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Automated Boiler Combustion Controls for Emission Reduction and Efficiency Improvement

Final Report
October 1997

Work Performed Under Contract No.: DE-FC22-94PC94118

For
U.S. Department of Energy
Office of Fossil Energy
Federal Energy Technology Center
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Disclaimer

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ABSTRACT

In the late 1980s, then President Bush visited Krakow, Poland. The terrible air quality there motivated him to initiate a USAID-funded program, managed by DOE, entitled "Krakow Clean Fossil Fuels and Energy Efficiency Program." The primary objective of this program was to encourage the formation of commercial ventures between U.S. and Polish firms to provide equipment and/or services to reduce pollution from low-emission sources in Krakow, Poland.

This program led to the award of a number of cooperative agreements, including one to Control Techtronics International. The technical objective of CTI's cooperative agreement is to apply combustion controls to existing boiler plants in Krakow and transfer knowledge and technology through a joint U.S. and Polish commercial venture.

CTI installed automatic combustion controls on five coal boilers for the district heating system in Krakow. Three of these were for domestic hot-water boilers, and two were for steam for industrial boilers. The following results have occurred due to the addition of CTI's combustion controls on these five existing boilers:

- 25% energy savings
- 85% reduction in particulate emissions

The joint venture company CTI-Polska was then established. Eleven additional technical and costing proposals were initiated to upgrade other coal boilers in Krakow. To date, no co-financing has been made available on the Polish side. CTI-Polska continues in operation, serving customers in Russia and Ukraine. Should the market in Poland materialize, the joint venture company is established there to provide equipment and service.

1.0 EXECUTIVE SUMMARY (English)

This report presents the findings of the project entitled "Automated Boiler Combustion Controls for Emission Reduction and Efficiency Improvement." In 1995 the U.S. Department of Energy contracted with Control Techtronics International, Inc. (DOE Contract No. DE-FC22-94PC94118) to apply combustion controls to existing boiler plants and transfer knowledge and technology through a joint U.S. and Polish commercial venture. This project is part of DOE's program to achieve the following:

1. reduce the particulate and CO emissions from boiler operations through the use of controls on existing facilities

2. increase the efficiency of heat production with existing boilers

3. create the technical capability needed to transfer this technology in the form of a Polish led commercial venture that can act as a leader for increased energy efficiency and coal use in heating districts throughout Poland.

Control Techtronics International, Inc. (CTI) conducted this project to reduce air emissions and increase efficiency in coal-fired boilers in Krakow, Poland. In Budget Period I (first year), CTI demonstrated both efficiency improvement and emission reduction at the Balicka district heating plant in the Widok section of Krakow. The Balicka plant is owned by MPEC, Krakow's distrrict heating utility.

The Budget Period I activity involved upgrading three stoker-fired coal boilers at MPEC's site in Balicka. As the engineering proceeded on the project, the customer wanted a second installation at Balicka on their steam boilers. Money from Budget Period II was moved to Budget Period I to basically count as a "second" installation. The installation and start-up of CTI controls on these first two boiler upgrade projects at Balicka resulted in the following:

1. 85% reduction in particulate emissions into the atmosphere
2. 25% reduction in fuel consumption
3. a two-year payback on the investment

These installations were inspected by CTI in early September 1997 and were found to be functioning extremely well and the customer was quite satisfied.

In December 1995 and January 1996, CTI established a subsidiary company in Poland, called CTI Polska. The mission of CTI Polska is two-fold:

1. Secure other contracts in the Krakow region, similar to these at MPEC
2. Provide a technical support company for other CTI installations in Central Europe and Russia.

The initial president of CTI Polska was Tomasz Szewczyk; he served in that role from December 1995 to January 1997. The current president is Darek Rajtak. The original and current Vice-President is Wieslaw Kalinowski.

With the guidance of BRK, CTI made many contacts with owners of coal-fired boiler houses in the Krakow region. The first contracts were with FAMO and the Children's Hospital, on which CTI provided engineering documentation and technical proposals. Other potential project sites included Krakow's Energy Institute, Armatura, KFAP, Alvernia, Kable, a chemical plant south of Krakow, PHRO Greenhouse (in support of TCS), Myslenice Boiler House (Zorza), and the Rzaska Military Facility. In spite of considerable efforts by CTI, no co-funding (the other 50% of installation costs) was available from the Polish customers.

In April of 1996, CTI participated in a Trade Mission to Poland with Mark Schweiker, the Lieutenant Governor of Pennsylvania. Mr. Schweiker witnessed the signing of letters of intent for the Myslenice and Rzaska Projects. Both of these prospects partially paid for detailed system engineering and, as of the time of this report, discussions are still being held with these potential customers.

CTI-Polska has utilized its location and experience to transfer automatic-combustion-control technology elsewhere in Central Europe as well as to Eastern Europe and Russia. Both Darek Rajtak and Wieslaw Kalinowski have traveled to Siberia where CTI secured a large controls contract. A second prospective customer has been brought to Krakow to receive a technical proposal and inspect the Balicka installation. Darek has also made trips into Sarajevo and to Kiev in Ukraine. Based on these successes, CTI was awarded the 1996 Pennsylvania Governor's Export Excellence Award.

2.0 EXECUTIVE SUMMARY (Polish)

1.0 STRESZCZENIE

W niniejszym raporcie przedstawiono wyniki projektu o nazwie "Automatyczne sterowanie procesem spalania w kotle w celu zmniejszenie emisji i poprawy sprawności". W roku 1995 Departament Energetyki USA podpisał kontrakt z Control Techtronics International, Inc. (Kontrakt DOE nr DE-FC22-94PC94118), którego przedmiotem było zastosowanie systemu sterowania procesem spalania w istniejących kotłowniach oraz dokonanie transferu wiedzy i technologii poprzez wspólne amerykańsko-polskie przedsięwzięcie komercyjne. Projekt ten jest częścią programu DOE zmierzającego do osiągnięcia następujących celów:

1. zmniejszenia emisji pyłów i CO przy eksploatacji kotła poprzez zastosowanie systemu sterowania dla istniejących urządzeń,

2. podniesienie sprawności produkcji ciepła w istniejących kotłach,

3. stworzenie możliwości technicznych koniecznych dla transferu tej technologii w formie prowadzonego przez polskich partnerów komercyjnego przedsięwzięcia, które mogłoby posłużyć jako przykład poprawy sprawności energetycznej i wykorzystania węgla w systemach ciepłowniczych w całej Polsce.

Control Techtronics International Inc. (CTI) przeprowadziła to przedsięwzięcie dla zmniejszenia emisji zanieczyszczeń powietrza i podniesienia sprawności w opalanych węglem kotłowniach w Krakowie. W Okresie Budżetowym I (pierwszy rok) CTI zamontowała swoje urządzenia w kotłowni "Balicka" na osiedlu Widok w Krakowie, co spowodowało zarówno podniesienie sprawności jak i zmniejszenie emisji. Właścicielem kotłowni "Balicka" jest Miejskie Przedsiębiorstwo Energetyki Cieplnej SA w Krakowie.

Działania w Okresie Budżetowym I obejmowały modernizację trzech kotłów z rusztem mechanicznym typu WR-10 zamontowanych w kotłowni "Balicka". W trakcie wykonywania prac projektowych klient zażyczył sobie rozszerzenia modernizacji na trzy kotły parowe typu PLM 2,5. Pieniądze z Okresu Budżetowego II przesunięto na Okres Budżetowy I, i prace te zaliczono jako "druga" niezależna instalacja. Zainstalowanie i uruchomienie układów sterowania firmy CTI w ramach przedsięwzięcia modernizacji dwóch kotłów WR 10 dało następujące efekty:

1. zmniejszenie emisji pyłów do atmosfery o 85%
2. zmniejszenie zużycia paliwa o 25%
3. dwuletni okres zwrotu kosztów inwestycji.

Instalacje te były sprawdzane przez CTI na początku września 1997 i stwierdzono, że funkcjonują doskonale a klient jest w pełni zadowolony.

W grudniu 1995 i styczniu 1996 firma CTI założyła w Polsce firmę zależną o nazwie CTI Polska. Misja firmy CTI Polska jest dwojaka:

1. Zapewnienie kontraktów w regionie krakowskim, podobnych do kontraktu z MPEC.
2. Stworzenie firmy, która zapewniałaby pomoc techniczną dla innych instalacji CTI w Europie Środkowej i w Rosji.

Pierwszym prezesem firmy CTI Polska był Tomasz Szewczyk; pełnił on tę funkcję od grudnia 1995 do stycznia 1997. Obecnie prezesem jest Dariusz Rajtak. Od początku do chwili obecnej wiceprezesem jest Wiesław Kalinowski.

Przy współpracy z BRK SA firma CTI nawiązała liczne kontakty w regionie krakowskim z właścicielami kotłowni wyposażonych w kotły z rusztem mechanicznym. Pierwsze kontrakty podpisano z FAMO i ze Szpitalem Dziecięcym, dla których CTI dostarczyła dokumentację projektową i propozycje techniczne. Do innych potencjalnych lokalizacji przedsięwzięć należą Instytut Fizyki Jądrowej w Krakowie, Krakowskie Zakłady Armatur,

Krakowska Fabryka Aparatury Pomiarowej KFAP, Zakłady Chemiczne w Alwerni, Fabrykę Kabli w Krakowie, zakłady chemiczne na południe od Krakowa, szklarnie PHRO (w ramach pomocy dla TCS), kotłownia Spółdzielni Mieszkaniowej „Zorza" w Myślenicach i Jednostka Wojskowa w Rząsce. Pomimo znacznych wysiłków ze strony CTI, nie uzyskano współfinansowania (pozostałe 50% kosztów instalacji) ze strony polskich klientów.

W kwietniu roku 1996 firma CTI brała udział w Misji Handlowej w Polsce, w której uczestniczył Mark Schweiker, Zastępca Gubernatora Pensylwanii. Pan Mark Schweiker był świadkiem podpisania listów intencyjnych dla przedsięwzięć w Myślenicach i w Rząsce. Obydwaj potencjalni klienci zapłacili częściowo za szczegółowe projekty systemu i w czasie gdy tworzony jest niniejszy raport prowadzone są rozmowy z tymi potencjalnymi klientami.

CTI Polska wykorzystała swoje położenie i doświadczenie dla przeniesienia technologii automatycznego sterowania spalaniem w inne miejsca leżące w Europie Środkowej jak również w Europie Wschodniej i w Rosji. Zarówno Dariusz Rajtak jak i Wiesław Kalinowski odbyli podróż na Syberię, gdzie CTI zapewniła sobie duży kontrakt dotyczący sterowania. Inny potencjalny klient przyjechał do Krakowa, aby otrzymać ofertę techniczną i zbadać instalację kotłowni "Balicka". Dariusz Rajtak odbył także podróż do Sarajewa i do Kijowa na Ukrainie. Za te osiągnięcia przyznano firmie CTI za rok 1996 Nagrodę Gubernatora Stanu Pensylwania za Wybitne Osiągnięcia w Eksporcie.

3.0 INTRODUCTION

In Poland and the other Central and Eastern European countries there are thousands of stoker-type coal boilers. These low-emission sources are utilized for district heating and industrial plants. When they were built in the decades after World War II, their function was to reliably provide heat using subsidized and indigenous fuel--coal--and inexpensive labor for operations. Little concern was given for these boilers' energy efficiency or pollution. Since the nineties, numerous marketplace changes have occurred that affect these boilers. First, the price of coal is climbing to world prices. Second, the world cares about the pollution and is providing various incentives to reduce pollution. Third, cheap, good labor is less plentiful now as living costs have risen and socialism is a fleeting memory.

Several solutions exist. One is to scrap these industrial and institutional boilers and connect their owners to central district heating systems. A second is to convert the stokers to natural gas or oil firing. A third option is to replace them with one of various types of new boilers. A fourth is to upgrade coal-fired stoker boilers into efficient, low-pollution boilers. This was accomplished on the three hot-water district heating boilers for MPEC's Balicka boiler house in Krakow, and for their two steam boilers serving industrial customers.

The "as built" coal stokers have two fans which operated at full speed all of the time. One fan is a forced draft type blowing air across the moving bed of coal. The second is an exhaust fan which draws the harmful products of combustion, and coal ash particulates, out of the boiler and up into the air. At full seed these fans provide huge amounts of wasteful excess air when the boiler's output is less than 100%.

The principal solution to upgrade these boilers is to automatically vary the speed of both fans: one in conjunction with the speed of the moving coal bed; and the other to hold a constant, small negative pressure in the combustion chamber. This was accomplished on five of MPEC's boilers, using microprocessor controls, and variable speed drive inverters on the fans and stokers. These upgrades were accomplished using American controllers, inverters, and engineering; one Polish firm (Energoaparatura) provided the new panels, and a second one (Naftokrak-Naftobudowa) provided installation and start-up.

Results showed that 25% less energy was needed after the controls upgrade, and particulate emissions were reduced 85%. The payback on investment is less than two years. A joint venture company, CTI-Polska, was formed to transfer this technology into Central and Eastern Europe to accomplish similar results elsewhere. Ten different sites in the Krakow area expressed an interest in receiving 50% DOE co-financing to accomplish this. While CTI incurred significant engineering and operating expenses in the attempt to make additional installations, no further contracts in Krakow materialized.

Numerous boilers in the Krakow area have been scrapped and connections made to district heating, and others have been converted to natural gas firing. CTI's sales in this region during this time period have occurred in Siberia and Ukraine. It is expected that with Poland joining NATO, some Polish firms will yet upgrade their coal-fired stoker boilers.

4.0 BUDGET PERIOD I ACTIVITIES

After receipt of the DOE Cooperative Agreement in mid-February 1994, the next five months were spent in securing the contract and first progress payment from MPEC, Krakow's District Heating Company. This was initially for the upgrade of the three hot-water boilers at MPEC's Balicka plant in Krakow. Upgrading the two steam boilers was later added.

Upon contract signing, our technical team of CTI, Energoaparatura (ENAP), and Naftokrak-Naftobudowa (NK-NB) began the detailed control engineering. Those documents were submitted for MPEC's approval, which, after their review, was received. Production then began both in the United States on microprocessor-based controllers and their programming and in Poland on panel work and field wiring. Also, the Pennsylvania State University and Krakow's Polytechnic University teamed to translate technical training manuals required for operator training, gather baseline performance data, and prepare to train boiler operators.

Much time-consuming and expensive discussion occurred as to the nature and composition of a joint venture company. It was finally resolved that CTI-Polska would be formed. Ownership would be 80% CTI in Pennsylvania, 10% each of the two key Polish employees. This firm would regularly coordinate activities with NK-NB, rather than NK-NB have shares. We would also coordinate with a marketing firm in which MPEC had part ownership, again rather than MPEC have shares. This avoided several conflicts of interest.

Finally the control systems were shipped and installed at Balicka. The two ENAP panels had to be extensively re-wired in the field (by Wieslaw Kalinowski) during start-up. Ample graded coal was purchased, and the performance testing was conducted on the modified boilers. See Peter Cyklis' report in Appendix A, as well as CTI's analysis (Section 6.0) which computed an energy saving of 25% and a particulate emission reduction of 85%.

These results were presented to the Krakow community both during a DOE conference there in Fall, 1995, and at a luncheon there in April 1996.

During this time the necessary operator manuals were translated into Polish, and Balicka operators received training. Wieslaw Kalinowski and Tomasz Szewczyk were selected as the technical and marketing personnel for CTI-Polska, and Penn State developed a protocol to look for budget year II sites. The final activity in budget year I involved the initial development of a commercial Polish version of the CTI control system.

5.0 BUDGET PERIOD II ACTIVITIES

The first task was the legal formation of the joint venture company, CTI-Polska. Founding notarial deeds were developed. Initially we tried using a Polish attorney, but negotiations were not successful. CTI then had its international attorney, Paul Lewis, prepare documents, and this process went through several iterations. Finally there was agreement, and in December 1995 the papers were signed in Krakow by CTI's John West and Krakow citizens Tomasz Szewczyk and Wieslaw Kalinowski.

To select our Budget Period II sites, CTI-Polska worked closely with BRK, the Krakow Development Office. Part of BRK's function was to pre-qualify potential host sites for DOE project participants. Since DOE could co-finance 50% of these projects, it was essential to meet with representatives from each prospective site, open a trusting dialogue, and spend considerable engineering time on each offering so that they could arrange their 50% of the funds. This is because each prospective boiler house is slightly different, both technically and in what they want to accomplish. Polish protocol seems to require that most details are worked out before the final decision/action is taken.

Further, since most of these prospective participants were looking to some Polish fund or government agency for most of their 50% co-financing, this process added more time and cost once the site became interested in proceeding with CTI's upgrade. Also, since permits were needed from the city, Krakow's government had to agree with the project.

For the two years during which CTI searched for Budget Period II sites, the following locations had various degrees of effort associated with them:

1. Children's Hospital of Krakow. A letter of intent was received. Several job site visits were made and a detailed engineering quotation was prepared. However, the offer was withdrawn when it was decided that a new gas boiler, which could supply the hospital's needs, would be installed near the hospital.

2. FAMO. A great deal of engineering effort and trusting rapport was developed with this client, including the development of a contract that involved more funding than MPEC had spent on Balicka. FAMO is a profitable Krakow employer and had funds to implement this project. The contract was signed by both parties and a cash deposit was made. However, since MPEC's district heating supply pipes had been extended close to FAMO, regulatory authorities insisted on FAMO's stoker boilers being shut down.

3. Krakow Water Company. A quotation was developed, but the city did not commit to co-financing a CTI system upgrade.

4. Energy Institute. Several meetings were held and a proposal was developed. The Institute could not decide whether to connect to the MPEC energy supply if that became available, or to upgrade, or continue polluting. No co-financing funds materialized.

5. Brick company in suburban Krakow. A visit was made to this an excellent prospect, and an engineering and cost proposal was developed. The company was going through privatization, and no co-financing materialized.

6. Kable. Several visits were made to this company, and a letter of intent was received. An engineering and cost proposal was developed and presented. However, this potential customer eventually chose to convert to natural-gas-fired boilers.

7. KFAP. Same as for Kable.

8. Chemical plant in Alvernia. After a personal visit, CTI developed an engineering proposal, with discounted costs. The project was financially attractive, but the client could not generate the cost-sharing necessary.

9. Armatura. A proposal was given to this company. The firm installed an LSR Core Separator, but did not proceed with CTI controls.

10. PHRO Greenhouse. This facility was the site of a potential DOE project involving TCS Coal, on which TCS would utilize CTI controls and CTI-Polska to manage the project in Poland. In addition to detailed engineering and costing, CTI-Polska made numerous site visits and provided environmental engineering support to get that project moving. However, cost-sharing funds never materialized.

In April of 1996, CTI had a luncheon in Krakow. At this luncheon, it was announced that MPEC had accepted the control installation at Balicka, and had committed to additional projects at Rzaska and at the Zorza housing cooperative in Myslenice. See the photographs of the signing ceremony in Appendix B. In the next year and a half, Polish co-financing could not be obtained. CTI has a continuing offer of 40% reduction off of control equipment pricing for either of them to proceed.

One of the objectives of this project was to develop a company in Poland whose business will be to serve, in conjunction with CTI in Harrisburg, the Central and Eastern European markets. That goal is being achieved. CTI secured business in Russia, and CTI-Polska provided personnel to support the engineering and start-up of that work. CTI will shortly be shipping controls into Ukraine, with CTI-Polska technical support. Having a corporate presence in Poland was an essential element in CTI receiving that work. CTI hopes for a long and successful future as a follow-on to this project. And if the Polish coal-fired market opens up, CTI-Polska will be in a position to serve it.

6.0 EMISSIONS REDUCTION ACHIEVED BY THIS PROJECT (English)

The particulate emissions reduction from installing automatic boiler controls onto stokers could be significant for Krakow. It was reported in the early 1990s that Krakow's total particulate emissions from stoker boilers and stoves were 3,541 metric tons.

Krakow's particulate emissions from stoker boilers were: (237,666 metric tons of coal per year) x (0.0249 mt/mt particulate emission factor) x (1-.75 avg. cyclone efficiency) = 1,479 metric tons/year.

In the 1995-96 winter, estimates showed that the metric tons/year of coal burned in Krakow was 207,285.

Of the 207,285 mt/year of coal burned by stoker boilers in Krakow, MPEC's Balicka plant burned 16,692. This resulted in approximately 104 mt of the 1,290 mt of particulates emitted.

After CTI's controls were installed, to produce the same amount of heat, the 25% energy reduction would result in the Balicka plant only burning 16,692 x .75 = 12,519 mt of coal. These automatic controls reduced particulate emissions by 85.5%. Thus the new amount of particulates emitted = 12,519 x 0.0249 x .25 x (1 - .855) = 11.3 mt. Particulate emissions were reduced from 104 mt to 11.3 mt for a reduction of 92.7 mt.

From the layman's viewpoint, before the automatic controls were installed, smoke was seen coming out of this boiler house's stack. Recently on a mild day the chief boiler house operator took the author inside the boiler house for verification that a boiler was operating. Then upon returning outside the author saw *nothing* was visibly emitting from the stack. This is because *before* adding controls over 800 g/GJ of particulates was emitted; now, at low load, less than 40 g/GJ is emitted (95% reduction), and that is not visible.

The Balicka plant boiler upgrade resulted in a 7% reduction in particulate emissions for the entire stoker population in the city of Krakow. If the rest of the stokers there were similarly upgraded, another 1,014 mt of particulates would be reduced in Krakow. That would be equivalent to a 92.7+ 1,014 or 1,106.7 mt reduction out of 3,541 mt total, which would be a 31% reduction in all particulate emissions in Krakow.

7.0 EMISSIONS REDUCTION ACHIEVED BY THIS PROJECT (Polish)

6.0 ZMNIEJSZENIE EMISJI UZYSKANE DZIĘKI TEMU PRZEDSIĘWZIĘCIU.

Zmniejszenie emisji pyłów dzięki zainstalowaniu automatycznego sterowania procesem spalania na kotłach z rusztem mechanicznych może mieć istotne znaczenie dla Krakowa. Na początku lat dziewięćdziesiątych całkowita emisja pyłów z kotłów i pieców wynosiła w Krakowie 3541 ton. Emisja pyłów przez kotły z rusztem mechanicznym w Krakowie wynosiła: (237.666 ton węgla rocznie) x (0,0249 t/t współczynnik emisji pyłów) x (1-0,75 średnia sprawność cyklonów) = 1,479 ton/rok). Liczby te można znaleźć w Raporcie z Pierwszego Etapu Krakowskiego Programu Paliw Kopalnych i Oszczędności Energii, wydanego przez T. Butchera i B. Pierce, BNL-52479, sporządzonego przez Departament Energetyki USA w ramach kontraktu nr DE-AC02-76CH00016.

W sezonie zimowym 1995/96 uaktualnione oszacowanie wykazało, że ilość spalanego w Krakowie węgla wynosiła 207.285 ton rocznie. Po przemnożeniu otrzymujemy wartość: 207 285 x 0.0249 x 0.25 = 1290 ton pyłu rocznie. Z ilości 207.285 ton węgla spalanego rocznie w Krakowie przez kotły z rusztem mechanicznym, kotłownia Balicka spalała 16.692 ton. Dawało to w przybliżeniu emisję 104 ton pyłów, wobec całkowitej emisji pyłów wynoszącej 1290 ton.

W wyniku zainstalowania systemu sterowania firmy CTI dla wytworzenia w kotłowni Balicka tej samej ilości ciepła spalono o 25% mniej paliwa, to jest.16.692 x 0,75 = 12.519 t miału węglowego. Automatyczne sterowanie pozwoliło na zmniejszenie emisji pyłów o 85,5%. Po modernizacji emisja pyłów wynosi 12.519 x 0,0249 x 0,25 x (1-0,855) = 11,3 t. Emisja pyłów zmniejszyła się ze 104 t do 11,3 t, to jest o 92,7 t.

W wyniku modernizacji kotłowni Balicka emisja pyłów z kotłów z rusztem mechanicznym w Krakowie uległa zmniejszeniu o 7% (92,7 podzielone przez 1290). Modernizacja pozostałych kotłów z rusztem mechanicznym w Krakowie pozwoliłaby na zmniejszenie całkowitej emisji pyłów do wartości 140,3 t [1290 t x 0,75 x (1-0,855)].

Przed wprowadzeniem automatycznego sterowania często widoczny był dym wychodzący z komina kotłowni. Ostatnio w dzień o niezbyt niskiej temperaturze kierownik kotłowni wprowadził autora tego opracowania do kotłowni dla sprawdzenia, że kocioł pracuje. Następnie, po wyjściu na zewnątrz, autor nie zauważył *żadnej* emisji z komina. Dzieje się tak dlatego, że *przed* zainstalowaniem sterowania emisja pyłów wynosiła 800 g/GJ; a obecnie, nawet przy niskim obciążeniu kotła, emitowane jest zaledwie 40 g/GJ, a taka ilość nie jest widoczna gołym okiem.

8.0 CONCLUSIONS

The CTI project in Krakow led to four principal conclusions, as presented below.

1. Upon the installation and utilization of CTI combustion controls at Balicka, a comparison of the automatic controls performance testing to baseline data showed that 85% of the particulate emissions from this boiler house were eliminated by the installation of those controls. This resulted in a 7% reduction for all the stoker boilers in Krakow, and a 2.5% reduction in all of Krakow's particulate emissions. If all the stoker boilers in Krakow were similarly upgraded, 31% of the entire particulate emissions in Krakow would be eliminated. That could be accomplished with an investment on the order of several million dollars, which would be returned in less than two years from the 25% energy savings.

2. It was seen and understood that state-of-the-art microprocessor-based combustion control systems can be adapted to and correctly installed in a Polish boiler house. Operators can be trained to operate them successfully. User-friendly, reliable equipment has functioned well for two heating seasons.

3. It has been demonstrated that technology transfer was sufficient to enable Polish-trained technical personnel from this project to travel into Siberia for six weeks to start up similar projects there. Further, the combination of the Polish experience, coupled with the Russian one, is resulting in an improved next-generation control system.

4. A better method of securing project financing from overseas prospects should be utilized in the future. Letters of intent were not meaningful on this project. On other projects CTI now requests that the customer provide us with a request for quotation, with a funding commitment behind it, before we spend our resources for engineering and/or a quotation. In the successful case of the MPEC contract, CTI/DOE required and received a written funding commitment before project approval. Looking ahead, perhaps with the widespread dissemination of the results of this project, previously reticent prospects will now either invest their own funds, or be willing to borrow, in order to upgrade their coal-fired boiler houses.

APPENDIX A

PRE ECOLOGICAL MODERNIZATION OF BOILERS WITH MECHANIZED GRATE, SUPPORTED BY AUTOMATED COMBUSTION PROCESS

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1. Foreword.

The research and testing associated with the scope of this article were carried out by the staff of the Division for the Thermodynamics and Testing of Heat Process Machines, sponsored by the US Department of Energy for the Polish - American Program to Reduce Pollution in the city of Krakow. The test equipment used was supplied by The Brookhaven National Laboratory in accordance with Polish and EPA (USA) Standards by the Bureau for the Development of the City of Krakow. The test team had an extensive experience in boiler performance testing.

2. The goal for the modernization of boilers.

Krakow is one the cities with greatest air pollution. It influences negatively the health of its inhabitants, their life span, also destroying the medieval architecture of the buildings.
One of the pollution sources are coal firing boiler installations with mechanized grates.
Exploitation of many such plants is justified economically, but the associated products of combustion create a significant pollution problem in the area.

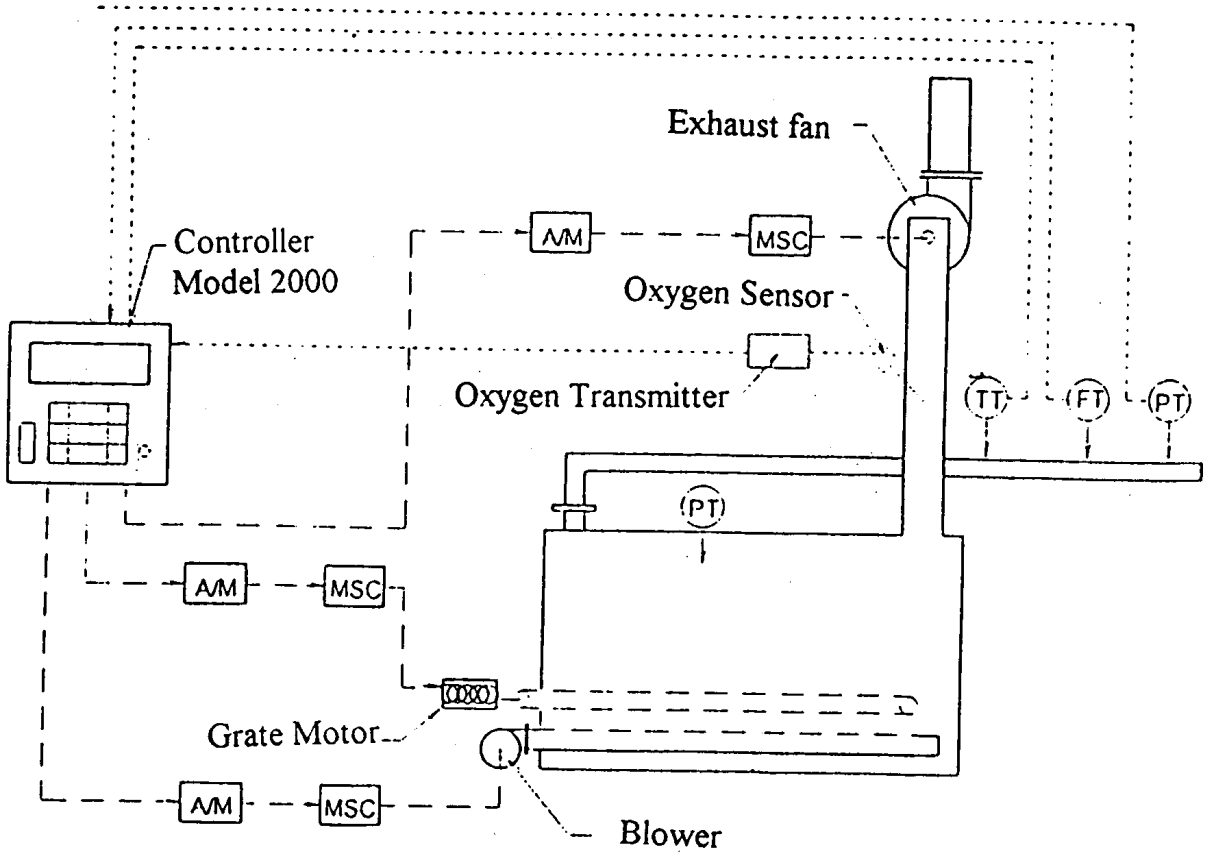
The new ministerial regulations will enforce the reduction of pollutant emission as of December 31 1997 and it forces the boiler plant owners to emission control modifications. The imposed emission limits necessitate, amongst others, the use of more expensive fuels with lower sulphur contents. For those reasons the need arises to reduce the effluent emission while improving the boiler efficiency, and maintaining energy price at the present level.

3. Object for Modernization and Testing.

It was decided to make the first Polish installation of the Control Techtronics International, Control System Model 2000, at the Krakow City Enterprise for Heat Energy (Miejskie Przedsiebiorstwo Energetyki Cieplnej w Krakowie) at the Balicka Boiler Plant boilers Model WR-10 and PLM-2.5 ; The plant is located at Lindego Street 4 and it is managed by Mr. Leszek Ciurlik.

It was decided to instal two systems: one for three water boilers # WR-10 and one for two steam boilers # PLM-2.5. This decision was based on an analysis of the efficiency test results of these boilers, as carried out during the first phase of the Polish-American Program for Liquidation of Pollution in Krakow by the PPB ENERGOEXPERT s.c.

The control system for each boiler was shown schematically in Fig. 1. The associated boiler control parameters measured are: water flow and outlet temperature for water boilers or steam flow and pressure for a steam boiler; combustion chamber vacuum, also oxygen contents in the flue. There were three parameters controlled by the measurements: grate speed (deciding the boiler load), efficiency of blowers and exhaust fans (adjusting air flow to the combustion process, thus boiler load).



Input signal
Output Signal

MSC - Controller
FT - Flow Transmitter
A/M - Auto/Manual Station

TT - Temperature Transmitter
PT - Pressure Transmitter

4. TEST RESULTS.

The tests were in accordance with PN-72/M-34128, BN - 86/1317-02 and EPA and for three boiler loads. The minimum and maximum boiler efficiencies were limited by the existing heat exchangers. The control system installed on the boiler # WR-10 permitted additional tests at a load lower than 25% of the rating.

The control system installation had improved efficiency and decidedly reduced emission of particulates. This is shown tabulated below and in Fig. 2, 3, 4, and 5. It can be seen that the mean efficiency increase for the tested boilers exceeds 15% (assuming annual load variations of 30% minimal load, 50% median load and 20% maximum load). A 90% reduction of particulate emission was obtained for low loads and 60% reduction for median loads. The control system was fully qualified for an effective emission control.

Fuel Type	Boiler Load	Fuel caloric value	Boiler efficiency	Particulates emission	Emission of organic particles	NOx Emitted	SO2 Emitted
Units	[MW]	[kJ/kg]	[%]	[g/GJ]	[g/GJ]	[g/GJ]	[g/GJ]
PLM-2.5	0.8	20899	61.8	633	8.68	152	513
STASZIC	1.5	20173	67.4	274	7.77	129	603
Manual Control	2.7	19951	72.2	63	2.13	130	583
PLM-2.5	1.2	21931	73.2	54	4.34	133	518
SIEMIANOWICE	1.8	21931	74.7	61	0.85	142	523
Controllers CT1	2.5	21931	75.5	64	0.55	149	528
WR-10	4.3	20982	57	816	1.52	127	512
STASZIC	6.4	20984	64	149	1.02	100	405
Manual Control	9.2	20844	75	112	0.45	92	353
WR-10	2.5	21873	82	35	1.09	131	465
SIEMIANOWICE	4.4	21873	81	35	1.09	116	475
siany	6.7	21950	77	69	0.56	109	490
Controllers CT1	9.6	21950	79	112	0.45	106	538

The installed system did not significantly influence the remaining effluents. It was to be noted however, that it resulted a 30% - 40 % reduction of power used by the blowers and exhaust fans.

5. Economical assessment of the installation.

The cost per boiler of the installation is 150 000 - 200 000 zl. ($60 000 - $80 000). Assuming 85zl./ tone ($34) as the cost of fuel and removal of slag, it amounts to an equivalent of 2 100 tons of fuel. The savings associated with the increased efficiency, costs of energy and environmental taxes saved exceed 15% for the tested WR - 10 boiler. Having all that in mind, this investment will repay its cost after 12 000 tons of fuel are burned in this boiler.

Fig 2. Boiler WR-10 efficiency comparison before & after modernization

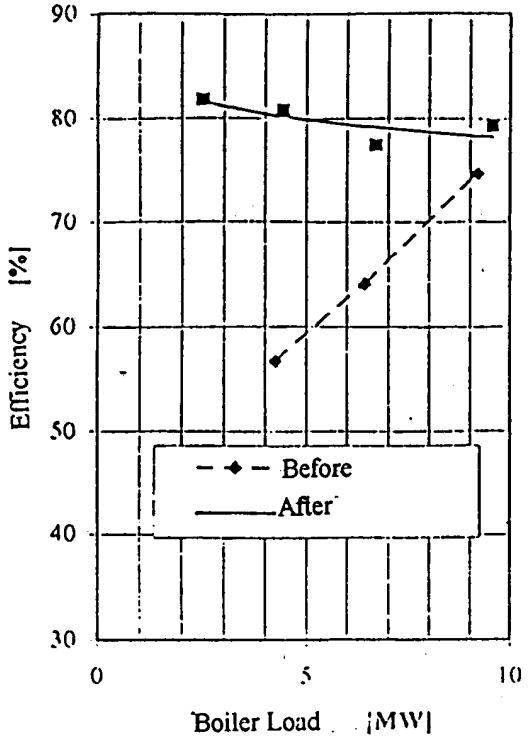


Fig 3. Boiler WR-10 particulates emission comparison before & after modernization

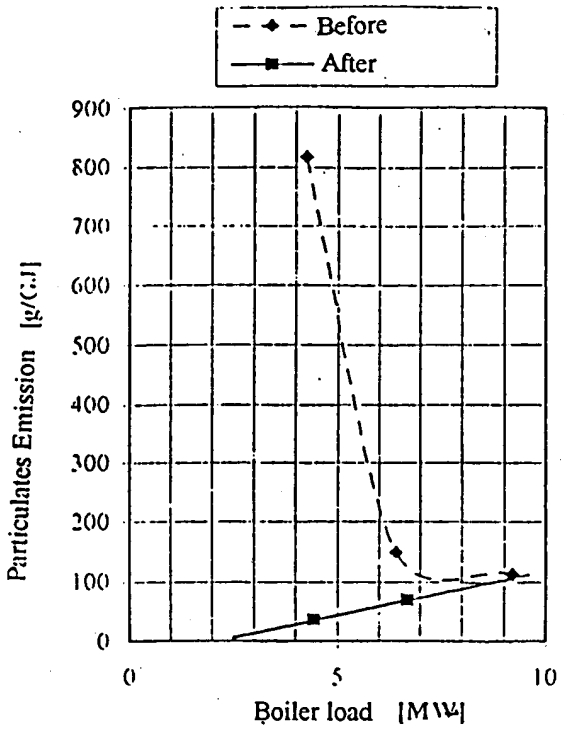


Fig 4. Boiler PLM-2.5 efficiency comparison before & after modernization.

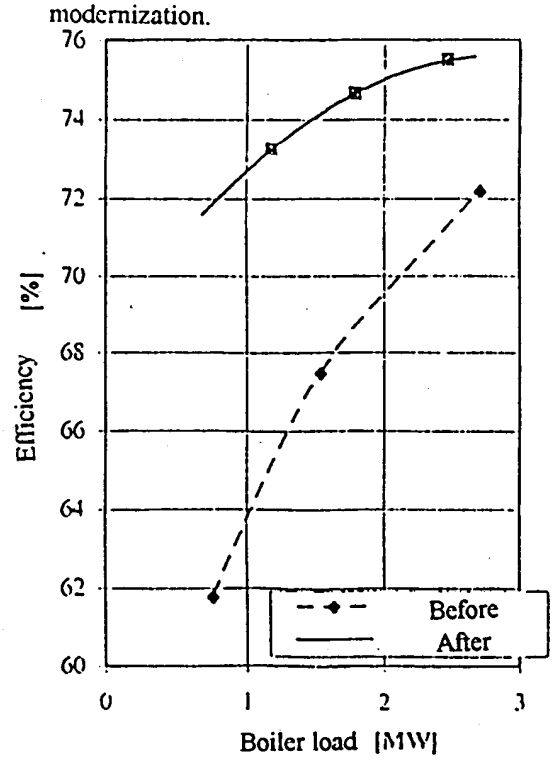
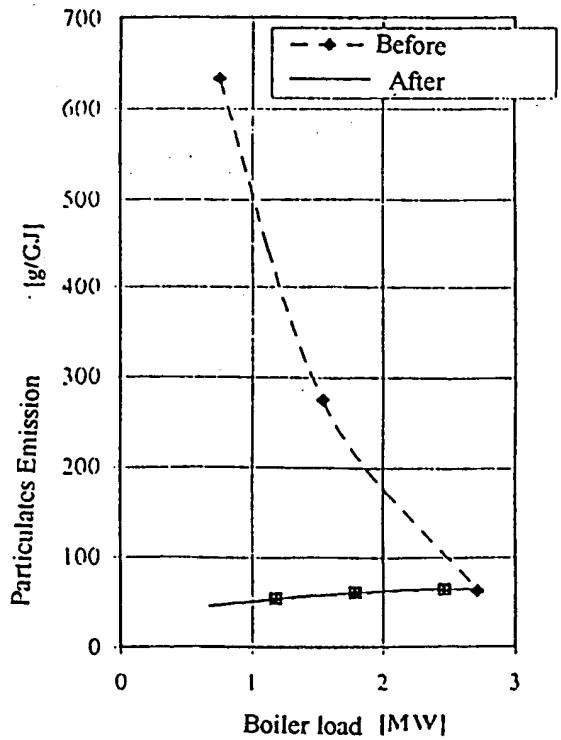


Fig. 5. Boiler PLM-2.5 particulates emission comparison before & after modernization



APPENDIX B

Signing of DOE Letters of Intent by Zorza and RzaSka in Krakow, April, 1996