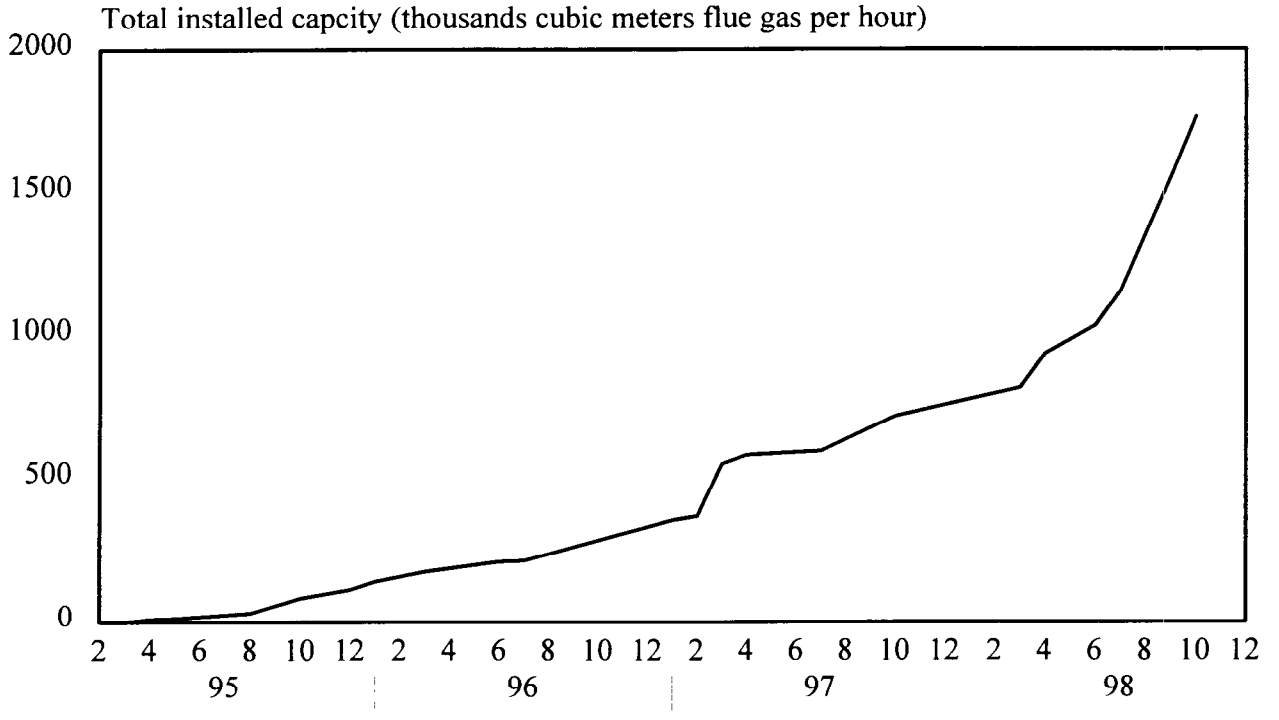

Figure 4. Trend in installed capacity of Core Separators in Poland

since the project started (Note: data in the second half of 1998 is projected, based on projects in progress).

Project Impact

For the two sites in Cracow formally included in this program the particulate reduction impact can be estimated from the performance test results and average operating parameters for boilers of this type [1]. Specific assumptions include:

boiler efficiency = 63%
coal heating value = 19.014 MJ/kg (lower heating value)
capacity factor = .186
uncontrolled particulate emission factor = .0249 kg per kg of coal

The capacity factor here is the annual energy output divided by the energy which would be output if the boiler ran at full rated load for a solid year. The combined capacity for the two sites is 7.5

MW. Using this and the above assumptions, the uncontrolled particulate emissions are 91.36 metric tons per year.

For some of the Core Separator installations in Poland no particulate control devices were installed in the baseline case. More typically, however, mechanical cyclones were installed and were in relatively poor condition. Assuming preexisting cyclones with a particulate collection efficiency of 70%, the particulate emissions for the two Cracow sites would be 27.4 metric tons per year. After the installation of the Core Separators with collection efficiency of 95%, emissions are reduced to 4.6 metric tons per year. The net benefit of the work at these two sites, then, is 27.4 - 4.6 or 22.8 metric tons per year.

The impacts of the LSR project are much greater if installations outside of this program are also considered. The total coal consumption for all of the sites in Poland is estimated to be 557,000 metric tons per year. This exceeds annual coal consumption in all of the Low Emission Sources in Cracow. Particulate capture in Core Separators installed to date across Poland is estimated to be 2,775 metric tons and this exceeds by 2.5 times particulate emissions from all stoker-fired boilers in Cracow in 1991 (1,083 metric tons).

Activities Beyond the Project

Eco-Instal is continuing to market and install Core Separators in Poland and is expanding throughout Europe. As a result of the Core Separator activity employment at Eco-Instal has increased from 30 to 100 employees. In 1997, EcoInstal received a national environmental award, largely due to their sales of Core Separators.

CONCLUSIONS

The joint venture projects have, to date, made significant impact on the production of pollutants by Low Emission Sources. The work of eliminating air pollution caused by these sources, however, is far from over. Probably the most important contribution to date has been the technologies, institutions, and information introduced to the region. This program is continuing to support these and other efforts such as the development of a long term plan for these sources and direct participation in the elimination of small boilers through cooperation with MPEC, ECKSA, and other organizations.

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