

**Particulate Emission Abatement
for Krakow Boilerhouses**

Final Report

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Abstract

A U.S./Polish Bilateral Steering Committee (BSC) and the Department of Energy (DOE) selected LSR Technologies, Inc. as a contractor to participate in the Krakow Clean Fuels and Energy Efficiency Program. The objective of this program was the formation of business ventures between U.S. and Polish firms to provide equipment and services to reduce air emissions in the city of Krakow. A cooperative agreement was entered into by DOE and LSR to begin work in April 1994 involving implementation of particulate control technology called a *Core Separator*TM for coal-fueled boilerhouses in the city. The major work tasks included: (1) conducting a market analysis, (2) completion of a formal marketing plan, (3) obtaining patent protection within Poland, (4) selecting a manufacturing partner, and (5) completing a demonstration unit and commercial installations. In addition to work performed by LSR Technologies, key contributors to this project were (1) the Polish Foundation for Energy Efficiency (FEWE), a non-profit consulting organization specializing in energy and environmental-related technologies, and (2) EcoInstal, a privately held Polish company serving the air pollution control market. As the project concluded in late 1998, five (5) *Core Separator*TM installations had been implemented in the city of Krakow, while about forty (40) others were completed in other regions of Poland.

1.0 Executive Summary

Environmental cleanup and pollution control have been considered foremost national priorities in Poland during the post-communist era. More than four decades of centralized planning has produced severe contamination of air, water, and soil throughout the country and a resulting deterioration of public health. The government of Poland has begun to implement environmental controls in order to reverse this condition. One of the targets of these controls has been the Polish coal industry, which in 1990 represented about 80% of primary energy production. Coal utilization in Poland has been very inefficient with as much as 2 to 3 times more energy consumption as western Europe per unit of gross domestic product (GDP).

As part of the Krakow Clean Fuels and Energy Efficiency Program, LSR Technologies, Inc. was selected by a U.S./Polish Bilateral Steering Committee to participate in one of the five (5) pilot project areas. The chosen pilot area focused on reducing particulate emissions from boilerhouses firing coal and coke, using new dust collector technology called a *Core Separator*TM. It had been postulated that the *Core Separator*TM, a cost-effective device with much higher efficiency than multicyclones, would be an excellent match for the highly fragmented boilerhouse emitters in Krakow. In the early 1990s, the city had about 1,300 boilerhouses containing about 2,900 heating boilers. And, while many of the older boilerhouses have since been retired, there remains in Krakow a sizeable boiler population that is still a primary source of particulate air emissions.

A cost-shared Cooperative Agreement was entered into by LSR and DOE in 1994 to provide equipment and services to reduce emissions from these sources. A two-phase project was created by dividing the work tasks into two successive and well-defined structures. Phase I consisted of infrastructure studies including: (1) completion of a business plan and market strategy, (2) evaluation and selection of a manufacturing partner to service the anticipated market, and (3) insuring that adequate financing and cost-share commitments were in place for the initial installations. To complete this effort, the Polish Foundation for Energy Efficiency (also known as

FEWE) was contracted by LSR to assist in the overall planning and execution of work. At the completion of the first work phase, the Polish firm, EcoInstal, was also selected as the principal business partner for LSR.

The Phase II effort involved a more substantial financial commitment to essentially implement the technology in boilerhouse applications. A demonstration site for the first *Core Separator*TM was contracted with Krakowskie Zaklady Armatur, as part of a dust collector upgrade on a WR-5 heating boiler. Four (4) additional *Core Separator* units were installed at other sites in Krakow. In each, dust collector efficiency increased from 75-80% to the range 94-97%. Emission rates for dust particles correspondingly decreased to less than 20 grams/GJ (0.05 lb/MBTU), which approaches that of more costly devices such as ESPs and fabric filters. In parallel to the installations sited in Krakow, forty (40) additional *Core Separator* units were placed in operation in other regions of Poland, including many in nearby Silesia which is a source of air pollution in Krakow.

To accommodate the demand for *Core Separator* units in Poland, the manufacturing capability of EcoInstal was expanded substantially. The process of upgrading the manufacturing process involved a major collaborative effort that included the following tasks: (1) development of modular designs using CAD/CAM techniques, (2) technology transfer adapted to Polish metal sizes and specifications, (3) developing fixtures to standardize component parts, (4) the acquisition of new manufacturing equipment, and (5) extensive training for production workers. As a result of these improvements, EcoInstal is recognized today as a respected air pollution equipment manufacturer that can compete with just about any metalworking company with respect to cost and product quality.

During the course of this project, both LSR and EcoInstal received prestigious awards that were each related to the *Core Separator*. In 1996, LSR won the R&D 100 Award given annually to the best technology-based new products of the year worldwide. In 1997, EcoInstal won the Polish Environmental Leadership Award given by the Minister of the Environment for exceptional

contributions toward pollution control.

This project has been very successful in achieving goals originally set forth by the U.S./Polish steering committee. The project has been able to claim the following accomplishments consistent with those goals:

- Creation of a mutually beneficial business venture between a Polish and U.S. firm which will sustain itself on a continuing basis
- Installation of five (5) *Core Separator* installations in Krakow as well as many other nearby units all of which improve air quality in this historic city
- Installation of forty-five (45) *Core Separator* installations throughout Poland with a combined capacity of 1.7 million M³/h (1.0 million acfm)
- A reduction of particulate emissions in Krakow of more than 115 metric tons per year and a reduction of more than 2,150 metric tons per year throughout Poland
- Introduction of a new technology to a Polish firm, enabling that firm to grow substantially and triple its employee work force
- An added benefit to the Polish firm of exporting equipment out of the country, creating jobs for the local economy, while having a positive effect on the Polish trade balance.

2.0 Phase 1 -- Infrastructure Studies

2.1 Background

The Krakow Clean Fossil Fuels and Energy Efficiency Program was originally evolved from the Support for Eastern European Democracy (SEED) Act of 1989. Through funding from the Agency for International Development (AID) and the Department of Energy (DOE), the program was created to reduce air pollution in the City of Krakow from about 1,300 boiler houses. In 1992 when the program was initiated, these boiler houses contained more than 2,900 boilers that provide heat for industrial, commercial, and residential use. The 2,900 boilers represented a combined input capacity of approximately 1,000 MW(t), which is substantial as it compares to 200 MW(t) capacity for 100,000 room heating stoves in Krakow. More than 75% were coal- or coke-fired units and released an estimated 1,400 Tonnes/year of particulate matter. Since the facilities contain short (low) stacks, combustion products enter the atmosphere close to ground level. They are therefore referred to as “low emission sources.”

These low emission sources are the primary source of particulate air pollution in the City of Krakow. The uncontrolled boilers, those with no control equipment, produce about 75% of the total particulate emissions from coal- or coke-fired boilers. The remaining boilers which are generally larger in capacity employ cyclonic collectors and produce 25% of the particulate emissions. There presently are no provisions in place to control fine particulate matter, often referred to as PM₁₀, which is most hazardous to human health.

This project addresses **Reduction of Emissions from Boiler Houses Firing Coal and Coke**, one of the five pilot projects identified by the U.S./Polish Bilateral Steering Committee. This target application is significant for the following reasons:

- Air quality improvements are needed both to protect the health of citizens of Krakow and to preserve the city's historic monuments.

- The *Core Separator* developed by LSR is a new technology and a cost-effective solution to the particulate emission problem in uncontrolled boilers. An important feature is its ability to control PM₁₀ particulate matter, which consists of dust particles below 10 microns in diameter.
- The efficiency, ease of maintenance, and low cost compared to electrostatic precipitators or fabric filters, make it practical for large numbers of low capacity boilers. It can also be used to replace the existing cyclone collectors during normal boiler overhaul periods. Since dust emissions resulting from such replacement would be 4 to 6 times lower, particulate levels emitted would be comparable to that of EU countries.

It is significant that since 1992 there has been a major reduction in the number of coal- and coke-fired boilers located in Krakow. This reduction was the result of several factors including (1) extensions in the district heating system, (2) fuel conversions to natural gas, and (3) retirement for economic reasons. The reduction process was also accelerated by the gradual deregulation of coal prices and loss of coal subsidies during the 1990's. Nonetheless, even with this large reduction in the number of boiler houses, there is still a sufficient number of operating boilers to justify investment in and cost recovery of a business venture related to emissions reduction.

A team was formed to provide the necessary technical, manufacturing, and infrastructure knowledge to make this project economically viable. LSR Technologies, Inc., a small business located in Acton, Massachusetts and the developer of the technology and holder of its patent rights, has been the primary contractor for this work. LSR has sold *Core Separators* in the U.S. and Europe and has been leading the team to commercialize this technology in Poland, starting with penetration of the market opportunity in Krakow. The company's overall objective in this project has been to make a positive impact on the coal-fired boiler market in Krakow, then eventually expand to other cities in Poland, and ultimately elsewhere in Europe. The *Core Separator* had been

developed under DOE-sponsored research and was cited as one of its successful technologies.

Another team member and subcontractor for this work was the Polish Foundation for Energy Efficiency (FEWE), which has offices in Krakow, Katowice, and Warsaw. FEWE had been a contractor to both DOE and EPA, and has extensive knowledge of energy usage in Poland and its environmental impact. Because of its familiarity with the industrial base in Southern Poland, FEWE played a major role in identifying and selecting a manufacturing partner.

2.2 Accomplishments in Phase I

A Commercialization Plan submitted to DOE and the BSC by LSR was used throughout this project and has largely remained intact. One significant change or deviation from this plan involved a decision to identify and select a Polish manufacturing company for partnership rather than to establish a grass roots organization. This alternative became apparent during early infrastructure studies of Polish business practices. Thus, the major efforts during this period included the following:

- Conduct an Evaluation of Potential Manufacturing Companies
 - Solicit Proposals for Collaboration
 - Select the Most Promising Candidate
 - Enter a Formal Cooperative Agreement

- Complete a Detailed Business Plan
 - Evaluate Krakow's Boiler Market
 - Assess Polish Environmental Regulations
 - Create a Plan for a Joint Venture Company or Licensing

2.2.1 Evaluation of Polish Manufacturers

LSR efforts to identify a suitable manufacturing partner concentrated exclusively on companies located in or near the City of Krakow. About 12 companies were contacted and visits were made to each of these. Negotiations were conducted with three of these companies, in order to determine the level of interest and commitments. Regrettably, none of these companies were able to make significant financial commitments to this project. Each was interested in a form of licensing that required minimal cost and no dilution of their equity.

LSR also received unsolicited proposals from manufacturers in other cities in Poland. One substantial boiler company located near Katowice, and EcoInstal based in Koscian, each presented stronger proposals to LSR than any of the Krakow companies. EcoInstal's proposal clearly represented the strongest financial commitment, and became LSR's first choice. The selection of EcoInstal took place only after discussions and concurrence with DOE personnel.

EcoInstal is a privately held company with a single owner in Poznan. The company was founded in 1985 when communism was still deeply entrenched in Poland. By 1989 when the Polish government changed, the company had grown to about 30 employees. Its principal products include air pollution control products, including cyclone collectors and fabric filters. It also produces several types of solids conveyers and an excellent mechanical air lock. It sells and markets its products throughout Poland, but has a particularly strong presence in the central region and in Silesia. EcoInstal has always been a very entrepreneurial company and has a western style of management.

LSR recommended to DOE that EcoInstal be selected for partnership in this project. On November 11, 1994 a Cooperative Agreement was signed by LSR and EcoInstal to produce *Core Separators* for the Polish and Central European market. The agreement included a commitment by EcoInstal to cost share for the bulk of work performed in the second budget period.

2.2.2 Business Planning

A detailed business plan was prepared by LSR with significant input from FEWE. The business plan was submitted to DOE in November 1994. The business planning evolved around the establishment of a joint venture company recognizing the capabilities of both LSR and EcoInstal. In 1994, EcoInstal's capabilities for producing high volumes of equipment were very limited. While it had an excellent work force and good management, its equipment was largely outdated and obsolete by U.S. standards. This was typical of many manufacturers in Poland. Thus, new fabrication equipment would be needed and will make the joint venture company more competitive, both in Poland and internationally. A summary of this plan follows.

The business venture is to be created in Poland for the purpose of producing and selling pollution control equipment in this Central European nation. The joint venture would be owned by LSR Technologies, Inc. and EcoInstal, a supplier of air pollution control equipment based near the City of Poznan. The new venture is being established to market, sell, manufacture, and install pollution control equipment within the industrial sector of Poland and also for the export market.

Decades of central government planning have left a situation of near environmental disaster in Poland, particularly in the southern region where low-grade coal is used extensively for heat and electricity. With severe public health problems and a lower life expectancy today than 20 years ago, there is an urgent need to reduce particulate air emissions in this region. For this reason, the World Bank and several ecological relief organizations have set aside funds for the environmental restoration of this area. The U.S. AID Program in cooperation with the Department of Energy is also providing assistance to the area around historic Krakow, which has been hit especially hard by environmental neglect.

While Poland, the Czech Republic, and Hungary will be key markets for the joint venture, the City of Krakow will be the focal point for early implementation of pollution control projects. Krakow, the third largest city in Poland, is located adjacent to the Upper Silesian coal basin. The

city contains thousands of historic sites, and is listed by UNESCO as one of the 12 most important cultural centers in the world. The city also has close to 1,000 boiler houses containing nearly 2,000 boilers to provide heat for industrial, commercial, and residential use. The 2,000 boilers have a combined input capacity of nearly 1,000 MW(t), which is substantial as it compares to 200 MW(t) capacity for 100,000 room heating stoves in Krakow. More than 75% of these are coal- or coke-fired units and release about 1,000 Tonnes/year of particulate matter. These sources and others represent a potential market for particulate control equipment of about \$200 million annually in all of Poland.

Low emission sources are the primary source of particulate air pollution in Krakow. Uncontrolled boilers, those with no control equipment, produce about 75% of the total particulate emissions from coal- or coke-fired boilers. The remaining boilers, which are generally larger in capacity, employ cyclonic collectors and produce 25% of the particulate emissions. There presently are no provisions in place to adequately control fine particulate matter, which is most hazardous to human health.

The new venture will be a major supplier of emission control equipment for boiler houses firing coal and coke, a significant undertaking for the following reasons:

- (1) Air quality improvements are needed both to protect the health of the citizens of Krakow and to preserve the city's historic structures and monuments.
- (2) Similar air quality improvements are needed in other parts of Poland and Central Europe.
- (3) The new venture intends to market the *Core Separator*, a high efficiency device for particulate control.

- (4) The technology can also reduce particulate emissions from the boilers currently controlled with cyclone dust collectors.

In 1990 Poland enacted its own version of the Clean Air Act. Since that time, the market has been ready to accept the challenge presented. The establishment of a new business in a soon-to-be expanding segment of the air pollution industry will have the following advantages:

- Poland has the largest and fastest growing homogeneous consumer market in Central Europe and the fastest growing economy in all of Europe.
- The new product is entering the fastest growing segment of the air pollution control industry.
- The potential market for this type of equipment in Poland is substantial and American technology is highly respected.
- With the advanced design which this new product represents, the new technology could capture 10% of the market served within five years, which is \$10 million.
- Profitability is assured by the market requirements for this product, the proven experience of the founding group, and the low cost manufacturing to be employed.

2.2.3 Other Phase I Accomplishments

LSR together with EcoInstal have also performed several other functions which are complimentary and supportive of the project in Krakow. A summary of these accomplishments are cited below. It should be noted that many of these accomplishments were not performed with DOE financing.

- A *Core Separator* unit was sold, built, and installed to treat flue gas from a WR2.5 boiler in Oborniki. This unit went into operation in April 1995, was tested by an independent organization, and was found to have dust emissions below 50 mg/M³.
- A *Core Separator* unit was also sold and installed an a fluidized bed boiler used for heating and located near Tarnow. This unit has been operating successfully since April 1995 and also tested satisfactorily even at low load (off-design) conditions.
- A *Core Separator* unit was sold, built, and shipped to a foreign customer for a stoker-fed boiler in Mauritius. This unit, also built by EcoInstal, was started up in 1996.
- A *Core Separator* patent application was prepared and filed in Poland, Germany, Slovakia, and the Czech Republic.
- Purchase orders were received for two new *Core Separator* units, one for a WR10 boiler in Gliwice and a second for a metal smelter near Lubin.
- Letters of intent were received from three Krakow companies for five *Core Separator* units for boiler applications. These units would be eligible for DOE financing.
- A letter of intent was received for four (4) new *Core Separator* units for boiler applications. These units are to be installed in other regions of Poland.
- EcoInstal and LSR have also conducted broad marketing activities in Krakow and elsewhere including the preparation of product brochures, visits to sites to promote the technology, exhibits at trade fairs, and presentation of technical papers at conferences.

3.0 Phase II - Commercial Implementation

3.1 Prototype Demonstration

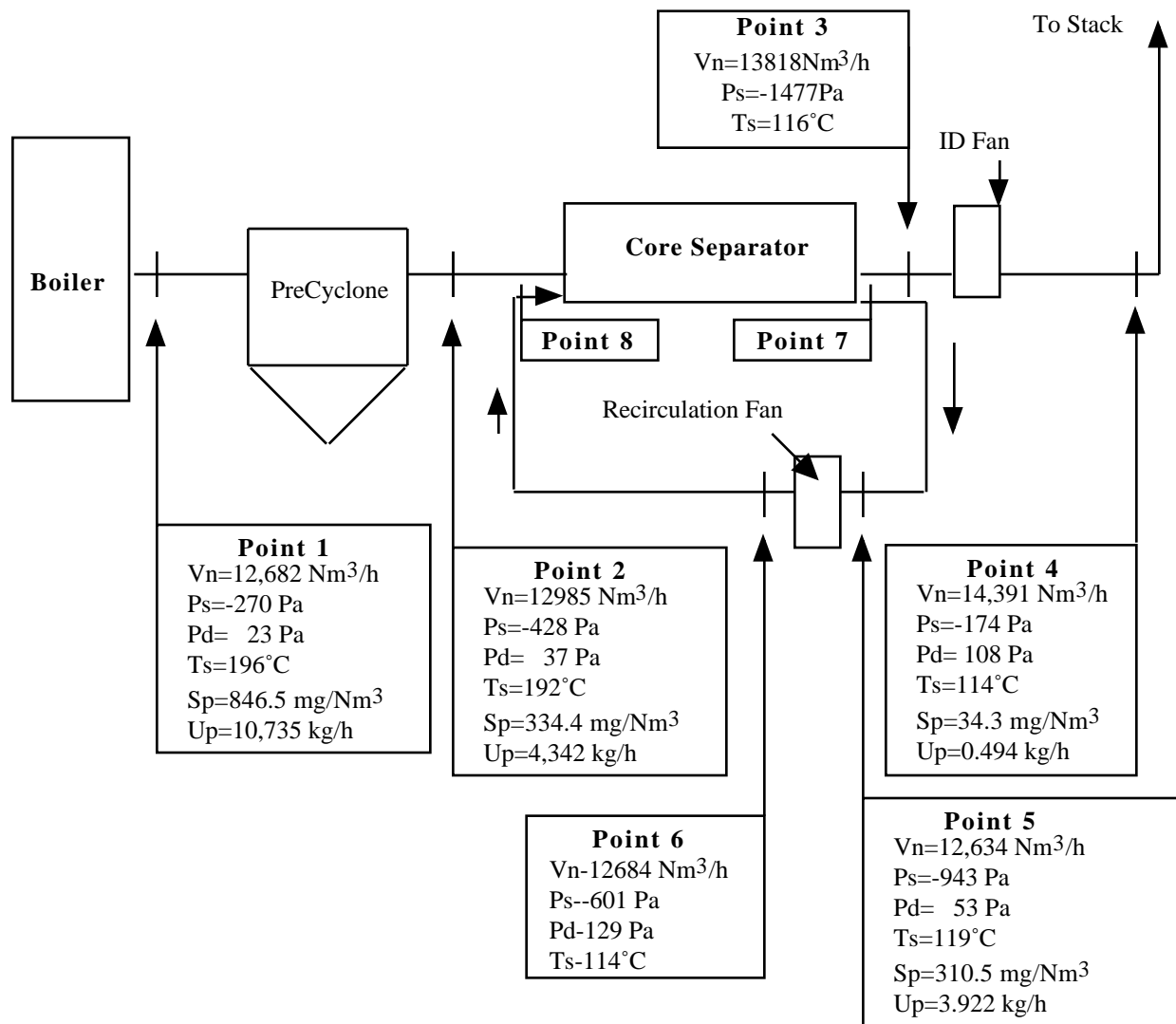
The first major task in Phase II was the installation of a demonstration unit in Krakow. The site selected was that of Krakowskie Zaklady Armatur, a mid-sized manufacturer of household fixtures. Armatura has a well-maintained heating plant with several hot water heating boilers providing heat for facility needs. A Core Separator™ system was contracted from EcoInstal to replace a multicyclone collector that had been in operation for several years on a WR-5 boiler.

The Core Separator™ at ARMATURA went into operation in January 1996 during one of the coldest winters in recent years. Initially, some moisture problems were experienced from condensation inside the collector. The condensation resulted from the unusually low temperatures, and caused intermittent plugging in the ash removal system. The solution to this problem was the addition of insulation to outside surfaces in order to remain above the dewpoint.

Particulate emissions and efficiency of the Core Separator™ was measured by the Polish testing firm *Emitor*, located in Opole. The particle concentration measured at the boiler outlet was 846 mg/Nm³ and at the dust collector outlet was 34 mg/Nm³, representing a removal efficiency of 95.4%. The outlet emission rate was less than 20 grams/GJ, which is well below the Polish standard for grate-type boilers. A summary of the data collected during acceptance testing is shown in Figure 1. The full test report can also be found in the Appendix.

The precleaning cyclone for ARMATURA was actually located inside the boilerhouse, and the gas temperature drop through this device was minimal. However, the temperature drop through the *Core Separator* unit was about 70°C, as this unit was located outdoors just before the stack. This data taken during the winter of 1996 clearly shows substantial convective cooling and the need for insulation of the dust collector. Figures 2 and 3 are photographs of the installation at ARMATURA.

Figure 1.
Emission Data for WR-5 Boiler
ARMATURA Plant



Parameter	Temperature Flue Gas	Static Pressure	Dynamic Pressure	Gas Flow Rate	Dust Con- centration	Dust Content
	$^\circ\text{C}$	Pa	Pa	Nm^3/h	mg/Nm^3	kg/h
Point 1	196	-270	23	12682	846,5	10,735
Point 2	192	-428	37	12985	334,4	4,342
Point 3	116	-1477	97	13818	-	-
Point 4	114	-174	108	14391	34,3	0,494
Point 5	119	-943	53	12634	310,5	3,922
Point 6	114	-601	129	12684	-	-
Point 7	118	-925	-	-	-	-
Point 8	116	-851	-	-	-	-

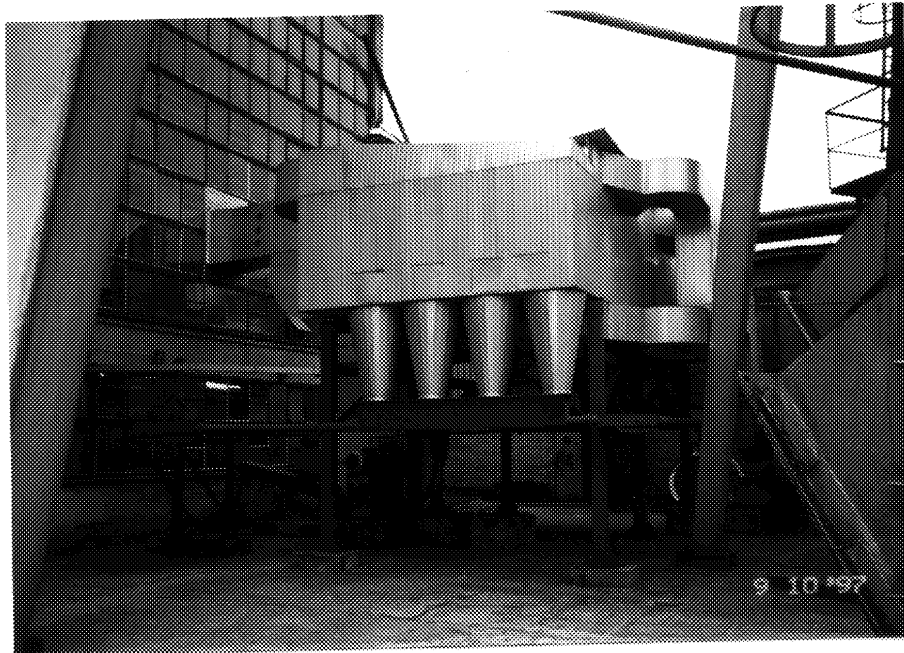


Figure 2. ARMATURA Installation

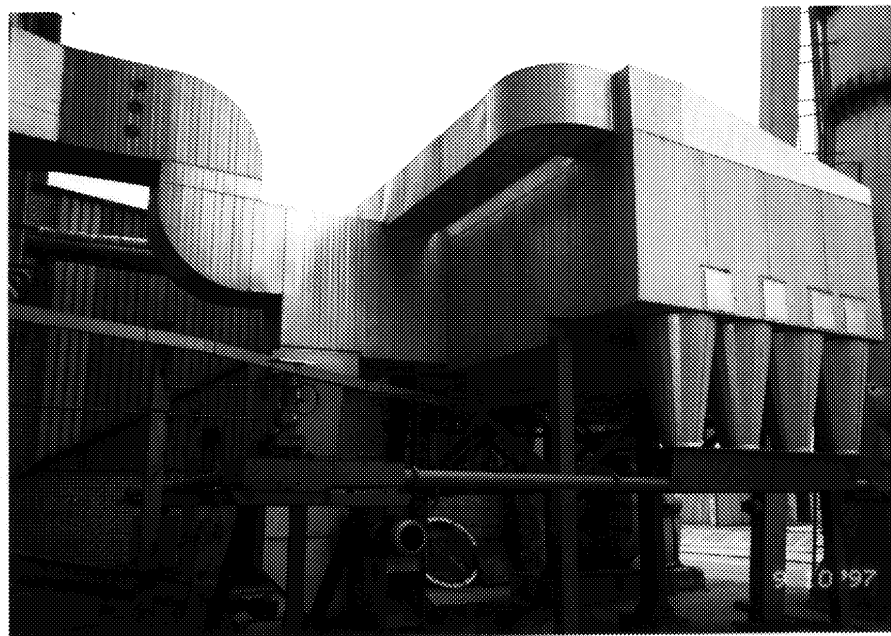


Figure 3. ARMATURA Core Separator

3.2 Other Commercial Installations in Krakow

Miejskie Przedsiębiorstwo Komunikacyjne (MPK) is the municipal transit company for the city of Krakow, operating buses and a trolley car system within city limits. MPK operates a few boilerhouses throughout its system to meet its heating needs. One of these boilerhouses was contracted to install new dust collecting equipment for three (3) type WCO-80 stoker boilers.

Three (3) *Core Separator* units were placed into operation in January 1996. Prior to this, no emission control equipment had been in place. The new dust collectors were located outside of the boilerhouse due to space limitations, and a roof enclosure was added to protect it from weather elements. All three (3) dust collectors were tested for particulate emissions and also for efficiency by the firm *Emitor*.

These units operated very smoothly from the start. Unlike the unit at ARMATURA, there was no evidence of moisture condensation. During the testing however, the measurements of collector efficiency and particle emissions showed some variation between each of the three units. It was determined that the isokinetic sampling equipment had been affected by extremely low temperatures and should be tested again. Following another set of tests, it was concluded that the *Core Separator* units were all performing quite satisfactorily.

A summary of data collected during acceptance testing is shown in Figures 4, 5, and 6 below. The full test reports are located in the Appendix. Outlet emissions from these units are also well below 20 gram/GJ. Figures 7-10 are photographs of the dust collectors and sampling equipment at MPK.

Figure 4.
Emission Data for WCO-80 Boiler
MPK Boilerhouse Unit #1

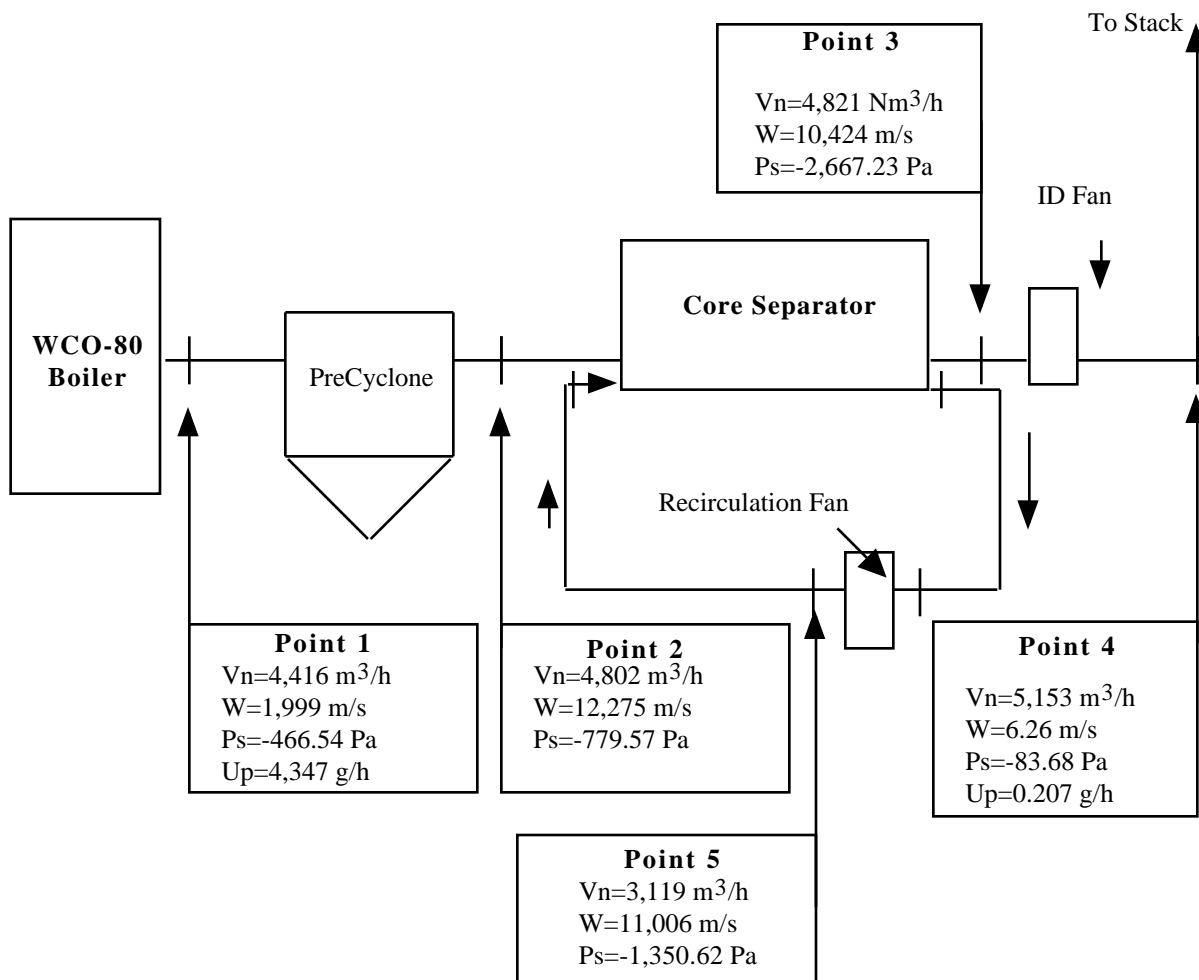
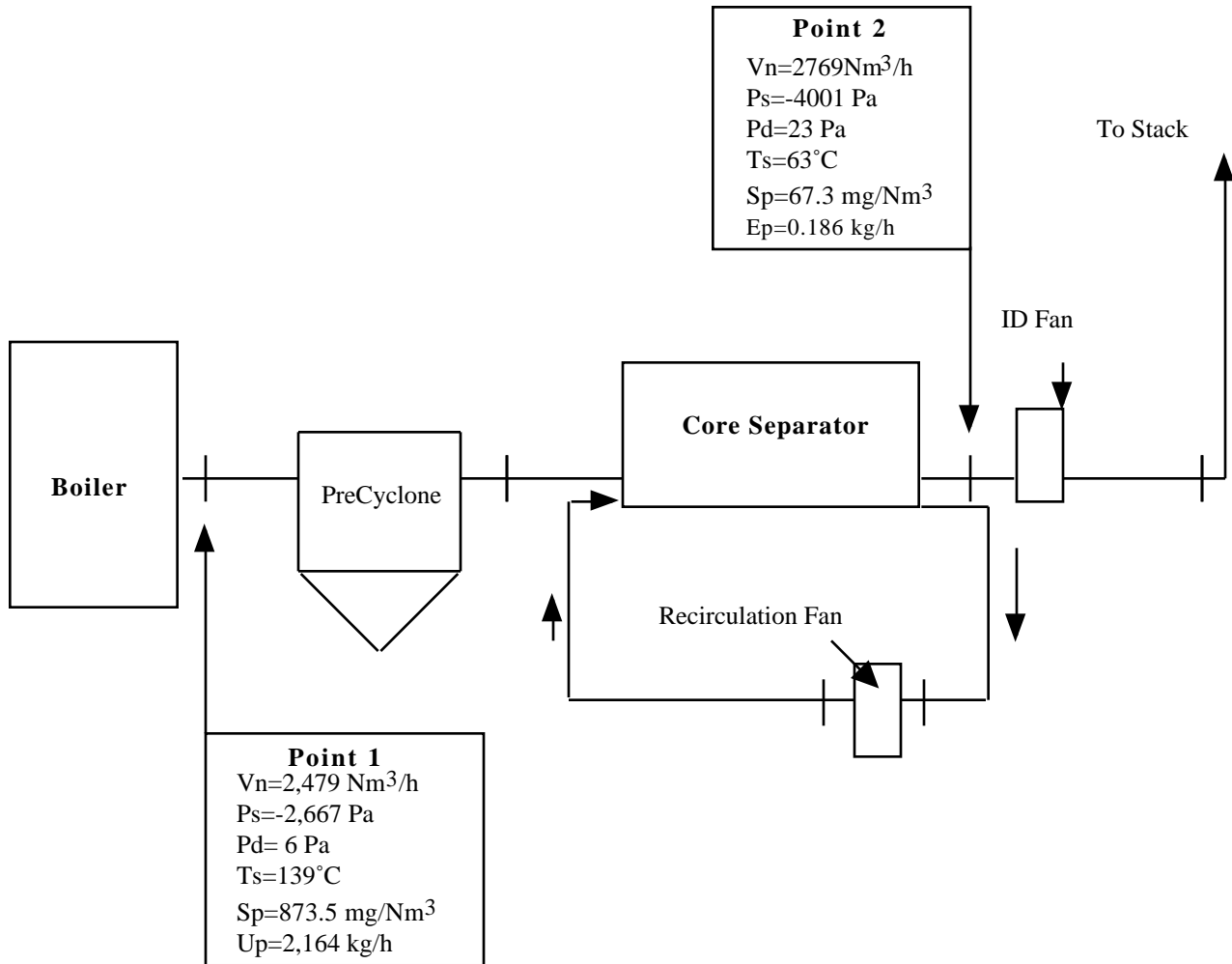
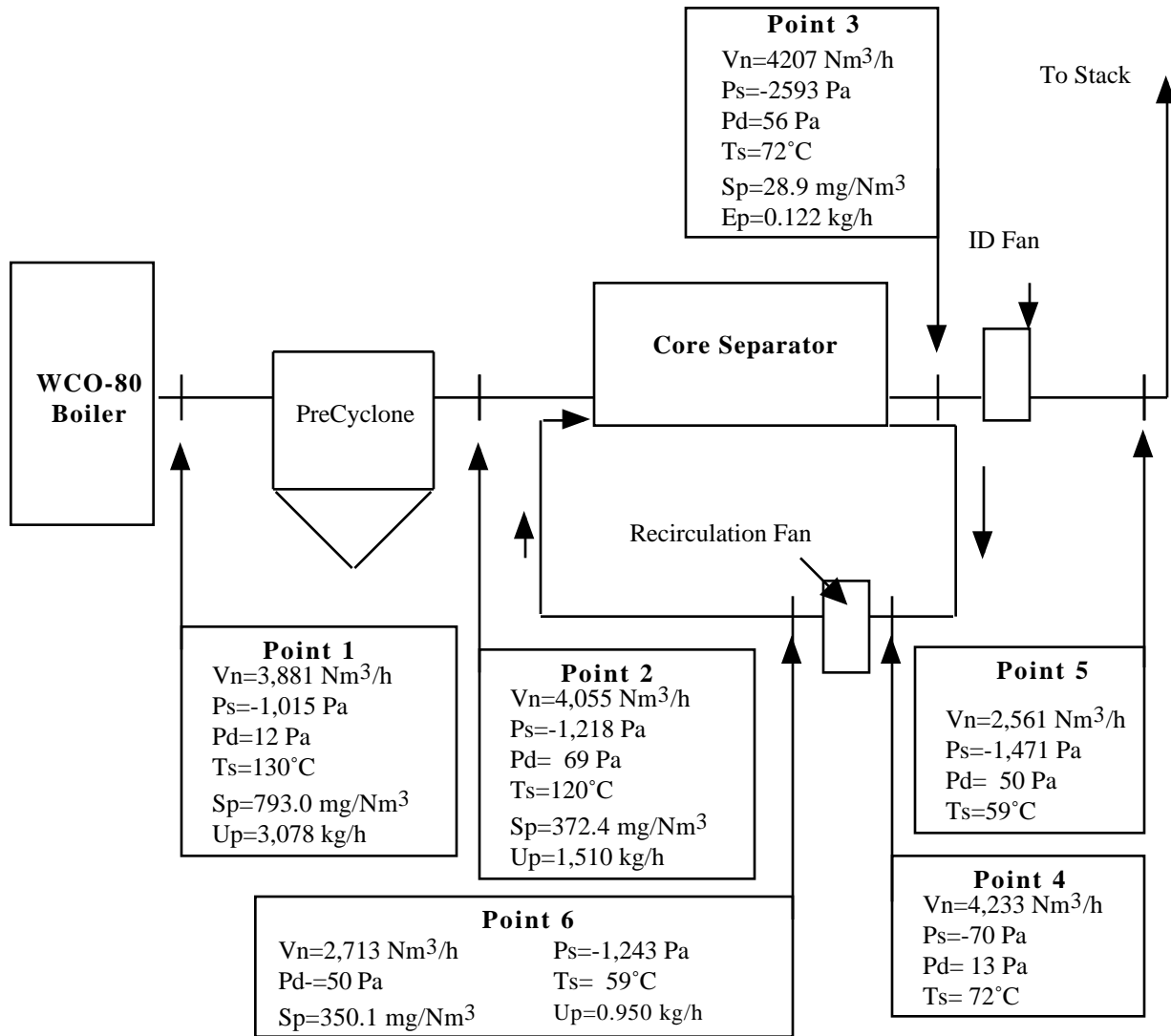


Figure 5.
Emission Data for WCO-80 Boiler
MPK Boilerhouse Unit #2



Parameter	Temperature Flue Gas	Static Pressure	Dynamic Pressure	Gas Flow Rate	Dust Con- centration	Dust Content
	$^\circ\text{C}$	Pa	Pa	Nm^3/h	mg/Nm^3	kg/h
Point 1	139	-2667	6	2479	873.5	2
Point 2	63	-4001	23	2769	67.3	0

Figure 6.
Emission Data for WCO-80 Boiler
MPK Boilerhouse Unit #3



Parameter	Temperature Flue Gas	Static Pressure	Dynamic Pressure	Gas Flow Rate	Dust Con- centration	Dust Content
	$^\circ\text{C}$	Pa	Pa	Nm^3/h	mg/Nm^3	kg/h
Point 1	130	-1015	12	3881	793.0	3.078
Point 2	120	-1218	69	4055	372.4	1.510
Point 3	72	-2593	56	4207	28.9	0.122
Point 4	72	-70	13	4233	-	-
Point 5	59	-1471	44	2561	-	-
Point 6	59	-1243	50	2713	350.1	0.95

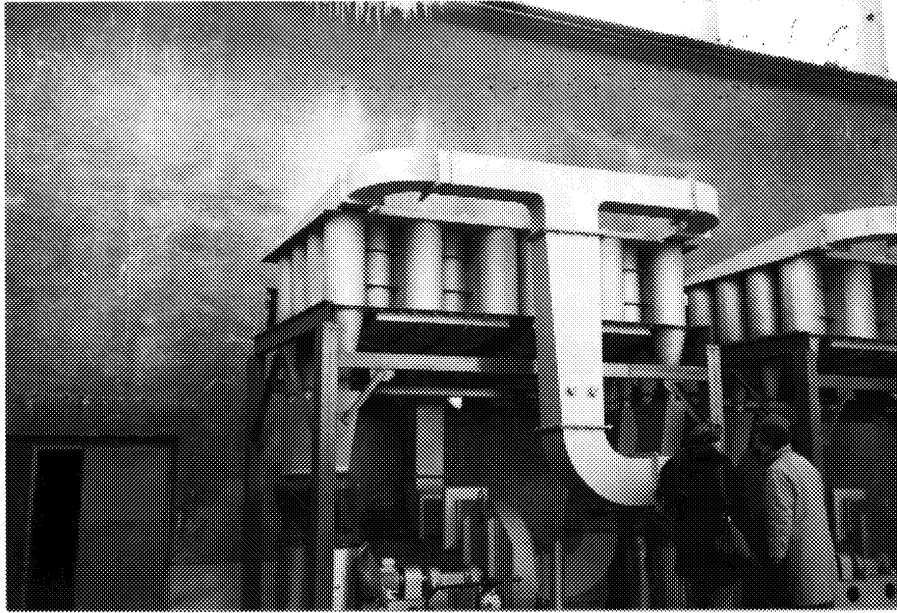


Figure 7. MPK Installation in Construction



Figure 8. MPK Emission Test Equipment



Figure 9. MPK Installation During Commissioning



Figure 10. Completed MPK Installation

Another *Core Separator* unit was installed in Krakow for the company Budostal, a producer of asphalt materials. The Budostal dust collector, shown in Figures 11 & 12 were designed to handle much higher dust concentrations than those found in coal-fueled heating boilers. The unit shown in Figures 11 & 12 was tested by *Emitor* and was found to have an efficiency of 98.6%, making it one of the most efficient units built by EcoInstal.

3.3 Other *Core Separator* Units Installed in Poland

The first *Core Separator* installation that was undertaken by EcoInstal in Poland was contracted to a boilerhouse in the village of Oborniki, which is located just north of Poznan. The site was a typical boilerhouse rehabilitation where an old worn-out multicyclone was replaced and upgraded. The multicyclone had been collecting dust emissions from a WR 2.5 stoker-fired boiler. Figures 13 & 14 show the arrangement of the installation at Oborniki.

Dust emissions from the *Core Separator* unit at Oborniki were measured in early 1995 and were found to be about 10 grams/GJ. This emission level was actually quite a bit lower than expected, and the lowest measured to date. This unit remains one of the best performing units yet installed in Poland.

The next significant milestone involved an installation on a WR-10 boiler in Knurow. This boilerhouse was found to be in dire need of repair and reconditioning, and the stack opacity was visibly one of the worst observed in southern Poland. The multicyclones, ID fan, and draft system from the boiler outlet to the stack were completely replaced with new equipment including a new *Core Separator* dust collector. The improvement in dust emissions from this boiler was drastic. The measured efficiency of the *Core Separator* was just over 95%, which produced a “clear stack”, even during sootblowing and part load operation.

The installation at Knurow was also tested in 1996 with sorbent injection into the boiler backpass for multipollutant control. This testing was a collaborative effort with the NALCO

FUELTECH company, a U.S. firm whose SO₂/NO_x technology is being marketed in Poland. During these tests, the dust collecting system was subjected to much higher particulate loadings from the addition of sorbents. This test was significant in that it demonstrated the compatibility of the *Core Separator* with other emission control technologies in the event that more stringent regulations may be mandated in the future. Photographs of the Knurow dust collection equipment is shown in Figures 15 & 16.

Another technical and marketing achievement completed by EcoInstal in late 1996 was the *Core Separator* installation for the FIAT automobile company in Bielsko-Biala. This was a significant milestone since it occurred on a WR-25 heating boiler with a gas flow rate of 140,000 M³/h (85,000 acfm). This facility is located about 50 kilometers southwest of Krakow, and due to prevailing winds and climatic conditions, it is an emission source which affects the city of Krakow. The *Core Separator* dust collector at FIAT AUTOPOLAND went into operation in 1997 and has met performance expectations. Photographs of the FIAT installation are shown in Figures 17-20.

As of the writing of this report, about forty-five (45) *Core Separator* installations have been completed in Poland. Table 1 provides a list of all installations completed to date. As shown in this table, these installations represent about 250 MWe of equivalent boiler capacity.

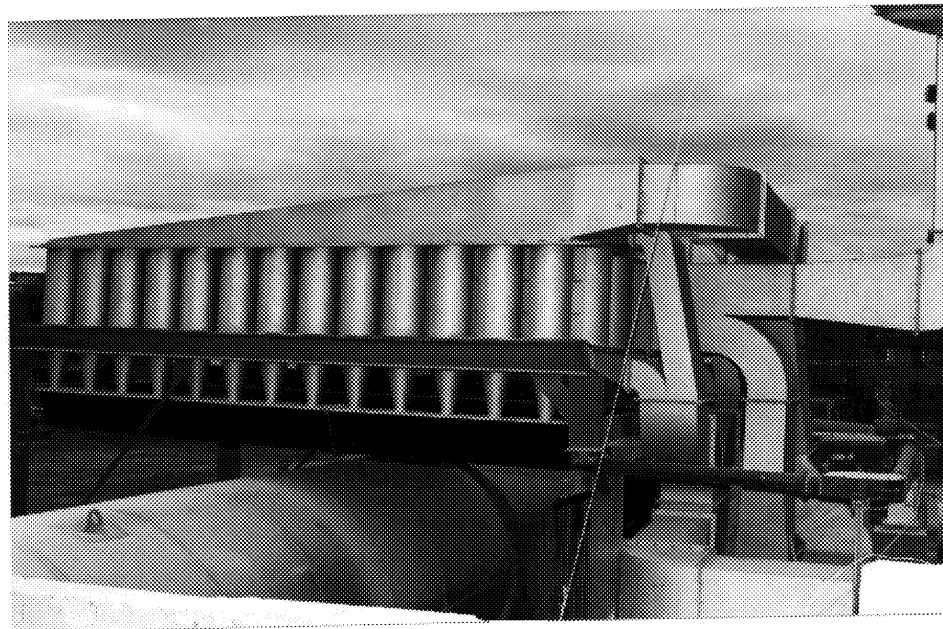
Table 1. Core Separators Produced by EcoInstal

<u>Installation</u>	<u>No. of Units</u>	<u>Initial Operation</u>	<u>Capacity (m³/h)</u>	<u>Application</u>
1. PEC Oborniki	1	4/95	10,000	WR-2.5 Stoker Boiler
2. EXBUD Tarnow	2	5/95, 6/96	7,300	Fluidized Bed Boilers
3. Kombinat RSP Czempin	3	8/95	18,000	WCO-80 Stoker Boilers
4. PEC Knurow	1	10/95	50,000	WR-10 Stoker Boiler
5. MPK Krakow	3	1/96	5,600	WCO-80 Stoker Boiler
6. Armatura Krakow	1	1/96	22,600	WR-5 Stoker Boiler
7. Institute Non Ferrous Metals	1	6/96	2,000	Copper Smelter
8. Matizol Gorlice	2	3/96	10,000	Asphalt Plant Drier
9. Odlewnia Zeliwa	1	3/96	25,000	OKR-5 Stoker Boiler
10. Argentchem Opalenica	1	6/96	800	Smelting Furnace
11. Klimawentex Rzeszow	3	6/96	3,000	Glassmelting/Sanderdust
12. Budostal Krakow	1	6/96	21,600	Rotary Drier/Asphalt
13. Zaklad Farbiarski Warsaw	1	6/96	9,000	PCO-60 Heating Boilers
14. FIAT Auto Poland	1	1/97	140,000	WR-25 Stoker Boiler
15. Krakodlew-Krakow	1	2/97	8,000	Rotary Drier/Sand
16. Cementownia Strzelce	1	2/97	6,400	Cement Kiln Drier
17. Zembiec Zembcu	1	3/97	35,000	Rotary Drier/Bentonite
18. PDM-Koscian	1	4/97	21,600	Asphalt Dryer
19. EkoBud-Grudziadz	1	4/97	3,500	SR-15 Boiler
20. ExBud-Tarnow	1	4/97	5,800	Fluidized Bed Boiler
21. Skleja Eko-Ostrow	1	7/97	13,600	WLM-2.5 Boiler
22. Czech Technical University	1	10/95	2,500	Fluidized Bed Boiler
23. Firma Dragowa Kutnie	1	3/97	45,000	Rotary Drier/Asphalt
24. PZL-Wola Warsaw	2	3/97	100,400	WR-5 Boilers
25. Sp. Energ. S.A. Moszczenica	1	10/97	120,000	PWRp 20 Boiler
26. Ferney Spinning Mills, Mauritius	1	12/95	30,000	Stoker Boiler
27. ZRD Poznan	1	3/98	100,000	Rotary Dryer/Asphalt
28. MZC Dzierzoniow	3	4/98	108,000	WR-5 Boilers
29. S.P. Energ. S.A. Pniowek	1	6/98	110,000	WR-25 Boiler
30. Zak. Energ. Cieplnej. Katowice	1	7/98	120,000	WR-25 Boiler
31. Daewoo Lublin	2	9/98	220,000	EKM-50 Boiler
32. Huta Im. Cedlera Sosnowiec	2	9/98	180,000	OR-32 Boilers
33. Cukrownia Raciborz	<u>2</u>	10/98	<u>210,000</u>	OR-32 Boilers
	47		1,764,700	



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**Figure 11. Budostal
Krakow Core Separator**



**Figure 12. Budostal
Core Separator Layout**

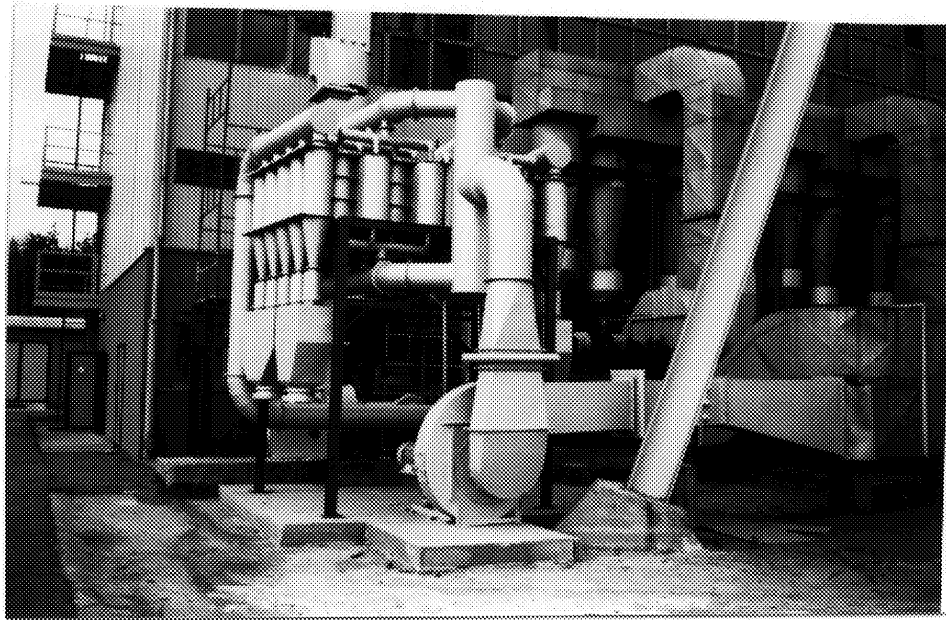


Figure 13. *Core Separator Installation - Oborniki*



Figure 14. *Side View - Oborniki Core Separator*



Figure 15. Stack Condition at Knurow Prior to *Core Separator*

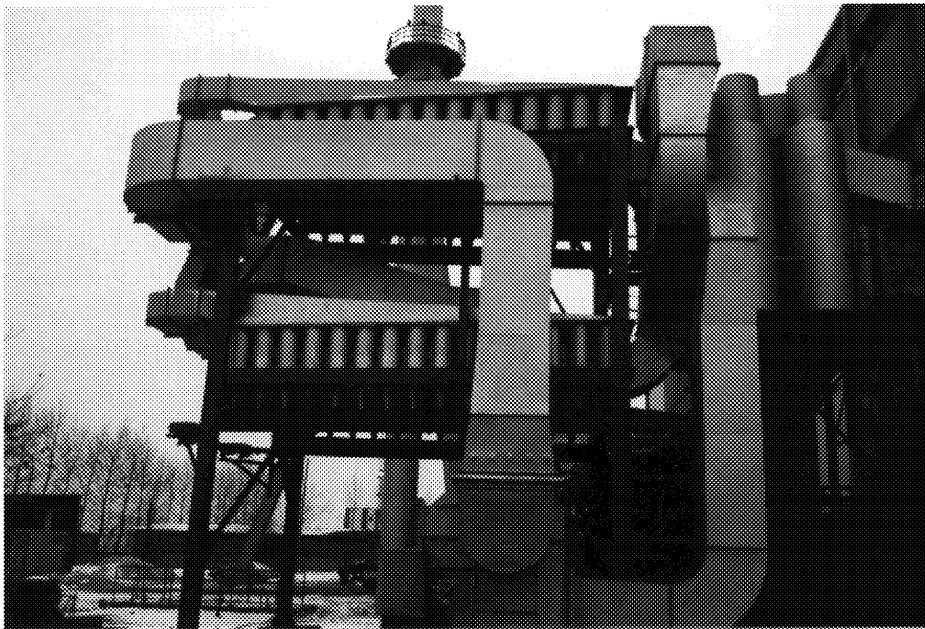


Figure 16. *Core Separator* Installation - Knurow



Figure 17. Structural Steel Installation - FIAT AUTOPOLAND



Figure 18. Core Separator Module Installation - FIAT AUTOPOLAND



Figure 19. *Core Separator* Near Complete - FIAT AUTOPOLAND

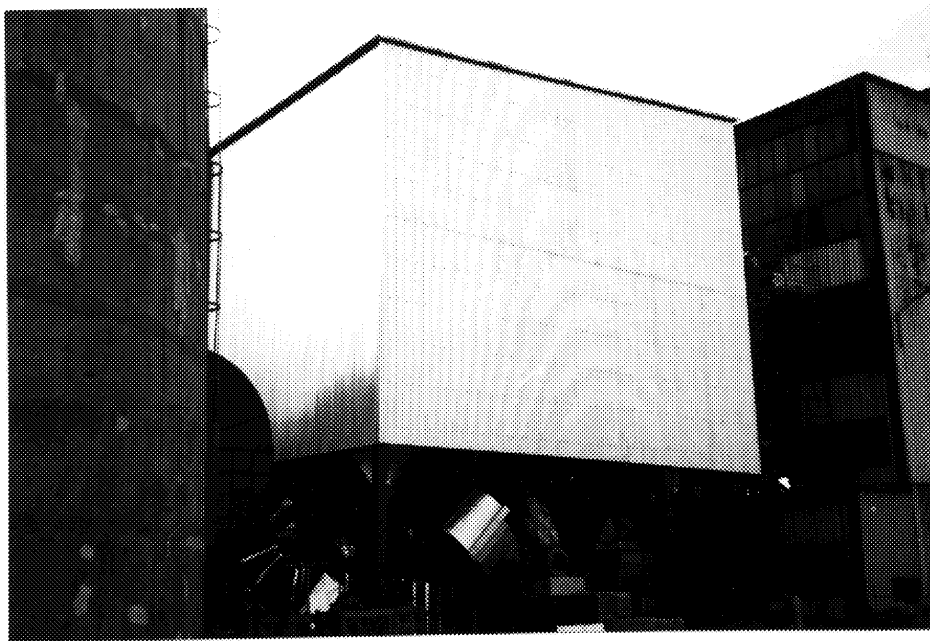


Figure 20. *Completed Core Separator* - FIAT AUTOPOLAND

3.4 Effect on Emission Reductions

The implementation of *Core Separator* dust collectors throughout Poland has had a significant impact on emissions reduction. An example of this can be seen in the Case Study shown below for a WR-10 boiler. This comparison shows that when a *Core Separator* is installed as a replacement for multicyclones, the average emission rate is reduced from about 300 mg/NM³ to 80 mg/NM³. Thus, based on typical boiler operating factors, the reduction in dust emissions annually with a replacement *Core Separator* is approximately 28.9 metric tons for a typical WR-10 boiler.

Case Study

WR 10-011 Boiler	
- Coal Consumption	2,560 kg/h
- Flue Gas Temp.	200 deg. C
- Boiler Efficiency	80 Pct.
- Operating Factor	240 days/yr.
Dust Emissions with Cyclone Collector	
- Average Emission	300 mg/M ³
- Annual Emission	39,485 kg
Dust Emissions with <i>Core Separator</i>	
- Average Emission	80 mg/M ³
- Annual Emission	10,529 kg
Difference in Dust Emission	28.9 MT/yr.

By using similar assumptions, a more comprehensive analysis can be applied to the entire list of *Core Separators* produced by EcoInstal (Table 1) to obtain an estimate of emissions reduction from all sources. Below, this estimate has been made for the five (5) operational *Core Separators* in Krakow and for the forty-five (45) units located throughout Poland.

Estimate of Particulate Emission Reduction Attributed to *Core Separator* Installations

<u>Location (# Units)</u>	<u>Particulate Emissions Reduced, Metric Tons/Year</u>
Krakow Region (5)	116.6
All of Poland (45)	2,154.0

3.5 *Core Separator* Marketing Efforts in Poland

Since 1995, EcoInstal and LSR expended considerable effort in marketing new technology throughout a region that is badly in need of emission control technology. The marketing efforts consisted of the following endeavors:

- Prepared and published technical papers in Polish trade journals
- Attended and exhibited at numerous trade shows
- Made presentations to industry executives and local government officials
- Advertised in select environmental trade magazines

Although EcoInstal exhibited at many trade shows in and near Krakow, it also exhibited at the large international fair known as EcoPol held annually in Poznan. EcoPol is a major world-class environmental trade fair with more than 1,000 exhibiting companies from 190 different countries. Several trade shows were also attended in various cities in Silesia, and in Plzen and Brno of the Czech Republic. Figures 21-24 contain photographs of *Core Separator* materials that were exhibited at EcoPol.

3.6 Awards and Citations

EcoInstal received two prestigious awards in 1996 and 1997 which were directly related to accomplishments associated with this project and the *Core Separator*. These awards are:

- (1) 1996 Best Exhibitor Award at EcoPol Trade Show: This award was made to only five (5) companies in a highly competitive selection process that included more than 2,000 eligible firms.
- (2) 1997 Polish Environmental Leadership Award: This award, given annually by the Minister of the Environment in Poland, was made to EcoInstal and four (4) other

companies for exceptional contributions to environmental cleanup. Most of these contributions were related to *Core Separator* installations.

3.7 Modernization of Manufacturing

In 1996, EcoInstal made a substantial investment to enlarge and improve its production capability. This investment was justified largely by the increase in sales activity from *Core Separator* installations. Having outgrown its 1,000 m² facility, the company acquired and moved into a renovated 5,000 m² facility, and obtained additional equipment for metal-working, welding, and processing large fabricated components.

The process of upgrading the manufacturing process actually involved a major collaborative effort between LSR and EcoInstal. This effort included the following:

- (a) Developing Modular Designs for Small and Large Capacity Units: LSR developed detailed manufacturing drawings with AutoCad® software to produce a maximum number of common (or identical) parts in all contracted units. Although all *Core Separator* units are custom-designed, a modular concept is essential for scale-up in size and to insure low-cost production.
- (b) Technology Transfer from Developer to Manufacturer: Production drawings developed by LSR were adapted to Polish material specifications for sheet steel sizes and thicknesses and conveyed to EcoInstal. AutoCad® drawings were prepared for CNC (computer numerical control) adaptation to the extent possible. LSR's computer performance model was also transferred for the purpose of predicting performance and developing arrangement designs.
- (c) Fixtures for Producing Modules: Jigs and fixtures were constructed for all common pieces used in *Core Separator* modules. The fixtures are a way of standardizing the

manufacture of as many component parts as possible.

- (d) Addition of New Production Equipment: Following a visit to the U.S. and tour of several mid-sized sheet metal companies, EcoInstal acquired a new brakepress, guillotine shearer, improved welders, and other miscellaneous equipment.
- (e) Technical Training of Production Workers: LSR engineers together with EcoInstal management conducted a comprehensive training program for all production workers including CAD/CAM techniques and quality control. This effort was made to implement western manufacturing standards and to prepare EcoInstal for the process of ISO-9000 requirements.

As a result of this upgrading, today EcoInstal is a reputable manufacturer that can compete with just about any sheetmetal company with respect to cost and product quality. Figures 25-30 contain photographs of several steps in the manufacturing sequence of commercial *Core Separator* units at EcoInstal.



Figure 21. EcoInstal Exhibit - EcoPol Trade Show



Figure 22. Core Separator Exhibit - EcoPol Trade Show



Figure 23. Polish/U.S. Exhibit - EcoPol Trade Show



Figure 24. Equipment Display - EcoPol Trade Show

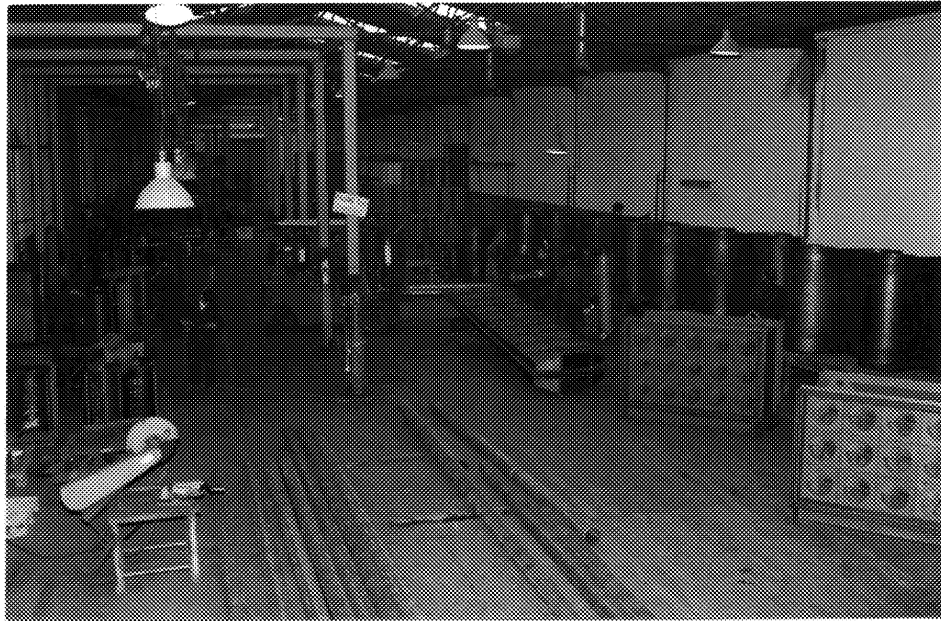


Figure 25. *Core Separator* Production at EcoInstal



Figure 26. Production Sequence at EcoInstal

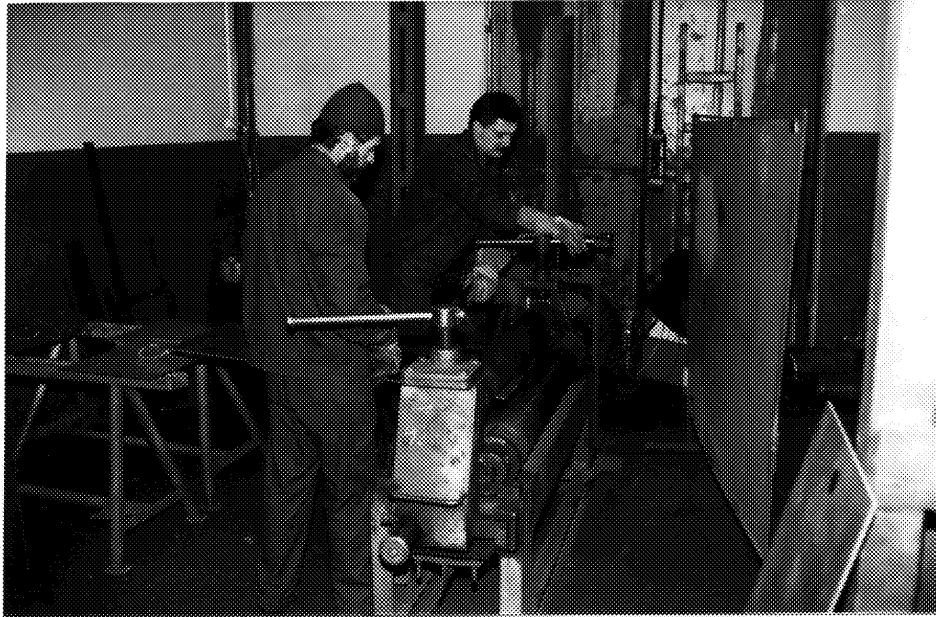


Figure 27. Initial Forming of *Core Separator* Module



Figure 28. Quality Control Department - EcoInstal

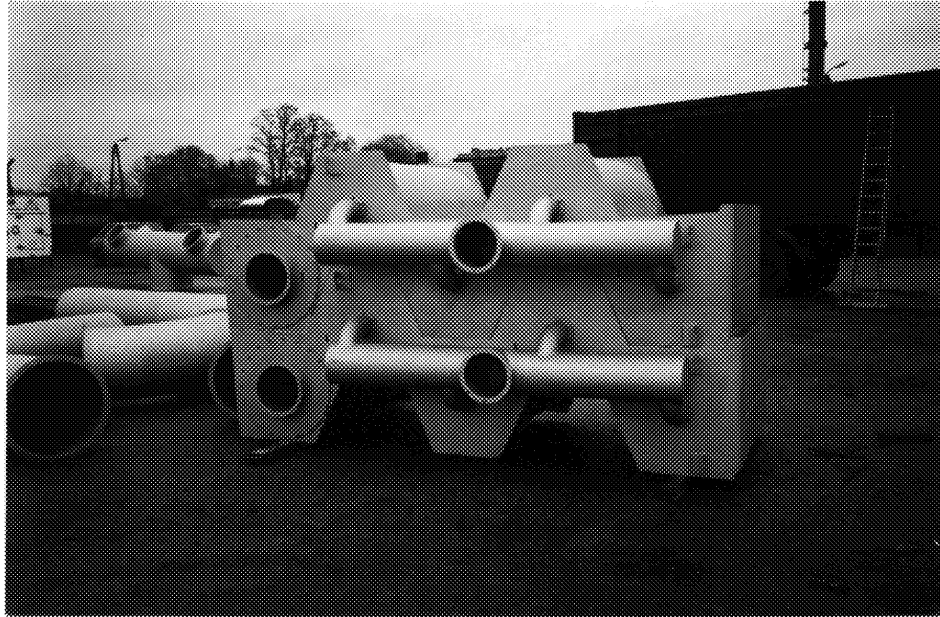


Figure 29. Completed *Core Separator* Modules - EcoInstal



Figure 30. Equipment Being Shipped from EcoInstal

4.0 Difficulties/Problems Encountered During this Project

During the course of this project, a number of challenges were faced by American firms which added to the complexity and difficulty of achieving goals. Most of these challenges were due to a rapidly changing business culture during a period of post-communist political change. In the early 1990s, there were many large state-owned companies throughout Poland, most of them bloated and inefficient by western standards. And while substantial improvements have occurred in Poland since 1989, the early 1990s was a period of substantial change. Some of the problems that were encountered while implementing this project are summarized below:

1. Environmental standards for air and water discharges from the Ministry of the Environment in Poland were promulgated in 1990 and contain regulations for particulate and gaseous emissions. Even though particulates are considered a “priority pollutant,” the Polish emission standard for coal-fired grate boilers is 600 g/GJ, which is roughly ten times higher than that of neighboring countries such as the Czech Republic. These regulations are also written in a way that allows considerable discretion and flexibility on the part of regulating authorities. Such discretion inevitably leads to inconsistent and even arbitrary decisions and rulings by local enforcement officials. It also promotes the continuation of strong central planning, rather than through the reliance of a free market. During this period, regulatory involvement has not been consistent and uniform, where all sources are held responsible for meeting their specific targets.

2. During the course of this project, LSR and its Polish partner made several proposals for emission control systems on boilerhouses in Krakow. A number of these seemed to be promising, but were declined at the last moment when an artificially low price was offered to convert to natural gas or to the district heating system. The volatility and uncertainty of fuel prices were difficult to deal with from the standpoint of suppliers of environmental and energy-related equipment.

3. The business climate in Krakow is more difficult than other regions of the country. This observation is evidenced by the fact that 40 *Core Separator* dust collectors were sold in other Polish cities without the benefit of subsidies. At the same time, only four systems were sold in Krakow despite a 50 percent subsidy incentive and a more concentrated effort. A commonly held belief is that Krakow businesses have come to expect full subsidies from either U.S. or E.U. sources.

5.0 Summary and Conclusions

The objective of the Krakow Clean Fuels and Energy Efficiency Program was the formation of business ventures between U.S. and Polish firms to reduce air emissions in the city of Krakow. The cooperative agreement between LSR Technologies, Inc. and EcoInstal is a long-term self-sustaining venture whereby modern U.S. technology can be offered commercially in Poland through a free-market mechanism. This project has been able to claim the following accomplishments consistent with U.S./Polish goals and objectives:

- Creation of a mutually beneficial business venture between a Polish and U.S. firm which will sustain itself on a continuing basis
- Installation of five (5) *Core Separator* installations in Krakow as well as many other nearby units all of which improve air quality in this historic city
- Installation of forty-five (45) *Core Separator* installations throughout Poland with a combined capacity of 1.7 million M³/h (1.0 million acfm)
- A reduction of particulate emissions in Krakow of more than 115 metric tons per year and a reduction of more than 2,150 metric tons per year throughout Poland
- Introduction of a new technology to a Polish firm, enabling that firm to grow substantially and triple its employee work force
- An added benefit to the Polish firm of exporting equipment out of the country, creating jobs for the local economy, while having a positive effect on the Polish trade balance.

Acknowledgment

The authors would like to thank the Department of Energy and Agency for International Development for supporting this project. The Krakow Clean Fuels and Energy Efficiency Program has definitely made a difference in that city and has brought about a betterment for the entire region. The authors would also like to recognize Mr. Douglas Gyorke for his invaluable support to this and the other Krakow projects. Doug spent almost as much time in Poland as a diplomat, and made vital contributions to the success of the Krakow projects.

APPENDIX

1.0 Sprawozdanie

Oczyszczanie środowiska i kontrola wylazów przemysłowych mają obecnie priorytetową pozycję w sferze poprawy warunków życia w Polsce post-komunistycznej. Poważne zanieczyszczenie powietrza, wody i gleby na terenie całego kraju jest wynikiem ponad czterech dekad centralnego planowania gospodarką. Zanieczyszczenia te są powodem obniżenia zdrowia ludności. Rząd polski rozpoczął wprowadzanie kontroli środowiska w celu odwrócenia tej sytuacji. Polski przemysł węglowy jest jednym z przedmiotów tej kampanii. W roku 1990 węgiel kamienny ciągle jeszcze był źródłem około 80-ciu procent podstawowej produkcji energii elektrycznej. Użytkowanie węgla w Polsce jest jeszcze bardzo niewydajne. Polska zużywa 2 do 3 razy więcej energii na jednostkę brutto produkcji krajowej (GDP) w porównaniu to krajów Europy Zachodniej.

Firma LSR Technologies została wybrana przez Dwustronny (Amerykańsko-Polski) Komitet Sterujący jako jedna z partycypantów Krakowskiego Programu Czystych Paliw Kopalnianych i Oszczędności Energii, aby wziąć udział w jednym z pięciu zakresów projektu wstępnego tego programu. Wybrany zakres tegoż projektu skupił się na ograniczeniu emisji pyłów z kotłowni węglowych i koksowych za pomocą nowej technologii odpylników, pod nazwą *Core Separator*TM (separator/oddzielacz rdzeniowy). Ponieważ *Core Separator* jest przyrządem bardziej opłacalnym i o wiele wydajniejszym od cyklonów wielostopniowych, zauważono, że byłby on doskonałym rozwiązaniem dla bardzo w Krakowie rozproszonych źródeł wydzielaczy pyłów. Na początku lat 90-tych Kraków miał jeszcze około 1300 kotłowni zawierających około 2900 kotłów ogrzewczych. Pomimo że od tego czasu wiele z tych kotłowni zamknięto, poważna jednak ich część pozostaje jeszcze w eksploatacji i stanowi główne źródło emisji pyłów do atmosfery.

W 1994 roku firma LSR Technologies podpisała umowę o współpracy, z podziałem

kosztów, z Departamentem Energetyki USA. Umowa ta zapewniała oprzyrządowanie, obsługę i serwis związane z zainstalowaniem systemów do ograniczania emisji zanieczyszczeń powietrza z kotłowni węglowych. Stworzony został dwufazowy projekt, którego zadania podzielono na dwie ściśle określone struktury. Pierwsza faza zawierała badania infrastruktury na które składały się: (1) opracowanie planu przedsięwzięcia i strategii rynkowej; (2) analiza i wybór partnera do produkcji i obsługi spodziewanego zapotrzebowania rynku, oraz (3) zabezpieczenie odpowiednich środków finansowych oraz zapewnienie zobowiązań o podziale kosztów na pierwsze instalacje. Do wykonania tej fazy firma LSR weszła w umowę z Fundacją Na Rzecz Efektywnego Wykorzystania Energii w celu uzyskania pomocy w ogólnym planowaniu oraz w wykonaniu prac. Pod koniec pierwszej fazy projektu polska firma EcoInstal została zatrudniona jako główny partner LSR Technologies.

Druga faza objęła zabezpieczenie poważniejszych zobowiązań finansowych do właściwego wdrożenia i instalacji nowej technologii w kotłowniach węglowych. Miejscem pokazowym dla zainstalowania pierwszego zespołu *Core Separator* zostały wybrane Krakowskie Zakłady Armatur, gdzie usprawniono kolektor pyłu w kotle typu WR-5. Cztery (4) kolejne zespoły *Core Separator* zainstalowano w innych kotłowniach Krakowa. W każdej z nich skuteczność kolektorów pyłu wzrosła z 75-80% do około 94-97%. Poziom emisji pyłu zmalał do poniżej 20g/GJ, co zbliżyło się do wydajności droższych urządzeń, jak filtrów elektrostatycznych (ESP) lub tkaninowych. Równolegle z instalacjami w Krakowie, 40 innych zespołów *Core Separator* zamontowano w innych rejonach Polski, m.in. na Śląsku, który jest jednym z głównych źródeł zanieczyszczeń powietrza w Krakowie.

W celu dostosowania się do zapotrzebowania na zespoły *Core Separator* w Polsce, konieczne stało się wyraźne powiększenie zdolności produkcyjnej EcoInstalu. Proces usprawnienia produkcji wymagał ściślej współpracy na którą złożyły się następujące zadania: (1) opracowanie oprojektowania modułowego przy użyciu techniki CAD/CAM (projektowanie układów wspomagane komputerem/produkcja wspomagana komputerem); (2) transfer

nowej technologii przystosowanej do polskich wymagań technicznych metalu; (3) wypracowanie osprzętu do standardyzacji komponentów; (4) nabycie nowych maszyn produkcyjnych, oraz (5) gruntowne szkolenie robotników. W wyniku tych wysiłków i usprawnień EcoInstal stał się szanowaną i znaną na rynku firmą produkującą układy do kontroli zanieczyszczenia powietrza. EcoInstal może obecnie konkurować pod względem ceny oraz jakości produktu praktycznie z każdą firmą przemysłu metalowego w Polsce.

Podczas trwania tego projektu, obie firmy, LSR jak i EcoInstal, otrzymały prestiżowe nagrody za zespoły *Core Separator*. W 1996 roku LSR zdobyła nagrodę R&D 100 Award przyznaną corocznie za najlepszy wyrób techniczny na świecie. EcoInstal zdobył w roku 1997 Polską Nagrodę za Przodownictwo w Ochronie Środowiska przyznaną przez Ministra Ochrony Środowiska, za wyjątkowy wkład w kontrolę zanieczyszczeń.

Projekt ten okazał się olbrzymim sukcesem i wypełnił wszystkie cele postawione przez Dwustronny Komitet Sterujący. Do osiągnięć projektu, które przyczyniły się do wypełnienia powyższych celi należy zaliczyć:

- Stworzenie wzajemnie korzystnego przedsięwzięcia pomiędzy polską i amerykańską firmą, które jest od tego czasu samodzielnie kontynuowane i utrzymywane;
- Zainstalowanie 5-ciu zestawów *Core Separator* w Krakowie oraz wielu innych w rejonie Krakowa, które przyczyniają się do znacznej poprawy jakości powietrza w tym historycznym mieście;
- Zainstalowanie 45-ciu zespołów *Core Separator* z łączną wydajnością 1.7 miliona m³/h w skali całego kraju;

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- Obniżenie poziomu emisji pyłów w Krakowie o ponad 115 ton rocznie oraz z górą 2150 ton rocznie na terenie całej Polski;
- Zapoznanie polskiej firmy z nową technologią, umożliwiła znaczny jej rozrost oraz potrojenie liczby jej pracowników;
- Zaistnienie dla polskiej firmy możliwości eksportu osprzętu jako dodatkowego ubocznego benefitu tego projektu; sytuacja ta łączy się pośrednio ze stworzeniem nowych posad (poszerzenie rynku pracy) oraz ogólnie wpływa pozytywnie na bilans polskiego handlu zagranicznego.

Prestiżowa nagroda ministra ochrony środowiska, zasobów naturalnych i leśnictwa

Lider Polskiej Ekologii

Protokół z posiedzenia Rady Programowej Konkursu Lider Polskiej Ekologii

W dniu 12.05.1997 r. odbyło się posiedzenie Rady Programowej Konkursu „Lider Polskiej Ekologii” w składzie:

przewodniczący:

Adam Mierzwiński - dyrektor generalny w Ministerstwie Ochrony Środowiska, Zasobów Naturalnych i Leśnictwa,

zastępcy przewodniczącego:

Ewa Marchwińska - dyrektor Instytutu Ekologii Terenów Uprzemysłowionych,
Stanisław Garlicki - wicedyrektor Departamentu Polityki Ekologicznej w Ministerstwie Ochrony Środowiska, Zasobów Naturalnych i Leśnictwa,

członkowie:

Tomasz Winnicki - Politechnika Wrocławska Instytut Inżynierii Ochrony Środowiska, Przemysław Trojan - Muzeum i Instytut Zoologii PAN,

Przemysław Czajkowski - koordynator krajowy GEF/SGP,

Jolanta Matlakowska-Karmańska - redakcja czasopisma „EKOPROFIT”,

Maciej Nowicki - prezes Fundacji EKOFUNDUSZ,

Wiesława Bogutyn - Ministerstwo Gospodarki, Departament Przemysłu,

Wacław Jedliński - Ministerstwo Zdrowia i Opieki Społecznej,

Barbara Pac-Kowalczyk - kierownik Zespołu Przemysłu Chemicznego Polskiego Centrum Badań i Certyfikacji,

Andrzej Miłoszewski - dyrektor Zespołu Kontroli Głównego Inspektoratu Ochrony Środowiska,

sekretarz:

Wanda Jarosz - Instytut Ekologii Terenów Uprzemysłowionych.

Na ogólnopolski konkurs o tytuł „Lidera Polskiej Ekologii” wpłynęły łącznie 162 zgłoszenia w czterech kategoriach: techniki i technologii, nauka, usługi, edukacja ekologiczna. Dziesięć z nich nie spełniało formalnych wymagań regulaminu konkursu i zostało odrzuconych - brak formularza zgłoszenia, opisu przedsięwzięcia.

W poszczególnych kategoriach zgłoszono:

- techniki i technologie - 72 wnioski,

- nauka - 14 wniosków,

- usługi - 14 wniosków,

- edukacja ekologiczna - 52 wnioski.

Po zapoznaniu się z treścią nadesłanych prac członkowie Rady Programowej postanowili przyznać tytuł LIDERA POLSKIEJ EKOLOGII w poszczególnych kategoriach następującym wnioskodawcom:

Kategoria techniki i technologie

- „Technologia produkcji oleju napędowego miejskiego”. Zgłaszający: Petrochemia Plock S.A., Plock

- Automatyczny pyłomierz grawimetryczny P-10ZA. Zgłaszający: BAASK - Aparatura Pomiarowa i ZUH ZAM Kety S.A., Kety.

Trzeciej nagrody w kategorii techniki i technologie nie przyznano.

Kategoria usługi

- „Kompleksowa realizacja inwestycji ochrony powietrza: projektowanie, montaż, produkcja, serwis”.

Zgłaszający: ECO INSTAL Specjalistyczne Przedsiębiorstwo Budowy Urządzeń do Ochrony Środowiska, Poznań.

- „Instalacja odsiarczania i odpylania spalin”. Zgłaszający: Fabryka Urządzeń Mechanicznych KAMAX S.A., Kańczuga.

- Prace doradczo-projektowe:

- Kompleksowe rozwiązywanie problemów ekologicznych w zakresie gospodarki wodno-ściekowej w mieście Zgierz.

- Kompleksowe uporządkowanie zagadnień gospodarki odpadami w mieście Bolesławiec.

- Kompleksowe uporządkowanie zagadnień gospodarki odpadami w mieście Puławy.

- Kompleksowy regionalny program gospodarki odpadami dla Stowarzyszenia Gmin Lubuskich „Pogranicze”.

Konsulting - przeglądy ekologiczne: Konsulting - szkolenia.

Zgłaszający: Przedsiębiorstwo Projektowo-Inżynieryjne EKOLOG Sp. z o.o., Pila.

Kategoria nauka

Podjęto decyzję o nieprzyznaniu nagrody „Lidera Polskiej Ekologii” w kategorii nauka.

Kategoria edukacja ekologiczna

- „Mikrosystem ekologiczno-wychowawczy Zielona Szkoła i jego realizacja w utworzonej Stacji Ekologicznej w Międzygórzu oraz w Międzyszkolnym Centrum Edukacji Prośrodowiskowej przy Zespole Szkół Chemicznych w Poznaniu”, „Ogród dydaktyczny ze stacją meteorologiczną przy Zespole Szkół Chemicznych w Poznaniu”, „Ochrona wód środowiska naturalnego”.

Zgłaszający: Zespół Szkół Chemicznych i XII Liceum Ekologiczne, Poznań.

- „Czysta sprawa” - pilotażowy program edukacji ekologicznej miasta Rzeszowa i MB-Rzeszów S.A. o zagospodarowaniu odpadów komunalnych”. Zgłaszający: MB-Rzeszów S.A., Rzeszów.

- „Polsko-Amerykański Program Edukacji Ekologicznej KRAG”. Zgłaszający: Regionalne Centrum Edukacji Ekologicznej, Plock.

Rada Programowa wnioskuję o przyznanie specjalnej nagrody ministra ochrony środowiska, zasobów naturalnych i leśnictwa, „Lidera Polskiej Ekologii” dla pracy:

- „Harcerski Program Edukacji Ekologicznej”. Zgłaszający: Główna Kwatera Związku Harcerstwa Polskiego, Warszawa.

Podpisał
przewodniczący Rady Programowej
Konkursu „Lider Polskiej Ekologii”
Adam Mierzwiński

Zatwierdził
minister Stanisław Żelichowski
16 maja 1997 r.

J. Cieciński - A. Pasacki



Zakład Wykonywania Pomiarów

Biurowo: ul. Oleska 123, 45-232 Opole, tel/fax (0-77)556037
Laboratorium: ul. Grota Roweckiego 9a, 46-256 Opole

BADANIA ZANIECZYSZCZEŃ POWIETRZA

Inwestor:

**Miejskie Przedsiębiorstwo Komunikacyjne
Stacja Obsługi Autobusów Kraków-Bieńczyce.**

Temat opracowania:

**Pomiary emisji pyłowej i skuteczności odpylania
Instalacji odpylającej KotłóW WCO-80 nr.2 i 3
w MPK - Stacja Obsługi Autobusów Kraków-Bieńczyce.**

Instalacje odpylania z zastosowaniem
CORE SEPARATORA wykonał:

ECO-INSTAL
Specjalistyczne Przedsiębiorstwo Budowy
Urządzeń Do Ochrony Środowiska
Zakład produkcyjny Nr 1 w Kościanie
64-000 Kościan ul. Łąkowa 5
tel. 065/ 120 595
fax 065/ 121 927

OPOLE MARZE



**SPECJALISTYCZNE PRZEDSIĘBIORSTWO
BUDOWY URZĄDZEŃ
DO OCHRONY ŚRODOWISKA**

Spis treści.

1. Cel i zakres pomiarów.
2. Metodyka i aparatura pomiarowa.
 - 2.1. Metodyka pomiaru emisji i unosu pyłu.
 - 2.2. Zestaw aparatury.
 - 2.3. Mierzone i wyznaczane parametry.
 - 2.4. Analiza składu chemicznego gazu
 - 2.5. Obliczenia emisji pyłowej i skuteczności odpylania.
3. Parametry pracy urządzenia technologicznego.
4. Punkty pomiarowe.
5. Wyniki i uwagi końcowe.
6. Wydruki komputerowe wyników pomiarów i kart danych pomiarowych.

1. Cel i zakres pomiarów.

Podstawą do wykonania niniejszych pomiarów jest zlecenie Eco-Instal Poznań Zakładu Produkcyjnego Nr 1 w Kościanie dotyczące wykonania pomiarów emisji pyłowej i skuteczności odpylania instalacji odpylających Kotłów WCO-80 nr.2 i 3 w Kotlewni Zakładowej Miejskiego Przedsiębiorstwa Komunikacji - Stacja Obsługi Autobusów w Krakowie-Bieńczyce ul. Makuszyńskiego.

Cykl pomiarowy obejmował następujące etapy prac:

Kocioł WCO-80 nr.2

- za kotłem, przed cyklonem i Core Separatorem (Up)
- za cyklonem i Core Separatorem - przed wentyl. (Ep)

Kocioł WCO-80 nr.3

- pkt.1 - za kotłem przed cyklonami (Up)
- pkt.2 - za cyklonami a przed odpylaczem Core Separatorem (Up)
- pkt.3 - za cyklonami i za odpylaczem Core Separatorem - przed wentyl. (Ep)
- pkt.4 - za cyklonami i za odpylaczem Core Separatorem - za wentyl. (Np)
- pkt.5 - na kanale recyrkulacyjnym przed wentylatorem (Np)
- pkt.6 - na kanale recyrkulacyjnym za wentylatorem (Up)

- Up - pomiar unosu pyłu
- Ep - pomiar emisji pyłu
- Np - pomiar natężenia przepływu

2. Metodyka i aparatura pomiarowa.

2.1. Metodyka pomiaru emisji pyłu i skuteczności odpylania.

Pomiar natężenia przepływu gazu i stężenia zapylenia za urządzeniem odpylającym przeprowadzono stosownie do zaleceń „Katalogu Metod Manualnych” Etap II - Emisja oraz Polskiej Normy PN-Z-04030-7 „Ochrona czystości powietrza. Badania zawartości pyłu. Pomiar stężenia i strumienia masy pyłu w gazach odlotowych metodą grawimetryczną”.

2.2. Zestaw aparatury:

- sondy zmodernizowane i zerowe, ogrzewane z końcówkami $\varnothing 13$ mm
- filtr mierniczy ogrzewany z filtrem tkaninowym
- chłodnica
- absorber wypełniony CaCl_2
- rurka spiętrzająca Prandtla - liczba kształtu $\beta = 1,00$

- gazomierz wyposażony w termometr i manometr
- pompa ssąca
- mikromanometr typu MPR-4 wypełniony etanolem o gęstości $\gamma = 0,8 \text{ g/cm}^3$
- mierniki temperatury typu EMT-07
- wskaźniki quasiizokinetyczności
- barometr ze skalą mosiężną i termometr rtęciowy
- komplet węży gumowych $\varnothing 13 \text{ mm}$
- komplet węży gumowych impulsowych $\varnothing 3 \text{ mm}$.

2.3. Mierzone i wyznaczane parametry / jednostka /

- ciśnienie barometryczne / mmHg, hPa /
- temperatura otoczenia / °C, K /
- wymiary kanału pomiarowego / mm, m^2 /
- zanurzenie sondy pomiarowej w kanale / mm /
- założenie stałej wielkości czasu do zassania częściowego strumienia gazu w każdym punkcie pomiaru / min /
- temperatura gazu w gazomierzu / °C, K /
- temperatura gazu w kanale pomiarowym / °C, K /
- podciśnienie w gazomierzu / mmHg, Pa /
- ciśnienie dynamiczne w kanale / $\text{mmC}_2\text{H}_5\text{OH}$, Pa /
- ciśnienie statyczne w kanale / $\text{mmC}_2\text{H}_5\text{OH}$, mmH_2O , Pa /
- pomiar zerujący / utrzymanie równowagi ciśnień statycznych w kanale i głowicy sondy z uwzględnieniem oporów hydraulicznych i stopnia rozprężenia gazu /
- ilość wyekroplonej pary wodnej w chłodnicy / g /
- ilość zaabsorbowanej pary wodnej w absorberze / g /
- wielkość częściowego strumienia gazu suchego / m^3 /.

2.4. Analiza składu chemicznego gazu i stężenia tlenu węgla.

Analiza składu chemicznego gazu, oznaczenie % zawartości CO_2 , O_2 i zawartości CO w ppm przeprowadzono przy pomocy analizatora gazu z czujnikami elektrochemicznymi typu TESTO-342-1.

2.5. Obliczenie emisji pyłu i skuteczności odpylania.

Obliczenia wyników z przeprowadzonych prac pomiarowych wykonano przy pomocy programu komputerowego „EMISJA 5.1” autorstwa mgr inż. Ryszard Samoć - Zakład Usług Komputerowych Dla Potrzeb Ochrony Środowiska 62-800 Kalisz.

3. Parametry pracy urządzeń technologicznych.

Pomiary emisji pyłowej i skuteczności odpylania wykonano przy następujących parametrach pracy kotłów WCO-80 nr.2 i 3.

Parametr mierzony	Jednostka	Wartość	
		Kocioł nr.2	Kocioł nr.3
Temperatura wody z kotła	°C	120	118
Temperatura wody do kotła	°C	73	75
Ciśnienie wody na kotle	MPa	0,19	0,19

Rodzaj paliwa: miał węglowy

kaloryczność - 20000 kJ/kg

zawartość popiołu - 21 %

zawartość siarki - 1,0 %

4. Punkty pomiarowe.

Ilość króćców pomiarowych zainstalowanych na instalacji odpylającej kotłów WCO-80 jest zgodna z zaleceniami Polskiej Normy PN-Z-04030-7 „Ochrona czystości powietrza. Badania zawartości pyłu. Pomiar stężenia i strumienia masy pyłu w gazach odlotowych metodą grawimetryczną” a ich usytuowanie jest optymalne do istniejącego kształtu instalacji.

Usytuowanie punktów pomiarowych przedstawiono poniżej: (długość odcinka prostego przed pkt. pom./ za pkt. pom. w metrach).

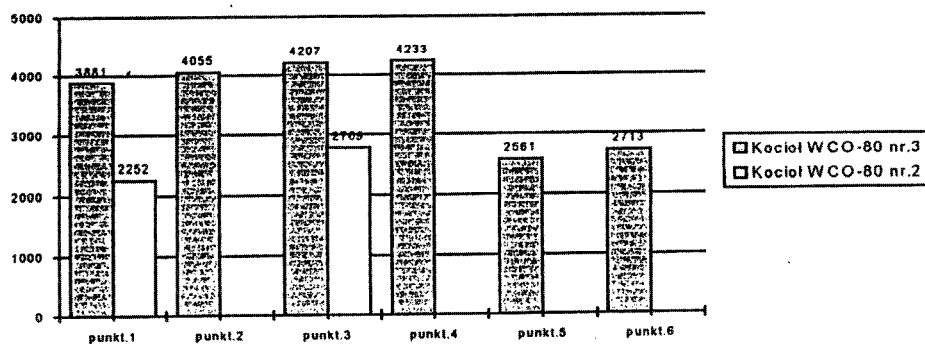
Kształt instalacji na obydwu kotłach WCO-80 jest ten sam.

za kotłem przed cyklonami	- (0,2/0,6)
za cyklonami a przed odpyl. Core Separatorem	- (0,3/0,1)
za cyklonami i za odpyl. Core Separatorem za wentyl. ciągu	- (0,5/1,0)
kanał recyrkulacyjny - przed wentylatorem	- (0,9/0,4)
kanał recyrkulacyjny - za wentylatorem	- (0,7/0,5)
za cyklonami i za odpyl. Core Separatorem przed wentyl. ciągu	- (0,6/0,2)

5. Wyniki i uwagi końcowe.

W poniższych tabelach i wykresach przedstawiono wyniki pomiarów.

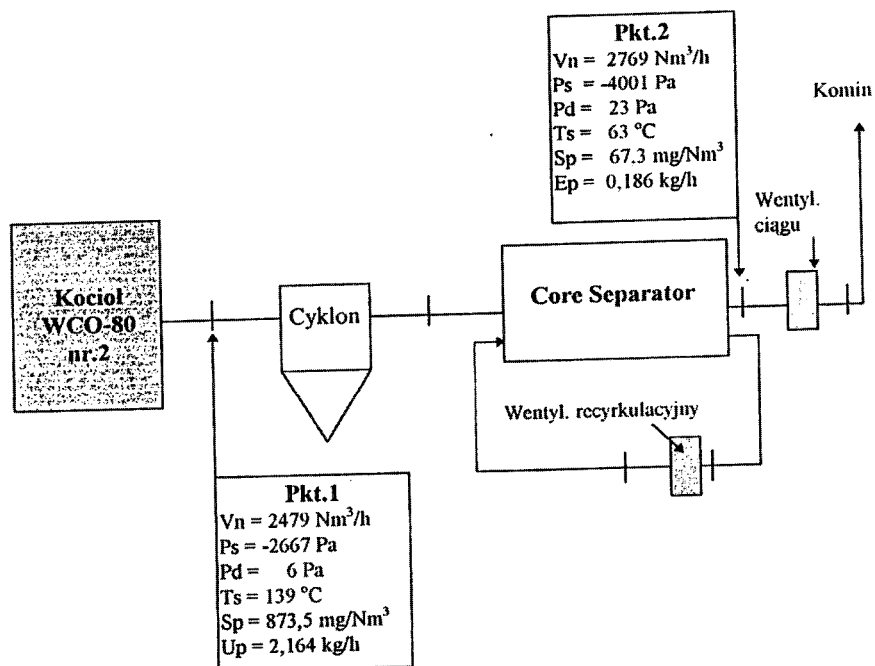
Wykres natężenie przepływu dla kotłów WCO-80 nr.2 i 3 / w m³/h /



Zestawienie wyników pomiarów na kotle WCO-80 nr.2

Miejsce pomiaru	Temp. spalin °C	Ciśnienie statyczna Pa	Ciśnienie dynamiczne Pa	Natężenie przepływu Nm ³ /h	Stężenie pyłu mg/Nm ³	Unos pyłu kg/h
Punkt.1	139	-2667	6	2479	873,5	2,164
Punkt.2	63	-4001	23	2769	67,3	0,186

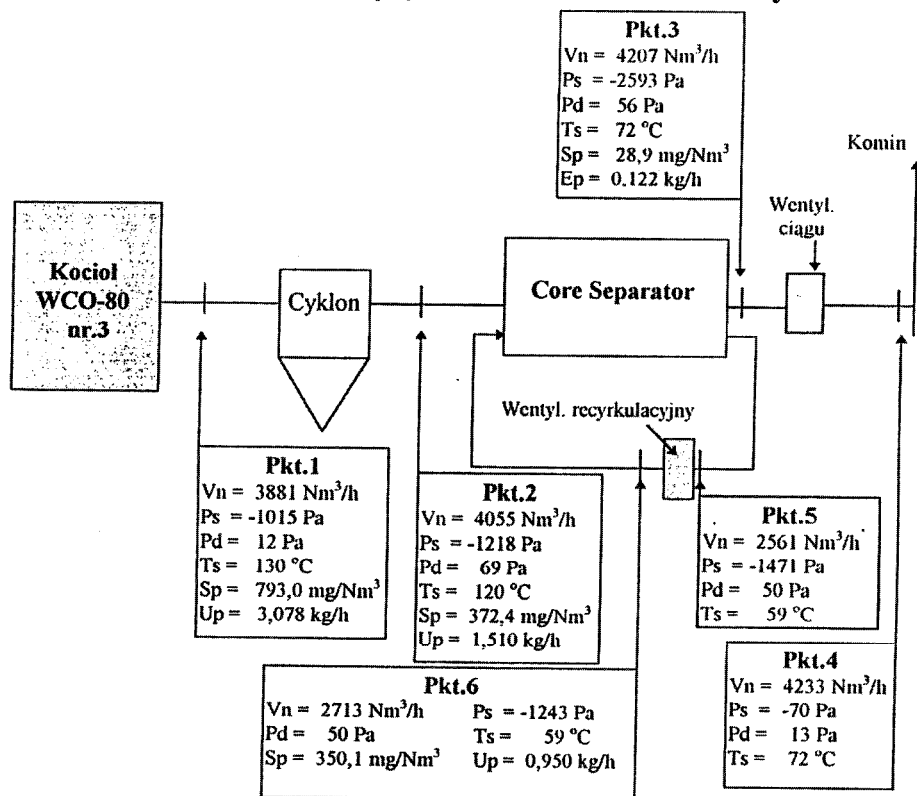
Schemat instalacji odpylającej kotła WCO-80 nr.2 wraz z wynikami.



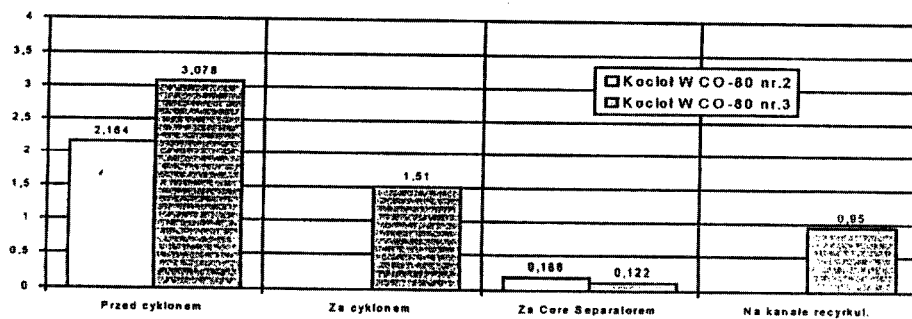
Zestawienie wyników pomiarów na kotle WCO-80 nr.3

Miejsce pomiaru	Temp. spalin °C	Ciśnienie statyczna Pa	Ciśnienie dynamiczne Pa	Natężenie przepływu Nm ³ /h	Stężenie pyłu mg/Nm ³	Unos pyłu kg/h
Punkt.1	130	-1015	12	3881	793,0	3,078
Punkt.2	120	-1218	69	4055	372,4	1,510
Punkt.3	72	-2593	56	4207	28,9	0,122
Punkt.4	72	-70	13	4233	-	-
Punkt.5	59	-1471	44	2561	-	-
Punkt.6	59	-1243	50	2713	350,1	0,950

Schemat instalacji odpylającej kotła WCO-80 nr.3 wraz z wynikami.



Wykres unosu i emisji pyłu kotłów WCO-80 nr.2 i 3 - w kg/h

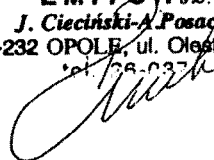


Skuteczność odpylania zespołu urządzeń odpylających kotła WCO-80 nr.2
 (cyklony + Core Separator) $So = 91,39 \%$

**Wyniki pomiarów skuteczności odpylania
zespołu odpylającego kotła WCO-80 nr.3**

Urządzenie odpylające	Skuteczność odpylania w %
Cyklon	50,9
Core Separator	91,9
Cyklon + Core Separator	96,0

Podpis i pieczęć
Wykonawcy
ZAKŁAD WYKONYWANIA POMIARÓW
EMITOR s.c.
J. Cieciński-A. Posacki
45-232 OPOLE, ul. Oleśka 123
tel. 76-637 76 637



Zakład Wykonywania Pomiarów
"EMITOR" s.c.
45-232 Opole, ul. Oleska 123

W Y N I K I P O M I A R U U N O S U nr 196p/E/96

Nazwa zakładu: MPK - Stacja Obsługi Autobusów Bienczyce-Kraków
Nazwa obiektu: Kocioł WCO-80 nr.2
Miejsce pomiaru: Punkt nr.1 - za kotłem (przed odpylaczami)
Data pomiaru: 1996-03-13
Wymiary kanału: przekrój prostokątny 0.530 x 0.550 m

Lp	P a r a m e t r	j.m.	1	2	Średnia
1	Ciśnienie barometrycz.	hPa	991.94	991.94	991.94
2	Ciśnienie statyczne	hPa	965.27	965.27	965.27
3	Temperatura w kanale	K	411.5	412.2	411.85
4	Ciśnienie dynamiczne	Pa	5.5337	5.855	5.6944
5	Gęstość w war.umownych	kg/m3	1.2905	1.2926	1.2915
6	Gęstość w war.rzeczyw.	kg/m3	0.8173	0.8172	0.8173
7	Prędkość gazów	m/s	3.6798	3.7853	3.7326
8	Nateż. przepływu umown.	m3/h	2445.7	2511.6	2478.7
9	Nateż. przepływu rzecz. Stężenie pyłu	m3/h	3861.6	3972.3	3917
10	-w warunkach rzeczyw.	mg/m3	568.19	535.66	551.93
11	-w warunkach umownych	mg/m3	898.54	848.54	873.54
12	Unos pyłu	kg/h	2.1976	2.1312	2.1644

Zakład Wykonywania Pomiarów
 "BMITOR" s.c.
 45-232 Opole, ul. Oleska 123

W Y N I K I P O M I A R U E M I S J I nr 197z/E/96

Nazwa zakładu: MPK - Stacja Obsługi Autobusów Bienczyce-Kraków
 Nazwa obiektu: Kocioł WCO-80 nr.2
 Miejsce pomiaru: Punkt nr.2 - za odpylaczami (przed wentyl.)
 Data pomiaru: 1996-03-13
 Wymiary kanału: przekrój kwadratowy 0.380 x 0.380 m

Lp	P a r a m e t r	j.m.	1	2	średnia
1	Ciśnienie barometrycz.	hPa	991.94	991.94	991.94
2	Ciśnienie statyczne	hPa	951.93	951.93	951.93
3	Temperatura w kanale	K	336.3	336.1	336.2
4	Ciśnienie dynamiczne	Pa	24.2656	23.4159	23.8408
5	Gęstość w war.umownych	kg/m3	1.2844	1.2859	1.2851
6	Gęstość w war.rzeczyw.	kg/m3	0.9816	0.9833	0.9825
7	Prędkość gazów	m/s	7.0313	6.9012	6.9662
8	Natęż. przepływu umown.	m3/h	2793.5	2743.4	2768.5
9	Natęż. przepływu rzecz. Stężenie pyłu	m3/h	3655.2	3587.5	3621.4
10	-w warunkach rzeczyw.	mg/m3	51.9034	50.8616	51.3825
11	-w warunkach umownych	mg/m3	68.0202	66.6152	67.3177
12	Emisja pyłu	kg/h	0.19	0.1828	0.1864

Błędy pomiarów fizykochemicznych i analiz

błąd pomiaru temperatury = 1 %
 błąd oznaczenia wilgotności gazu = 7.07 %
 błąd oznaczenia gęstości gazu = 7.21 %
 błąd pomiaru przepływu gazów w kanale = 5.2 %
 błąd oznaczenia stężenia pyłu = 5.39 %

ZESTAWIENIE BŁĘDÓW POMIARÓW EMISJI

nazwa zanieczyszczenia	średnia emisja [kg/h]	błąd względny [%]	błąd bezwzględny [kg/h]
pył	0.186	7.49	+ - 0.014

Obliczenie sprawności urządzeń oczyszczających

Zakład: MPK - Stacja Obsługi Autobusów Bienczyce-Kraków

Obiekt: Kocioł WCO-80 nr.2

Pomiar emisji w dniu 1996-03-13

Nazwa zanieczyszczenia	unos kg/h	emisja kg/h	sprawność oczyszcz. %
pył	2.1644	0.1864	91.4

Pomiary przed urządzeniami oczyszczającymi:

1. Punkt nr.1 - za kotłem (przed odpylaczami)

Pomiary za urządzeniami oczyszczającymi:

1 Punkt nr 2 - za odpylaczami (przed wentyl)

Zakład Wykonywania Pomiarów
"EMITOR" s.c.
45-232 Opole, ul. Oleska 123

W Y N I K I P O M I A R U U N O S U nr 189p/E/96

Nazwa zakładu: MPK - Stacja Obsługi Autobusów Bińczyce-Kraków
Nazwa obiektu: Kocioł WCO-80 nr.3
Miejsce pomiaru: Punkt nr.1 - za kotłem
Data pomiaru: 1996-03-13
Wymiary kanału: przekrój kwadratowy 0.550 x 0.550 m

Lp	P a r a m e t r	j.m.	1	2	średnia
1	Ciśnienie barometrycz.	hPa	991.41	991.41	991.41
2	Ciśnienie statyczne	hPa	981.28	981.23	981.26
3	Temperatura w kanale	K	403	402.4	402.7
4	Ciśnienie dynamiczne	Pa	11.7636	13.0797	12.4216
5	Gęstość w war.umownych	kg/m3	1.2862	1.2856	1.2859
6	Gęstość w war.rzeczyw.	kg/m3	0.8456	0.8464	0.846
7	Prędkość gazów	m/s	5.2749	5.5592	5.4171
8	Natęż. przepływu umown.	m3/h	3776.5	3985.8	3881.2
9	Natęż. przepływu rzecz. Stężenie pyłu	m3/h	5744.4	6054	5899.2
10	-w warunkach rzeczyw.	mg/m3	516.34	525.39	520.87
11	-w warunkach umownych	mg/m3	786.64	799.26	792.95
12	Unos pyłu	kg/h	2.9707	3.1857	3.0782

Zakład Wykonywania Pomiarów
 "ENITOR" s.c.
 45-232 Opole, ul. Oleska 123

W Y N I K I P O M I A R U E M I S J I nr 192z/E/96

Nazwa zakładu: MPK - Stacja Obsługi Autobusów Bienczyce-Kraków
 Nazwa obiektu: Kocioł WCO-80 nr.3
 Miejsce pomiaru: Punkt nr.3 - Za odpylaczami (przed wentylatorem)
 Data pomiaru: 1996-03-13
 Wymiary kanału: przekrój kwadratowy 0.380 x 0.380 m

Lp	P a r a m e t r	j.m.	1	2	średnia
1	Ciśnienie barometrycz.	hPa	992.07	992.07	992.07
2	Ciśnienie statyczne	hPa	966.2	966.07	966.14
3	Temperatura w kanale	K	345.3	344.5	344.9
4	Ciśnienie dynamiczne	Pa	56.7896	54.5922	55.6909
5	Gęstość w war.umownych	kg/m3	1.2869	1.2856	1.2862
6	Gęstość w war.rzeczyw.	kg/m3	0.9723	0.9734	0.9728
7	Prędkość gazów	m/s	10.8083	10.591	10.6997
8	Nateż. przepływu umown.	m3/h	4244.9	4168.6	4206.8
9	Nateż. przepływu rzecz. Stężenie pyłu	m3/h	5618.6	5505.6	5562.1
10	-w warunkach rzeczyw.	mg/m3	21.2122	22.5017	21.8569
11	-w warunkach umownych	mg/m3	28.1213	29.7658	28.9436
12	Emisja pyłu	kg/h	0.1194	0.1241	0.1217

Błędy pomiarów fizykochemicznych i analiz

błąd pomiaru temperatury = 1 %
 błąd oznaczenia wilgotności gazu = 7.07 %
 błąd oznaczenia gęstości gazu = 7.21 %
 błąd pomiaru przepływu gazów w kanale = 5.2 %
 błąd oznaczenia stężenia pyłu = 5.39 %

ZESTAWIENIE BŁĘDÓW POMIARÓW EMISJI

nazwa zanieczyszczenia	średnia emisja [kg/h]	błąd względny [%]	błąd bezwzględny [kg/h]
pył	0.122	7.49	+ - 0.0091

KARTA DANYCH POMIAROWYCH nr196p/E/96

Nazwa zakładu: MPK - Stacja Obsługi Autobusów Bienczyce-Kraków
 Nazwa obiektu: Kocioł WCO-80 nr.2
 Miejsce pomiaru: Punkt nr.1 - za kotłem (przed odpylaczami)
 Data pomiaru: 1996-03-13

POMIAR 1

Ciśnienie barometryczne = 991.9 hPa 744.2mmHg
 Temperatura gazu w przewodzie = 411.5 °K 138.5°C

Odczyty ciśnienia statycznego i dynamicznego
 Płyn w mikromanometrze : etanol o gęstości 0.8 g/cm³
 Gęstość płynu do pomiaru ciśnienia statycznego 13.6 g/cm³

Lp	hs [mm] 1/1	Ps [Pa]	hd [mm] 1/5	Pd [Pa]	w [m/s]
1	-20	-2667.23	0	0	0
2	-20	-2667.23	0	0	0
3	-20	-2667.23	0	0	0
4	-20	-2667.23	0	0	0
5	-20	-2667.23	0	0	0
6	-20	-2667.23	0	0	0
7	-20	-2667.23	0	0	0
8	-20	-2667.23	0	0	0
9	-20	-2667.23	0	0	0
10	-20	-2667.23	0	0	0
11	-20	-2667.23	0.5	0.78	1.386
12	-20	-2667.23	0.5	0.78	1.386
13	-20	-2667.23	0.5	0.78	1.386
14	-20	-2667.23	0.5	0.78	1.386
15	-20	-2667.23	0.5	0.78	1.386
16	-20	-2667.23	2	3.14	2.771
17	-20	-2667.23	1.5	2.35	2.4
18	-20	-2667.23	1.5	2.35	2.4
19	-20	-2667.23	2	3.14	2.771
20	-20	-2667.23	6	9.41	4.8
21	-20	-2667.23	7	10.98	5.184
22	-20	-2667.23	10	15.69	6.196
23	-20	-2667.23	10	15.69	6.196
24	-20	-2667.23	17	26.67	8.079
25	-20	-2667.23	36	56.48	11.756
26	-20	-2667.23	16	25.1	7.838
27	-20	-2667.23	22	34.52	9.19
28	-20	-2667.23	33	51.78	11.256
29	-20	-2667.23	38	59.62	12.079
30	-20	-2667.23	29	45.5	10.552

POMIAR 2

Ciśnienie barometryczne = 991.9 hPa 744.2mmHg
 Temperatura gazu w przewodzie = 412.2 °K 139.2°C

Odczyty ciśnienia statycznego i dynamicznego

Lp	hs [mm] 1/1	Ps [Pa]	hd [mm] 1/5	Pd [Pa]	w [m/s]

INERTIAL PARTICULATE SEPARATOR FOR REDUCTION OF LES EMISSIONS IN KRAKOW

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Introduction

Environmental clean-up and pollution control are considered foremost national priorities in Poland. More than four decades of centralized planning has produced serious contamination of air, water, and soil throughout the country and a resulting deterioration of public health. As a result, life expectancy is lower today than it was 20 years ago. Also, incidents of serious disease in adults and young children there have been on the rise. It is therefore, imperative that corrective action be taken.

The government of Poland has begun to implement strong environmental controls to reverse this condition. The target of these controls is the Polish coal industry, which currently comprises over 78% of primary energy production (65% hard coal and 13% lignite). The coal utilization, especially in low grade coals, is highly inefficient. For example, Poland uses almost three times as much energy as Western Europe per unit of gross domestic product (GDP). In many cases, coal combustors have no pollution controls. Moreover, most have relatively low stacks and release emissions relatively close to the ground, further aggravating the problem. The result is that concentrations of airborne dust have been found to be many times higher than the maximum safe level.

The City of Krakow, one of the world's great cultural centers, has a serious problem with airborne pollutants. These emissions are discharged from stacks burning coal, mainly unwashed. This paper discusses one of the projects initiated by the U.S. Department of Energy for environmental cleanup in Krakow. This particular project involves an efficient control technology for mitigation of particulate emissions. The technology is referred to as the *Core Separator*, and it has been under development by LSR Technologies, Inc. in the U.S.A.

Environmental Conditions in Krakow

During a visit to Poland a few years ago, former President Bush stated, "Today Krakow is under siege by pollutants. Its priceless monuments are being destroyed."

The destruction is caused primarily by airborne pollutants emanating from the combustion of hard coal and coke in so called Low Emission Sources (LES). Fossil fuels are used heavily for heating purposes during the winter season. The 750000 population in Krakow relies heavily on hard coal as the heating source. About 35% of the heating needs is provided by some 2900 local boilers, often with low efficiency cyclones for particulate removal and no sulfur abatement technologies. These boilers consume yearly an estimated 370000 tonnes of coal and coke. As a result, the combination of coal combustion and the city's location in a valley having a temperature inversion, quite often a heavy suspended smog is visible over Krakow.

A major portion of heating needs is provided by district heating supplied with heat from local power plants, Leg and Skawina. These plants have high stacks that dilute and distribute pollutants over large areas. The primary cause of low ambient air quality in Krakow is from suspended particles and SO₂ emissions. SO₂ pollution is generated to a large extent (some 47%) from the neighboring Upper Silesian Industrial Region, while the balance comes from Krakow industry and power sectors (some 18%) and Low Emission Sources (35%). The picture is, however, quite different with particulate matter. Low Emission Sources are almost entirely responsible for suspended particulate matter in the ambient air in Krakow.

By definition "suspended particles" are referred to as particles of dust with a size less than 10 µm in diameter that do not fall to the ground from the force of gravity. These particles are in the respirable range, i.e., they have potential for accumulating in the lungs of humans causing respiratory disease.

Krakow air is continuously measured by a network of Automatic Ambient Air Monitoring Stations. The instantaneous/real time concentrations of SO₂, CO, suspended dust, and NO₂ in the ambient air are monitored continuously. The 30-minute (D₃₀) and daily (D₂₄) average concentrations for each pollutant are plotted and tabulated. From this, the actual pollutant measurements can be compared with permissible values. According to Polish Law, Krakow is located in a "protected area." For designated protected areas, the permissible concentrations of the main air pollutants are given in Table 1.

Table 1 Allowable Concentrations- Pollutants in Ambient Air Protected Areas of Poland

Pollutant	30-Minute Concentration D ₃₀ µg/m ³	Daily Average Concentration D ₂₄ µg/m ³
SO ₂	600	200
NO ₂	500	150
CO	5000	1000
Suspended Particles	250	120
O ₃	100	30

It is of particular interest to compare measurements of suspended particulate concentrations in both the winter and summer seasons. Figures 1 and 2 show measurements taken at one monitoring station in February 1993 and in July/August 1993. In these figures, it is immediately apparent that: (1) concentrations are significantly higher in winter during the heating season, and (2) concentrations in wintertime very often exceed the permissible values from Table 1.

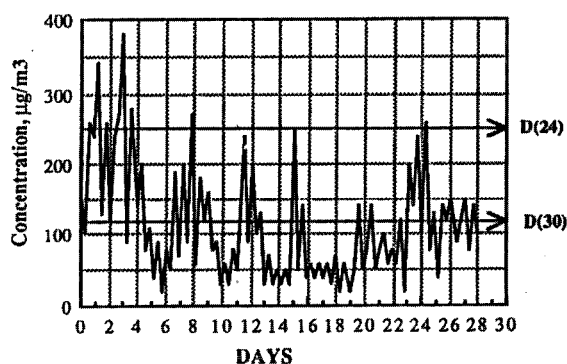
The same correlation can be observed in other air pollutants from coal combustion such as sulphur dioxide and carbon monoxide. The conclusion in each case is unmistakable, that Low Emission Sources used during the heating season are responsible for this situation.

Abatement Options for Dust Emissions

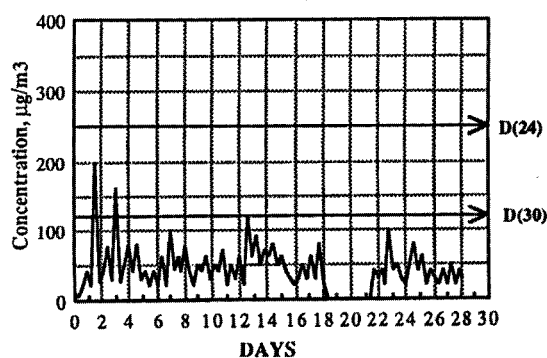
In order to improve ambient air quality in Krakow, the discharge of emissions during the heating season must be reduced. There are several ways to limit particulate emissions from LES. Conversion of coal/coke boilers to natural gas and connection of some heated areas to the district heating network are a couple of examples. Also in this category are improvements in energy saving measures in buildings, which would reduce fuel consumption. In the long run though, it is unlikely that coal combustion in local boilerhouses in Krakow will be entirely eliminated. The Ordinance of the Polish Ministry of Environmental Protection of February 12, 1990 on Protection of Air Against Pollution gives allowable emissions for combustion sources. The values are quite

stringent (600 g/GJ of fuel input for travelling grate boilers fired with hard coal), and much lower for coke and other firing systems. The deadline to comply with these limits was set for the beginning of 1998. In addition, the local voivod environmental standards will likely be even more stringent than that of the Polish Ministry. Existing pollution control equipment (mainly cyclones) is not likely to meet future regulations for dust mitigation in Krakow. Utilization of smokeless fuel or bag filters are possible options, but both are rather costly. The novel *Core Separator* technology developed by LSR Technologies can meet these regulations for either new or existing boilers. This technology will be described in more detail in the following section.

Monthly Suspended Dust Concentrations



**Fig.1 Transient Concentrations - Suspended Air, µg/m³
Krakow February 1993**



**Fig.2 Transient Concentrations - Suspended Air, µg/m³
Krakow July/August 1993**

Principle of Operation

The *Core Separator* is one of very few advances made in the field of particulate control in recent years. The technology was developed through research sponsored by the U.S. Department of Energy and Environmental Protection Agency. A number of these units have been placed in operation in the U.S. All of the units now in service are performing very difficult separations, i.e., those involving dust particles with small aerodynamic diameters. More recently, license agreements have been completed with firms in the U.K. and Australia.

Historically, mechanical separators 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 diameter. This is roughly equivalent to the performance of a medium-efficiency electrostatic precipitator (ESP). Figure 3, which was created by Industrial Filter & Pump Mfg. Co., illustrates the relative performance of several particulate control devices including cyclones, barrier filters, ESPs and wet scrubbers. The *Core Separator* performance is also superimposed on this figure. As illustrated, its performance is comparable to a medium-efficiency ESP or a high-energy venturi scrubber. Yet, the *Core Separator* still has the traditional advantages of mechanical collectors such as simplicity, reliability, compactness, and low maintenance.

A simplified schematic of the *Core Separator* system is shown in Figure 4. The system includes two conventional components, a cyclone collector for extracting solids and a fan for flow recirculation. The *Core Separator* is actually 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 and 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.

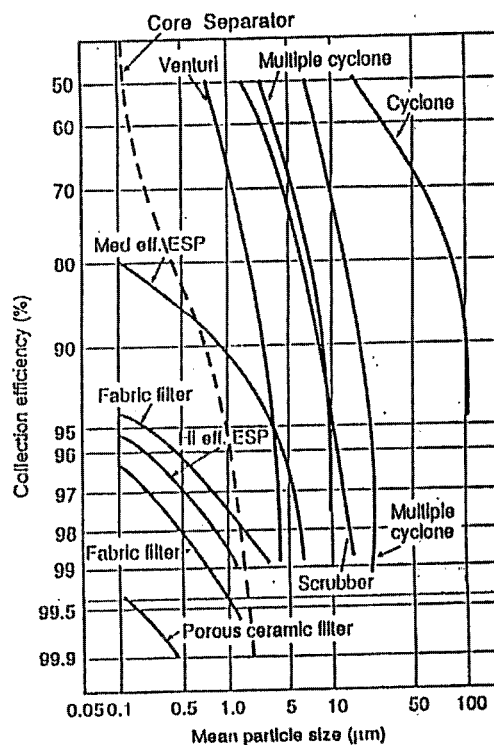
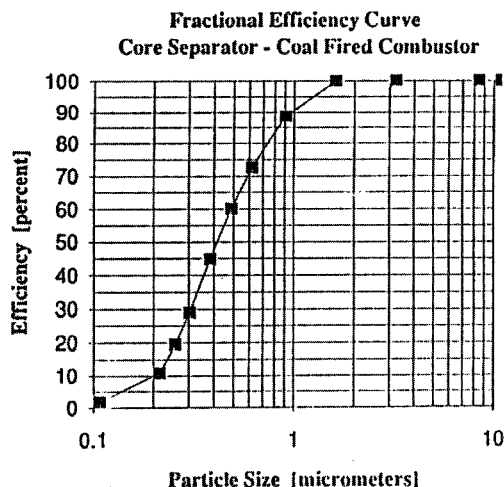


Fig.3 Particle Collector Performance (Printed with permission of Industrial Filter & Pump Mfg. Co.)



Currently, particulate control devices can be grouped into four(4) different categories: electrostatic precipitators, fabric filters, wet scrubbers, and mechanical collectors. The *Core Separator* is actually an advanced high performance mechanical collector. However, for the sake of comparison, it will be considered as a separate category.

In Table 2, many features used in the purchasing decision for this equipment are compared. The features of the *Core Separator* are highly differentiated from other methods of particulate control as shown in this table. Mechanical collectors are currently used to remove coarse particles (> 10 microns in diameter). They are preferred in this application since they require low capital and operating expenditures. However, mechanical collectors are inefficient in the removal of small particles (< 10 microns), sometimes referred to as "*respirable particulates*".

These particles are typically separated in a final stage by electrostatic precipitators, fabric filters, or in some cases, wet scrubbers. Each of these are high cost devices. As shown in Table 2, the *Core Separator* compares quite favorably against other devices in terms of fine particle performance. Also, it has most other attributes of mechanical collectors, making it highly desirable in dust collection applications.

The *Core Separator* has been under development since 1989. During its research, numerous laboratory and field prototypes were built and tested. As noted earlier, the Riley Stoker Corporation installed a *Core Separator* unit to remove flyash from their PC-fired Combustor Test Facility. Test results conducted by Riley Research showed the particulate removal efficiency of the *Core Separator* to range between 95 and 98% over a series of several controlled tests.

Several *Core Separator* units have also been sold on a commercial basis in the U.S. and abroad. These units range in size from 850 to 11,900 NM³/h (500 - 7,000 ACFM) and each perform difficult separations, i.e., those removing dust particles with small aerodynamic diameters. The boiler houses in Krakow are of a comparable scale to the *Core Separator* units currently in operation. Therefore, the only significant development issues and technology unknowns are as follows:

- (1) Performance with Polish Coals
- (2) Performance with Crushed Coal Feed Systems

Through this project and with the assistance of the Department of Energy, six demonstration units will be placed in operation in the City of Krakow during 1994-1995. These units will demonstrate performance of this technology with different Polish coals and firing systems.

Table 2 - Characteristics of Particulate Control Devices

FEATURE	ELECTROSTATIC PRECIPITATORS	FABRIC FILTERS	CYCLONE COLLECTORS	WET SCRUBBERS	CORE SEPARATOR
COLLECTION EFFICIENCY	HIGH	HIGH	LOW	HIGH	HIGH
CAPABILITY FOR HIGH SOLIDS LOADING	NO	NO	YES	NO	YES
PRESSURE DROP	VERY LOW	LOW-MED.	LOW-MED.	MED-HIGH	LOW-MED.
CAPITAL COST	VERY HIGH	HIGH	LOW	HIGH	LOW-MED.
OPERATING COST	HIGH	HIGH	LOW	MED-HIGH	LOW
HIGH TEMP./PRESS.CAPABILITY	YES	NO	YES	NO	YES
SPACE REQUIREMENTS	HIGH	HIGH	LOW	MEDIUM	LOW
DIFFICULTY WITH CERTAIN SUBSTANCES	SOME	SOME	NONE	NONE	NONE
EXPLOSION, FIRE, OR VOLTAGE HAZARD	YES	YES	NO	NO	NO
SPECIAL MAINTENANCE REQUIREMENTS	YES	YES	NO	NO	NO
OZONE PRODUCED	YES	NO	NO	NO	NO
WASTEWATER TREATMENT REQUIRED	NO	NO	NO	YES	NO

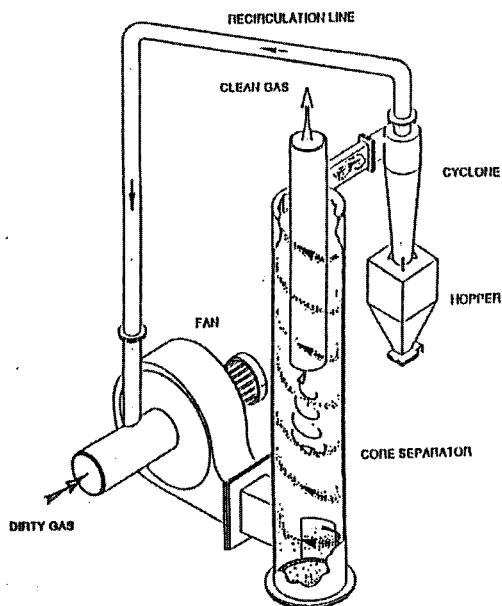


Fig.4 Simplified Arrangement - Core Separator

Two factors govern the performance of *Core Separator* systems: (1) a high separation efficiency of the *Core Separator* component, and (2) an interaction between individual components. To achieve high separation efficiency, a proper bleed flow value (ratio of the recirculation flow to the total flow) is required. By controlling bleed flow in the *Core Separator*, the tangential and radial velocities can be controlled independently to maintain them in the desirable range.

High efficiency in the *Core Separator* is due to low particle reentrainment. In this regard, the system is designed in such a way as to avoid formation of toroidal vortices. The *Core Separator* component functions as a separator, but not as a solids collector. This permits the avoidance of a flow U-turn within the device. It has a cylindrical shape, and surfaces promoting formation of vortices are moved away from the clean flow outlet. It should be pointed out that all these factors work together, and taken individually cannot prevent vorticity.

The separation efficiency of the *Core Separator* actually predetermines the efficiency of the system even if the collector efficiency is relatively low. The following formula can be used to calculate partial collection efficiency when the collector is situated downstream of the *Core Separator*,

$$E_{sys} = \frac{E_{cs} \times E_{cyc}}{1 - E_{cs}(1 - E_{cyc})}$$

When the collector is situated upstream of the *Core Separator*,

$$E_{sys} = \frac{E_{cyc}}{1 - E_{cs}(1 - E_{cyc})}$$

Here E_{cs} , E_{cyc} and E_{sys} relate to the *Core Separator*, collector and *Core Separator* system partial separation efficiencies, respectively.

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 single fan arrangement is the lowest cost design and can be used in most coal-fired boiler applications.

The *Core Separator* has been tested on the effluent stream from a pulverized coal-fired combustor. The site selected for this work was the Pilot Scale Combustor Test Facility owned and operated by the Riley Stoker Corporation, a major U.S. boiler manufacturer. Riley Research performed many tests to evaluate *Core Separator* performance in removing fine particulate matter in the combustor off-gas. A high volatile Eastern Bituminous coal from West Virginia was used to fuel the Combustor Test Facility and generate a typical flue gas condition (ie., 150-200 deg. C). This testing showed that particle retention under controlled test conditions ranged from 95 to 98%. This performance is actually higher than that of some ESP units under similar conditions. The cut point diameter (d_{50}) in these tests was consistently found to be below 0.5 μm , and the particle outlet concentration from the *Core Separator* was in some cases less than 100 mg/M^3 . A fractional separation efficiency curve was produced with data taken by Riley Research is shown in Figure 5.

Emissions Reduction Potential and Impact on Heating Cost

The City of Krakow has about 1300 boiler houses providing heat for industrial, commercial, and residential use. The boiler houses contain about 2250 boilers, some with no emission controls at all. Many boilers are equipped with cyclone collectors, which remove roughly 80% of the total particulate emissions. High efficiency collectors such as bagfilter units and electrostatic precipitators are practically non-existent due to their high cost and maintenance requirements.

The cost of emission reduction options requires careful analysis, and it is unlikely that any one option is best in all cases. In this section, attention will focus on ways to modernize boiler houses through the addition of particulate control equipment. The choices include:

- Addition of Cyclone Collectors
- Addition of Bagfilter Units
- Addition of *Core Separator* Systems

A cost analysis was performed based on data for particulate control equipment sold in the U.S. Table 3 provides a cost comparison of cyclones, pulse-jet bagfilters, reverse-air bagfilters, and the *Core Separator*. Cost data for the *Core Separator* was based on historical costs, whereas data for cyclones and bagfilters were based on recently completed studies by the Electric Power Research Institute (EPRI). The capacities shown in this table are typical of boiler capacities throughout the City of Krakow.

It is also interesting to compare the cost and respective benefit of each of these alternatives. As shown in Table 4, conventional cyclones provide the lowest cost per ton of pollutant removal. However, this criterion is not normally used in the U.S. or EC nations, since (1) cyclones cannot meet most regulatory standards, and (2) the incremental cost of higher efficiency increases sharply. For this reason, the penetration of the pollutant into the atmosphere is more meaningful. Such a comparison reveals that the *Core Separator* costs a little more than twice that of an equivalent sized cyclone, but allows only about 1/5 of the total penetration of solids to the atmosphere. The *Core Separator* also has the ability to meet future emission standards in Poland, which may not be within reach of cyclones.

The addition of any emission control equipment will involve some parasitic losses which must be factored into the total heating cost. For the *Core Separator*, the draft loss through the system is reflected in the power for the recirculation fan which is ultimately part of the operating cost. It has been demonstrated that the operating cost of the *Core Separator* is less than 1.0% of the boiler thermal input. And, unlike ESPs and fabric filters, maintenance costs are almost non-existent.

The *Core Separator* is very well suited to the LES sources of particulate emissions in Krakow. It is unique in that it has the following attributes:

- (1) Cost-effectiveness even at boiler capacities below 500 kw
- (2) Efficient in removing respirable (PM₁₀) particles

In recent years, particulate emissions have been the largest component of the air pollution control market, claiming well over 60% of annual expenditures. In addition to the 1300 boiler houses in the City of Krakow, the region also has many other industries requiring fine particle control equipment. The following industries require such equipment:

Combustor/Flyash	Hazardous Waste
Smelters	Incineration
Sinter Dusts	Sludge Incineration
Crushers	Waste Heat Boilers
Iron Ore	Saw Dust
Gypsum	Roasting
Fiberglass Dust	Catalyst Recovery
Pulp & Paper	Paints & Pigments
Pharmaceuticals	Coal Preparation
Asphalt Plants	Fertilizer Dusts
Furnaces	Cement Kilns
Solid Waste Recycling	Plastics Processing
Cereal/Grain	Lime/Limestone Dust
Glass Melting	Stone Dusts
Thermal Driers	

Table 3 Total Installed Cost - Particulate Control Devices

Size or Capacity		Device Type			
Gas Flow	Thermal Input	Cyclone	Pulse Jet Baghouse	Reverse Air Baghouse	Core Separator
M3/h	KW	\$(M3/h) [\$/KW]	\$(M3/h) [\$/KW]	\$(M3/h) [\$/KW]	\$(M3/h) [\$/KW]
2,000	402	0.99 [4.90]	14.52 [72.16]	22.47 [111.69]	2.47 [12.28]
5,000	1007	0.90 [4.47]	11.69 [58.06]	18.10 [89.86]	2.36 [11.71]
10,000	2,012	0.84 [4.18]	9.93 [49.36]	15.37 [76.39]	2.28 [11.32]
15,000	3,018	0.79 [3.92]	8.43 [41.90]	13.05 [64.85]	2.20 [10.93]
25,000	5,030	0.76 [3.77]	7.66 [38.07]	11.85 [58.91]	2.16 [10.73]

Basis: (1) Boiler Heat Rate 3150 Kcal/KWH

(2) Baghouse Data "Sloat, D.G., et al 1991 EPRI Particulate Control Symposium

(3) Cyclone Data "Vatavuk, W.M., Chemical Engineering, May 1990

(4) Core Separator Data from Historic Costs

Table 4
Cost/Benefit Comparison - Particulate Control Equipment

	<u>Cyclone</u>	<u>Core Separator</u>	<u>Baghouse</u>
Overall Collection Efficiency, %	75 - 85	94 - 98	98.0 - 99.9
PM10 Collection Efficiency, % (particles < 10 µm)	20	94	99.5
Cost, \$(M ³ /h)	0.79	2.20	8.43
Cost, \$(Kg/h) solids removal *	54.	126.	464.
Cost, \$(Kg/h) PM10 solids removal **	1353.	803.	2908.

* Based on 0.4 g/M³ solids loading

** Based on 0.1 g/M³ PM10 solids loading

Conclusion

The U.S. and Polish Bilateral Steering Committee with the assistance of DOE contractors have identified specific methods to improve air quality and reduce emissions throughout the city. These include:

- Extensions to the district heating system, which could eliminate many small uncontrolled boilers
- Conversion of hand-fired boilers to natural gas
- Elimination of home stoves in selected parts of the city
- Use of improved home stove designs
- Modernization of boiler houses to reduce emissions

This project addresses modernization of boiler houses through the application of new technology recently developed in the U.S. for particulate emissions. The technology is well-suited to the industrial size boilers located in Southern Poland and is capable of removing dust particles below 10 microns in diameter, the so called PM-10 emissions. Its performance is almost as good as ESPs and fabric filters, but without the attendant cost and maintenance. In small boiler applications such as those in Central Europe, it may be the Best Available Control Technology (BACT).

Acknowledgement

The authors would like to thank Mr. Douglas Gyorke for his guidance in preparing this paper and the Department of Energy for supporting this important project.

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