PD-ABL-581

EVALUATION OF EMISSIONS CONTROL TECHNOLOGIES

Taiwan
November 26 - December 12, 1994

Prepared for:

US - ASIA ENVIRONMENTAL PARTNERSHIP

WEC™
WORLD ENVIRONMENT CENTER

DISCLAIMER

This project was sponsored by the U.S. Agency for International Development through WEC's Cooperative Agreement in support of the U.S.-Asia Environmental Partnership (US-AEP). The opinions expressed herein are the professional opinions of the author and do not represent the official position of the Government of the United States of America or the World Environment Center.

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I. EXECUTIVE SUMMARY

Reaction Engineering International (REI), Salt Lake City, Utah, under contract from World Environment Center conducted an Environmental Business Exchange (EBE) in Taiwan. The purpose of the exchange was to introduce and discuss REI's Nitrous Oxide (NO_X) and Sulfur Dioxide (SO_2) control technologies with China Steel Corporation (CSC), located in Kaohsiung, Taiwan. The REI participants, Mr. Shih Lin (Stoney) Chen and Dr. Philip Smith, visited the Utilities Department, the Energy and Environmental Section, and Iron Making Process Department at CSC.

CSC has three 200 TPH (tons of steam per hour) coal fired boilers which produce NO_X and SO_2 emissions. In addition, CSC operates three blast furnaces for manufacturing iron. In order to increase its steel production capacity, CSC plans to build a new blast furnace. Taiwan government, however, requests that CSC reduce emissions from existing boilers and furnaces to make up for the increased emissions for the new blast furnace and ancillary facilities.

A selective non-catalytic reduction (SNCR) process is recommended for the reductions of NO_X emissions from CSC's coal-fired boilers. It is recommended that a feasibility study be conducted to determine the NO_X reductions achievable with SNCR and compare the control costs with urea and aqueous ammonia as the reducing agent. Furthermore, the SNCR process should be considered to be combined with calcium based sorbent injection for potential simultaneous NO_X and SO_2 reductions.

To reduce the operating cost of blast furnaces and reduce the pollutant emissions associated with coke production, pulverized coal injection (PCI) is recommended for coke replacement in blast furnaces. It is recommended that a feasibility study be performed to determine the potential of increasing PCI rates in blast furnaces and focus on coal reactivity screening, use of oxygen enrichment, and computer simulations for injector designs.

Funding for this project was provided through a Cooperative Agreement between the World Environment Center (WEC) and the United States - Asia Environmental Partnership (US-AEP).

II. INTRODUCTION

Under the U.S.-Asia Environmental Partnership (US-AEP) and World Environment Center (WEC) Environmental Business Exchange program, Mr. Shih Lin (Stoney) Chen, Director of Business Development, and Dr. Philip J. Smith, Vice President, both of Reaction Engineering International (REI) at Salt Lake City, Utah, visited China Steel Corporation, Kaohsiung, Taiwan, Republic of China. The visits were conducted during November 26 to December 12, 1994. The purpose of the visits was to introduce and discuss REI's technologies for reducing NO_X and SO_2 emissions from boilers and furnaces. At China Steel Corporation, the participants visited the Utilities Department, the Energy and Environment Section, and the Iron Making Process Department. The participants also visited the US-AEP Taiwan office in Taipei, Taiwan.

III. FINDINGS

A. CHINA STEEL CORPORATION

China Steel Corporation (CSC) located in Kaohsiung, Taiwan, is the only integrated steel manufacturer in Taiwan, Republic of China. It was founded in 1971 with an ultimate goal of producing 8 million metric tons of crude steel. To date three phases of construction and expansion projects have been completed and CSC's annual production of crude steel has reached 5.65 million metric tons. CSC now stands as one of the top 20 steel makers in the free world, earning itself a Regular Company Membership in the International Iron and Steel Institute (IISI) and concurrently a Board Director as well as Member of Executive Committee.

CSC is a state owned enterprise which currently employs approximately 9,000 people. The integrated iron and steel production processes used by CSC are schematically shown in Appendix A. The making of steel products from iron ore to the final product is accomplished in a series of consecutive, distinct processes:

1. ore preparation and agglomeration;
2. coke making;
3. iron making;
4. steel making and casting; and
5. rolling, finishing and surface treatment.

CSC's business activities predominately are the production and sale of steel products such as hot-rolled coils and sheets, cold-rolled coils and sheets, plates, wire rods, bars, billets, and pig iron. Most of the products are for domestic consumption, sold to metal retailers, steel piping, bolts and nuts, steel wire and cable manufacturers. Export market currently accounts for 15 - 20% of its total sales.

B. ENVIRONMENTAL ISSUES

CSC plans to launch the Phase IV expansion for an additional 2.4 million tons of steel-production capacity. The Phase IV expansion project is basically the building of its No. 4 blast furnace. With anticipated pollutant emissions from the new blast furnace and ancillary facilities, CSC is required by the Taiwan government to reduce emissions from existing boilers and furnaces.

CSC has three coal fired boilers which produce NO_X and SO_2 emissions. The boilers, Nos. 6, 7, and 8, are tangentially fired VU-40 units designed by ABB-Combustion Engineering. A schematic of the boiler Is shown in Appendix A. At 100% maximum continuous rating (MCR), the boiler units are designed to deliver 200 metric tons of

steam per hour at a pressure of 9.2 MPa and a temperature of 513°C to the superheater outlet.

When fired with Australian coal, each boiler unit produces NO_X emissions ranging between 340 and 420 parts per million (ppm) (dry, 6% O_2). CSC's goal is to reduce the NO_X emissions to 250 ppm or below. The current SO_2 emissions range between 300 and 400 ppm (dry, 6% O_2). CSC would also like to reduce the SO_2 emissions to 250 ppm or below.

In addition to coal-fired boilers, CSC has three blast furnaces which use coke for manufacturing iron. Coke is more expensive than coal. Furthermore, the coking process produces significant amounts of pollutant emissions. Thus, there is considerable interest in maximizing coke replacement with less expensive coal. In particular, CSC is interested in pulverized coal injection (PCI) into the blast furnace via the tuyeres. Currently the PCI rate is 60 - 80 kg/THM. CSC would like to increase the PCI rate to 150 - 200 kg/THM.

C. TECHNOLOGIES DISCUSSED

The EBE participants discussed several NO_X control technologies with CSC's personnel, including people in the Utilities Department and Energy and Environment Section. The NO_X control technologies discussed are: Low-NO_X burners (LNB), reburning and selective non-catalytic reduction (SNCR). Commercially available LNBs include the ABB-CE Low-NO_X Concentric Firing System (LNCFS), Mitsubishi Heavy Industry's Pollution Minimum (PM) burner with and without overfire air (OFA).

Reburning is a combustion modification technology which removes NO_X from combustion products by using fuel as the reducing agent. Although natural gas is not available to the CSC boilers, there are other gaseous fuels. Coke oven gas (COG), which consists of approximately 60% hydrogen, 28% hydrocarbons ($CH_4 + C_2H_6$), and 7% CO, appears as a potential reburning fuel. The other potential reburning fuel is Blast Furnace Gas (BFG), which consists of approximately 21% CO and 3% H_2.

Conceptually, the SNCR process is quite simple. Aqueous urea, aqueous ammonia or gaseous ammonia is injected into the flue gas at an appropriate temperature window. Upon injection, the reagent will decompose to yield NH_2 which then reacts with NO_X to form molecular nitrogen and water. The actual NO_X reductions with SNCR will depend upon the available "temperature window" of the boilers. With minor modifications, SNCR can be combined with calcium-based sorbent injection for simultaneous control of NO_X and SO_2 emissions.

In addition, the participants discussed PCI technologies with the Iron Making Process Department. A seminar on Simulation of Pulverized Coal Injection in Blast Furnaces

was presented to the Blast Furnace Plant employees. Results from a coal screening study were presented to illustrate the use of a small test furnace to provide a comparison of combustion characteristics under conditions typical of blast furnace injection. Discussions were also conducted on the use of computer simulations to provide information on the progress of combustion within the tuyere and the raceway.

IV. CONCLUSIONS AND RECOMMENDATIONS

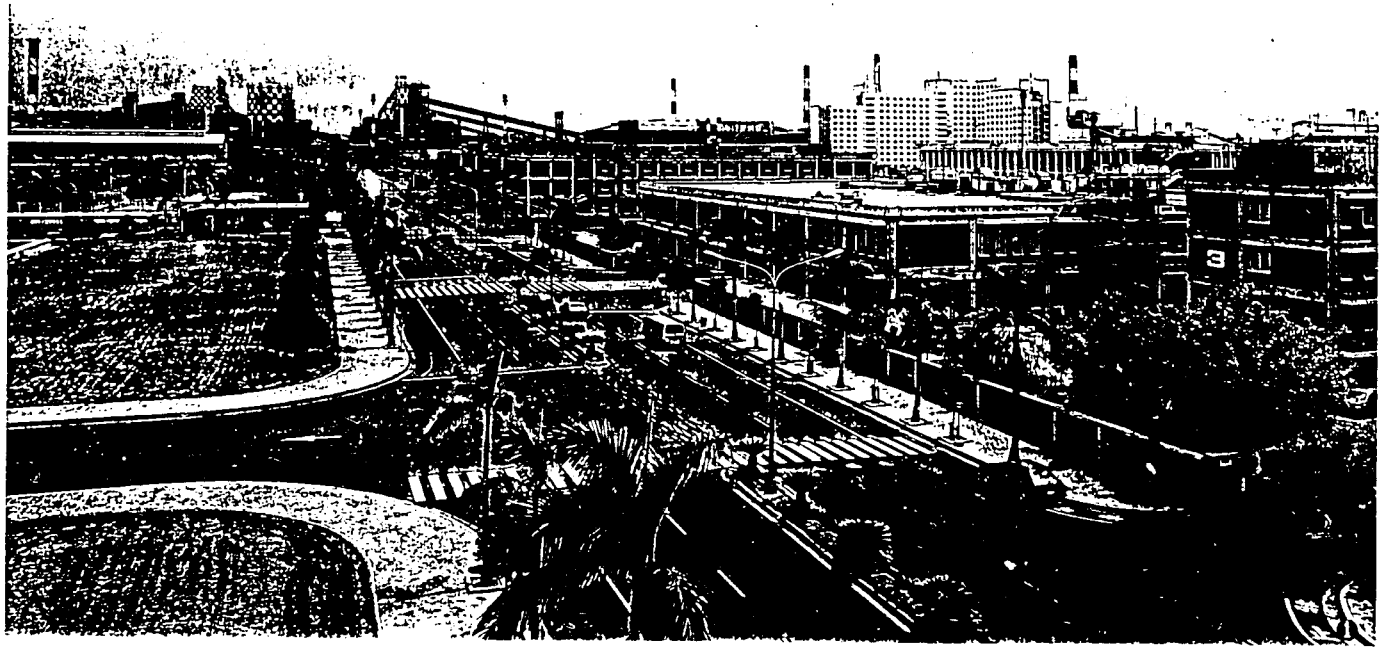
Although installations of LNB have been shown to achieve significant NO_X reductions without derating capacity or reducing boiler efficiency, potential problems with LNB are flame impingement on furnace walls, changes in heat release distribution and high unburned carbon content in the fly ash. Discussions with CSC also reveal concerns on the limited furnace space and considerable modifications required for LNB retrofit. Reburning with COG or BFG would be a viable NO_X control technology if the reburning gas is available. However, CSC has reservations on the continuous supply of either surplus gas.

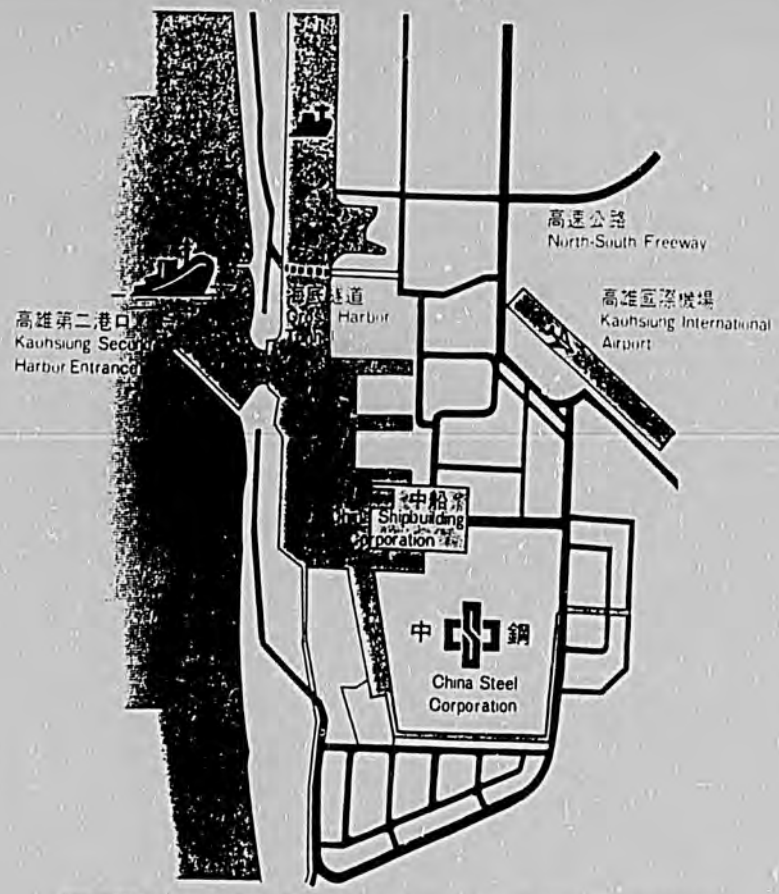
It appears that the only potential NO_X control technology for the CSC boilers is SNCR. It is recommended that a feasibility study be conducted to determine the NO_X reductions achievable with SNCR and compare the control costs with urea and aqueous ammonia the reducing agent. In addition, the feasibility study should consider the combination of SNCR with calcium based sorbent for simultaneous NO_X and SO_2 reductions.

It is further recommended that another feasibility study be performed to determine the potential of increasing PCI rates in blast furnaces at CSC. In particular, the study should focus on coal reactivity screening, use of oxygen enrichment and computer simulations of different injector designs.

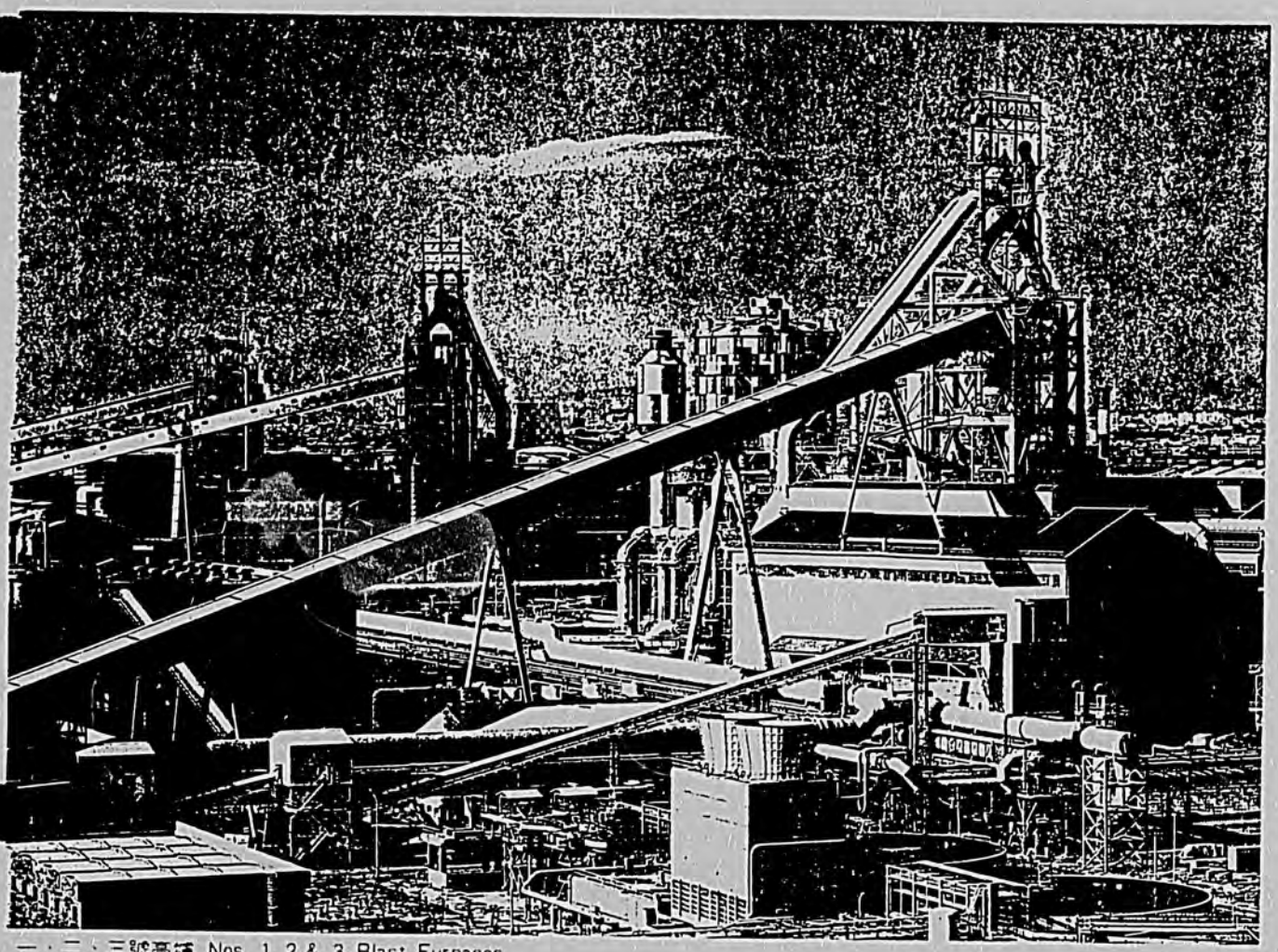
APPENDIX A

PICTURES AND SCHEMATICS OF CHINA STEEL CORPORATION





中國鋼鐵公司地理位置圖 Location of China Steel Corporation



一、二、三號高爐 Nos. 1, 2 & 3 Blast Furnaces

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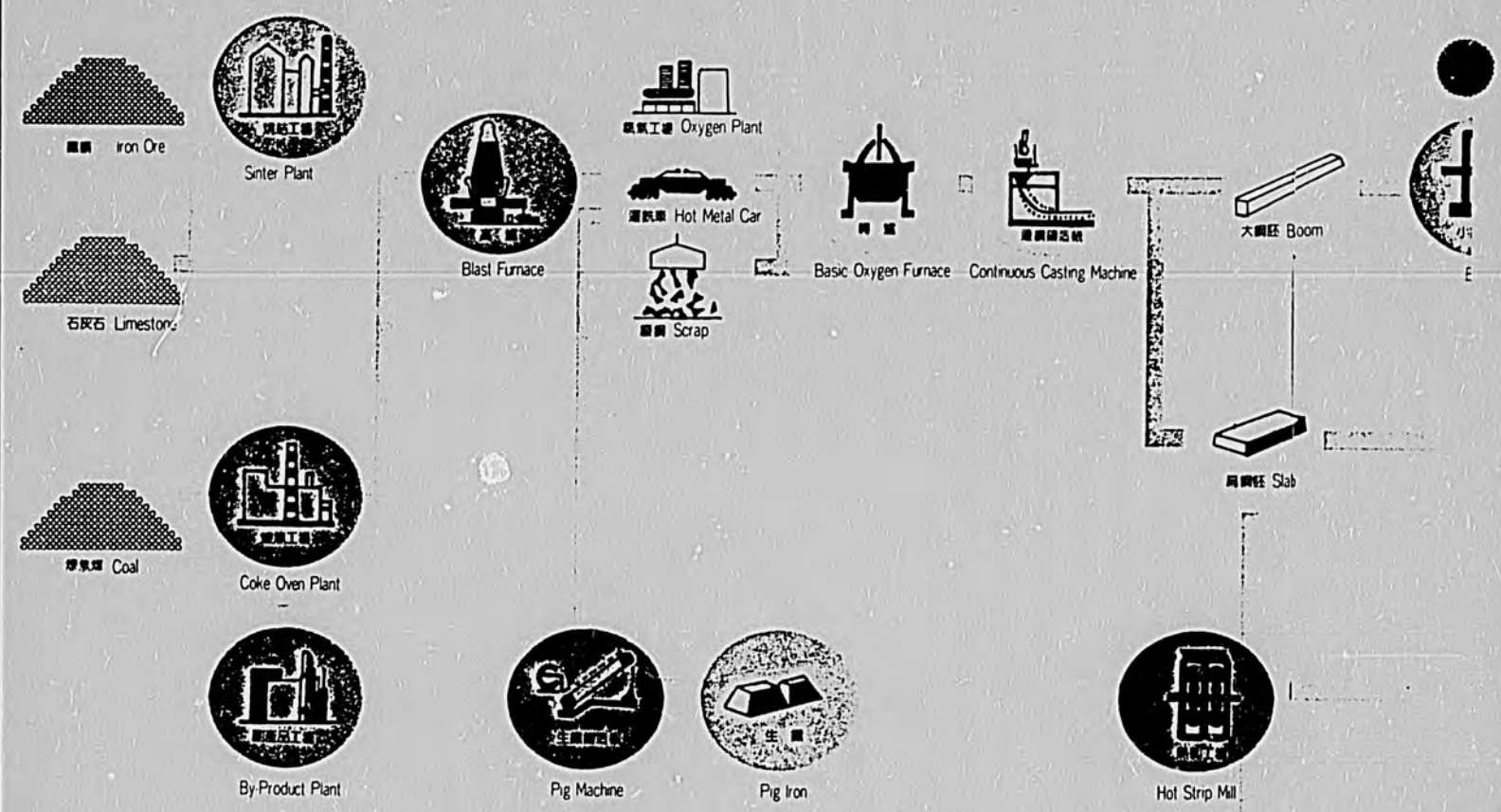
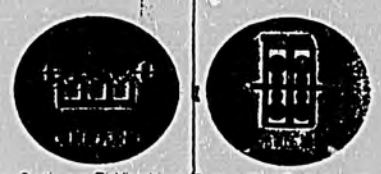
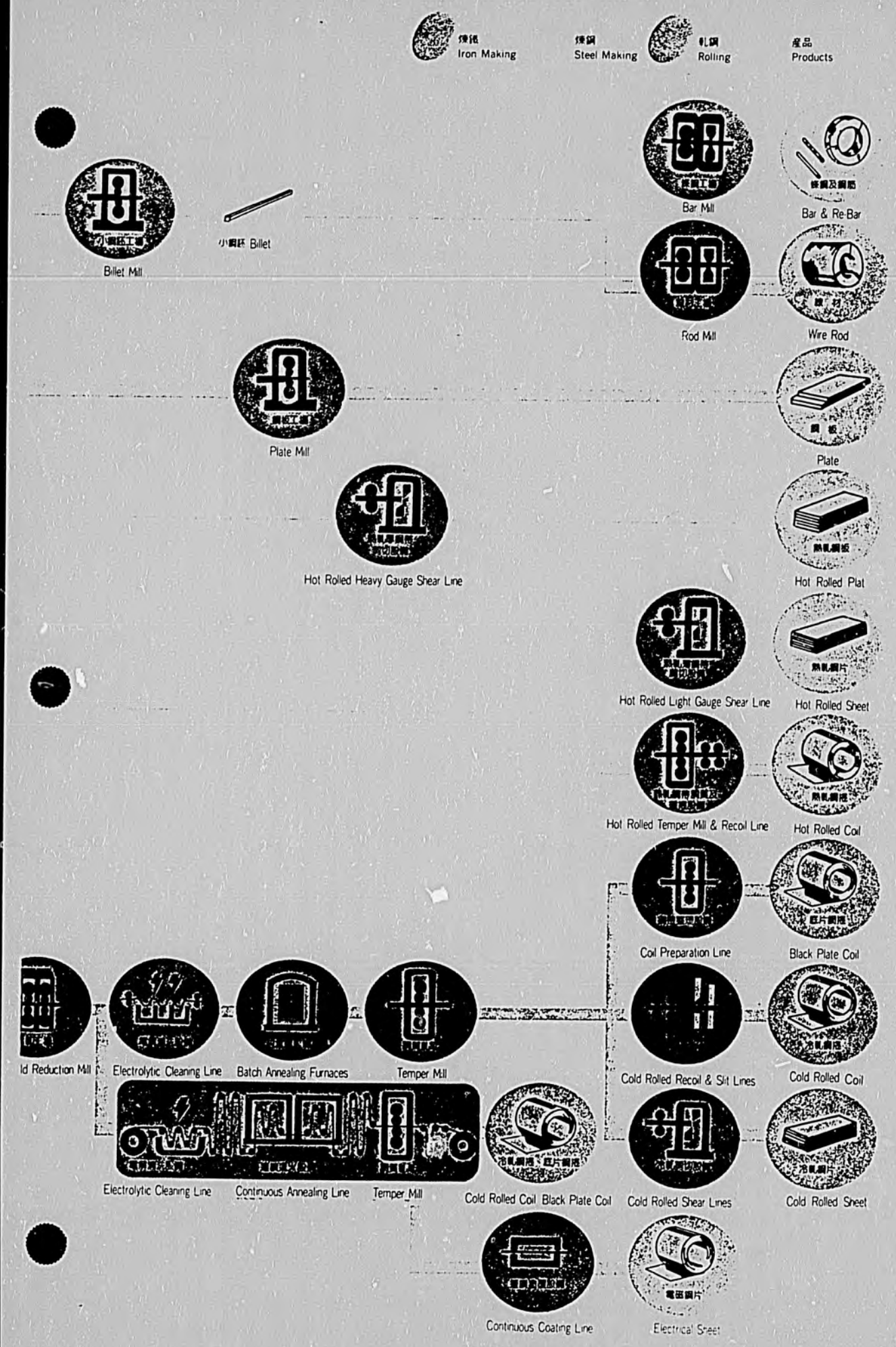
STEEL PRODUCTION FLOW CHART

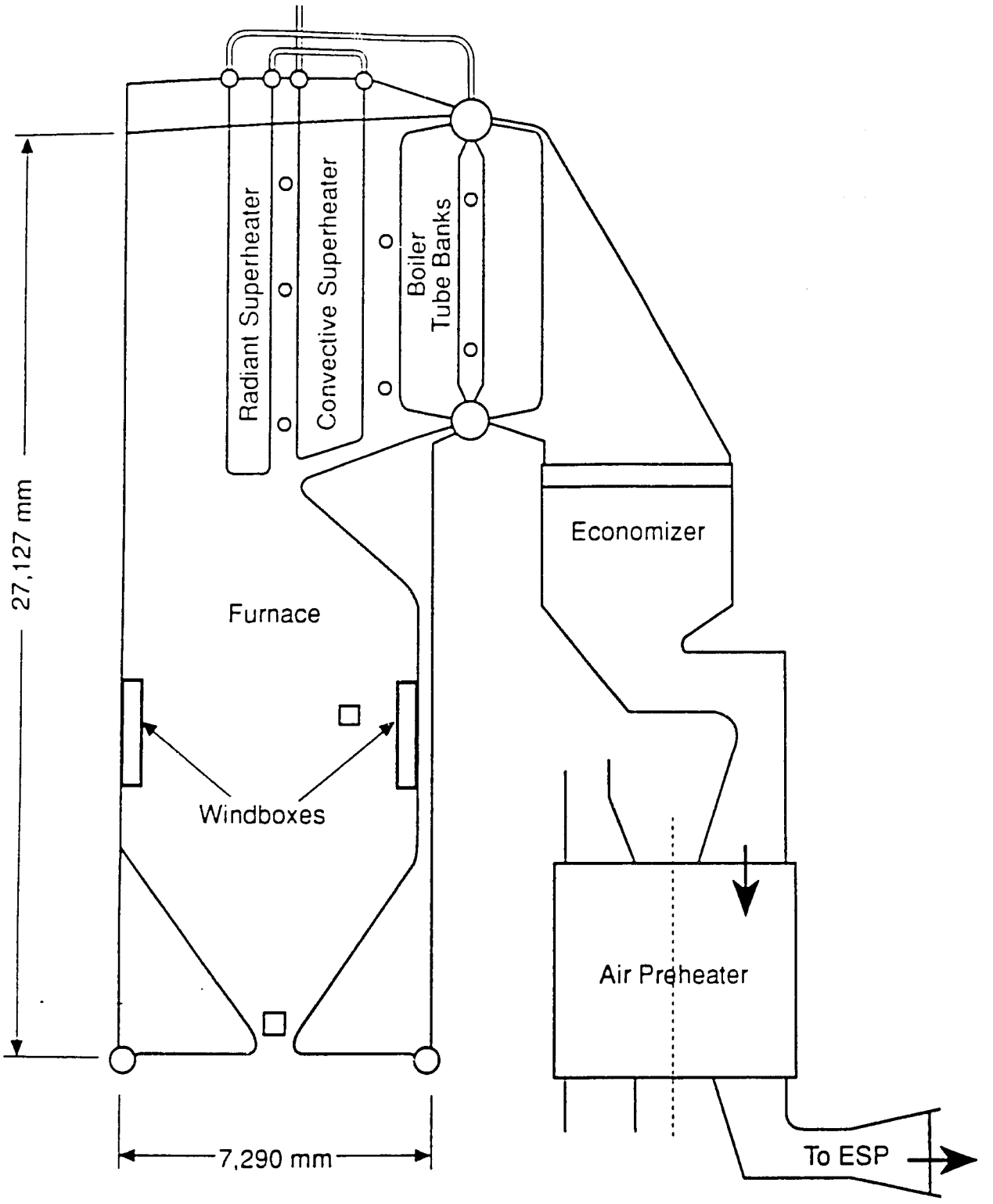


中鋼鋼品主要生產設備概要 CSC Steel Operational Facilities

工場	設備	Plant	Facility
煉焦工場	對分式多段燃燒系統型煉焦爐 6 米・39個煉焦室・2座 6 米・49個煉焦室・2座 7.3米・50個煉焦室・2座	Coke Ovens	Gun Type Battery 6 M, 39 Ovens×2 6 M, 49 Ovens×2 7.3M, 50 Ovens×2
燒結工場	無極循環式燒結機 燒結面積150平方米・1座 燒結面積280平方米・1座 燒結面積367平方米・1座	Sinter Plant	DL Type 150 M² ×1 DL Type 280 M² ×1 DL Type 367 M² ×1
高爐工場	全容積2,434立方米,有效容積2,101立方米・1座 全容積2,850立方米,有效容積2,360立方米・1座 全容積3,400立方米,有效容積2,850立方米・1座	Blast Furnace	2,434 M³ ×1 2,850 M³ ×1 3,400 M³ ×1
轉爐工場	塩基性頂部吹氧式轉爐 160公噸・3座；250公噸・2座	Basic Oxygen Furnace	160 MT ×3 250 MT ×2
連鑄工場	百分之百連續鑄造機 大鋼胚連鑄機2座・每座4段 扁鋼胚連鑄機5座・每座2段	Continuous Caster	4-Strand (Bloom)×2 2-Strand (Slab) × 5
鋼板工場	1座四重往復式軋延機	Plate Mill	1-Stand Roughing and Finishing Mill×1
條鋼工場	6座粗軋機・4座中軋機・6座精軋機	Bar Mill	16-Stand×1
線材工場	7座粗軋機・8座中軋機・10座精軋機	Rod Mill	25-Stand×1
小鋼胚工場	1座二重往復式粗軋機及垂直—水平精軋機各1座	Billet Mill	3-Stand Semi-Continuous×1
熱軋工場	3/4連續式熱軋鋼帶工場	Hot Strip Mill	3/4 Continuous Mill×1
冷軋工場	5座串列式軋延機	Tandem Cold Reduction Mill	5-Stand Tandem Mill×1




Iron Making
Steel Making
Rolling
Products
Billet Mill
Billet
Bar Mill
Bar & Re-Bar
Rod Mill
Wire Rod
Plate Mill
Plate
Hot Rolled Heavy Gauge Shear Line
Hot Rolled Plat
Hot Rolled Light Gauge Shear Line
Hot Rolled Sheet
Hot Rolled Temper Mill & Recoil Line
Hot Rolled Coil
Coil Preparation Line
Black Plate Coil
Electrolytic Cleaning Line
Batch Annealing Furnaces
Temper Mill
Cold Rolled Recoil & Slit Lines
Cold Rolled Coil
Electrolytic Cleaning Line
Continuous Annealing Line
Temper Mill
Cold Rolled Coil Black Plate Coil
Cold Rolled Shear Lines
Cold Rolled Sheet
Continuous Coating Line
Electrical Sheet



China Steel Corporation's CE VU-40 boiler design.

APPENDIX B

BUSINESS CARDS OF PERSONS CONTACTED

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APPENDIX C

CURRICULUM VITAES

SHIH LIN (STONEY) CHEN

Director, Business Development, Reaction Engineering International

Education

M. S., Mechanical Engineering, 1978
University of Kentucky, U. S. A.
B. S., Mechanical Engineering,1972
National Taiwan University, Taiwan

Summary

Mr. Chen has over 16 years of experience in conducting and managing programs on emissions control technology development and applications, fuels utilization and fuel quality evaluation, and waste incineration.

Experience

1991 - Aug 1994
Manager, Pacific Rim Projects, Energy and Environmental Research Corporation (EER), Irvine, California - managed and coordinated projects involving combustion, pollution control, and incineration in the Pacific Rim countries. I was responsible for all of the marketing activities in Taiwan, Korea, and China.

1985 - 1991
Manager, Combustion & Pollution Control, EER - supervised all experimental work in bench and pilot scale combustion and incineration test facilities located in a 25-acre test site. I also served as Program Manager for a variety of projects on advanced NO_X control processes, including reburning and selective non-catalytic reduction (SNCR). In addition, I was responsible for the development of low-cost sorbent injection processes for SO_X control and involved in studies on thermal treatment of solid wastes and control of PCDD/PCDF emissions.

1981 - 1985
Group Leader, Process Development, EER - completed extensive bench and pilot studies to identify the process parameters controlling reburning and sorbent injection for NO_X and SO_X reductions and develop a scaling methodology for applications to full scale boilers. I was also responsible for the development and designs of a series of laboratory scale reactors and furnaces for U.S. EPA for the investigation of hazardous waste incineration and combustion and process chemistry.

1978 1981

Research Engineer, Process Research, EER - conducted a comprehensive investigation of more than fifty coals from around the world to evaluate fuel properties and NO_X formation. In addition, I designed a bench scale combustor to simulate the generation of fly ash in utility boilers and studied the fly ash characteristics in relation to ESP performance.

Patents

U.S. Patent 4, 851,201 (1989): Methods of Removing NO_X and SO_X Emissions from Combustion Systems Using Nitrogenous Compounds.

U. S. Patent 4,851,567 (1989): Methods of Removing NO_X and SO_X Emissions from Combustion Systems.

U.S. Patent 5,116,584 (1992): Methods for Enhancing the Useful Temperature Window for NO_X Reduction in Combustion Systems.

U.S. Patent 5,139,755 (1992): Advanced Rebuming for Reduction of NO_X Emissions in Combustion Systems.

U. S. Patent 5,270,025 (1993): Methods for Controlling N_2O Emissions and for the Reduction of NO_X and SO_X Emissions in Combustion Systems while Controlling N_2O Emissions.

PHILIP J. SMITH

Vice President, Reaction Engineering International
Professor, Department of Chemical Engineering, University of Utah

Education

Ph.D., Brigham Young University, 1979
M.S., Brigham Young University, 1976
B.S., Brigham Young University, 1975

Summary

One of the founders of Reaction Engineering International; one of his goals is to use fundamental scientific information to solve problems related to the utilization of fossil fuels. Formerly an Associate Professor at Brigham Young University where he directed the development of advanced comprehensive computer models of thermal conversion processes. He has worked on reactive flow modeling at Los Alamos National Laboratory and directed the theoretical modeling activities of the NSF's Advanced Combustion Engineering Research Center. He was responsible for the development of a 3-dimensional, industrially applicable, computer model of coal combustion processes for an industrial and government consortium with a research budget of $1,300,000.

Experience

Feb 1990 - Present
Reaction Engineering International, Salt Lake City, UT - Vice President, responsible for the application and development of comprehensive computer models of combustion processes including natural gas, oil and pulverized coal fired boilers and recirculating fluidized bed combustors.

July 1990 - Present
University of Utah, Salt Lake City, UT - Professor, Department of Chemical Engineering.

1979 - 1990
Brigham Young University, Provo, UT - Associate Professor, Department of Chemical Engineering.

1982 - 1983
Los Alamos National Laboratory - Engineer, Energy Division worked on the modeling of reactive flows.

MICHAEL P. HEAP

President, Reaction Engineering International (REI)

Education

Ph.D., University of Salford, England, 1970
M.Sc., University of Salford, England, 1967
B.Sc., University of Salford, England, 1965

Summary

Dr. Heap has over twenty years of experience in R&D of combustion related problems including pollutant formation and control, furnace heat transfer, combustion system modeling, thermal treatment of waste, and coal quality for power generation. As President responsible for operations, he built EER into a research company with annual sales in excess of $15,000,000 and a backlog of $60,000,000. His research activities included low NO_X burner designs for oil and pulverized coal firing; engineering analysis of combustion systems; the development of improved noncatalytic selective reduction techniques for NO_X control; fuels evaluation; sorbent injection for SO_2 control and the use thermal destruction techniques for waste disposal. He helped design and managed the construction of combustion test facilities for coal, oil and gaseous fuels with firing rates ranging from 100,000 to 100,000,000, Btu/hr. He managed the EPA Fundamental Combustion Research Program for four years. He was responsible for the development of EER's Gas Reburning-Sorbent Injection Technology and directed the proposal efforts which resulted in two awards under DOE's Clean Coal Technology Program. His current interests include the application of advanced computer models to combustor system design.

Experience

<u>Feb 1990 - Present</u>
Reaction Engineering International, Salt Lake City, Utah - founded new company to apply fundamental research to industrial problems related to combustion and the environment.

<u>Feb 1977 - Feb 1990</u>
Energy and Environmental Research Corporation, Irvine, Calif. - President and co-founder responsible for all operations; developed combustion test facility for fossil fuels; directed all proposal efforts and development of new business areas.

Jul 1974 - Feb 1977

Ultrasystems Inc., Irvine, Calif. - Director Combustion Systems responsible for contact research concerned with pollution control from combustion systems including pulverized coal fired boilers, oil and gas fired package boilers and diesel engines.

Sep 1970 - Jul 1974

International Research Foundation, IJmuiden, Netherlands - Principal I..vestigator responsible for EPA contract to develop burner design criteria for low-NO_X coal, gas and oil burners.

Patents

U.S. Patent #4,381,718 - Low Emissions Process and Burner (pulverized coal).

U.S. Patent #4,861,567 - Methods of Rernoving NO_X and SO_X Emissions from Combustion Systems.

U.S. Patent #4,851,201 - Methods of Removing NO_X and SO_X Emissions from Combustion Systems using Nitrogen Compounds.