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Consultancy Assistance Promotion of UNIDO Knowledge-based Experience in the Aquisition of Anti SO_2/NO_x Pollution Technologies for Steel and Power Industries in Hungary, Czechoslovakia and Poland

prepared by

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Introduction

This paper is the report of Consultancy Assistance Promotion of UNIDO Knowledge-based Experience in the Assessment, Selection and Aquisition of Anti-SO_2/NO_x Pollution technologies for the Steel and Power Industries in Hungary, Czechoslovakia and Poland. One typical plant out of steel and power generating industries in those three countries respectively for the fact-finding mission. The current state and local conditions of SO_2/NO_x control as well as the compliance with regulation standards were surveyed in each plant and country.

On the other hand, the available technologies developed in USA, Germany and Japan were reviewed.

The difficulty in establishing a proper strategy for SO_2/NO_x control is due to the existence of many factors which should be considered, and many applicable processes. Some of those factors are variable and therefore very difficult to forecast. For instance, the level of regulation standards, the price of coal related to sulfur content, the progress of technologies, the level of industrial development, capability of management and engineering, ect. All these factors are not clear for the future in the East-European countries. Besides, the local conditons differ fromplant to plant.

In spite of such difficulties, some suggestions and recommendations for process selection and strategy establishment are made in this report.

Finally, a workshop of flue gas desulfurization(FGD) for the employees of power stations in East-European countries is proposed based on the results of fact-finding missions.

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1. Hungary

1-1 The Ministry of Industry and Trade

Date	: Nov. 19. 1991 3.00 pm - 5.00 pm
Interviewed counterpart	: Dr. M. Poos. Deputy Head of Dept., Dept. of Environmental Management and Safety
Coordinator	: Dr. Endre T. Balazs. UNIDO Consultant

(1) Organization and activity for environmental management

The ministry of industry and trade consists of the following five divisions.

The Division of Industry
The Division of Trade
The Division of Energy
The Division of Tourism
The Division of Economics

Air pollution problems are handled in the Department of Environmental Management and Industrial Safety, which, together with the Department of Energy Politics and the Department of Energy Net Work, belongs to the Division of Energy.

On the other hand, the Ministry of Industry and Trade has the supervisory and inspectoral responsibility for environmental and water pollution.

(2) Regulations

As for air quality control, the following three regulations have been issued so far in Hungary. The first is the clean air act, which regulates the allowable ambient level of pollutants.

The second is the emission standard for traffic which regulates CO, H-C, SO_2 and soot from vehicles. The third is the regulation for incinerators. Aaccording to this regulation, the incinerator for PBC has to be operated with the combustion temperature over 1100 C and a residense time in the combustion chamber of over 3 seconds.

The direct emission standard for stationary sources has not been introduced so far in Hungary. The allowable emission value for a particular stationary source has been calculated from the imission standard of the local point. That is, the concrete emission value is decided based on the difference between the allowable imission level and the background level, and applying it to diversion formulae with a number of meteorological factors of the local point. However, the calculation procedure of this regulating system is not simple and

the obtained values are easily affected by the assumed conditions. In order to make the regulation for environmental control effective and efficient, the direct emission control system is indespensable. As a matter of fact, the government of Hungary is well aware of it and the emission standard for incinerators is scheduled to be enacted in 1992. The emission standard for other stationary sources is also expected to be prepared in the near future.
In 1987 the Government of Hungary made an agreement with other European countries to achieve 30 % reduction of SO_2 emission by 1991. According to the Ministry of Industry and Trade, the aim is expected to be achieved, mainly due to the economic recession during the term. The contribution to the reduction might be described more in detail as 20 % by the recession and 10 % by technical efforts.

(3)Energy strategy

The energy supply in Hungary is largely dependent on the Soviet Union. For example, 40 % of electricity, 70 % of oil and 50 % of natural gas is supplied from the Soviet Union at present. As for the supply of oil, only 20 % of total demand is produced by the domestic oil field. Oil from the Arab countries is not currently supplied due to the destruction of the pipe line in Yugoslavia. From the view point of energy security, the divercification of energy source and energy supply is the first priority. The Government of Hungary has a plan to import natural gas from western Europe, and to import the oil from Algeria through Italy. The government also has a plan to import electricity from western Europe and to reduce the share imported from the Soviet Union. However, the import of electricity from western Europe encounters a technical problem due to the quality of electricity. The frequency fluctuation of the current electricity generated in Hungary and imported from the West Ukrainian Network is 50+-5 Hz, which is much more compared with 50+-0.05 of West Europe. One solution for this problem is to provide the convertor-invertor system but it is too expensive.

The current price level of energy in Hungary is as follows.

Gasoline	60 Ft/l(0.80 US$/l)
Electricity	3 Ft/Kwh (40 mill/Kwh)
Natural gas	8 Ft/m^3N (100 mill/m^3N)

(4)SO_2 strategy

There is no flue gas desulfurization(FGD) plant in Hungary. One project for SO_2 abatement is going on at Ajka Power Station. This project is applying the fluidized bed combustion system(FBC) by Hungarian patent. According to the Ministry of Industry and Trade, the FBC system is one good solution as to how to change the brown coal-fired boilors for the reduction of SO_2 emission. The investment cost of FBC is only 1/10 of that for wet FGD of 90 % SO_2 removal efficiency, that means, the ten units of FBC is advantagrous to one unit of FGD, even if the efficiency of FBC might be only 30 %. However, this logic should be carefully proven by the correct cost estimation including the operational cost, and the required level of SO_2 removal efficiency in the future for a long term.

Another solution for SO_2 emission is fuel switching. The current situation of coal consumption is 80 % from domestic coal and 20 % from imported coal. The domestic coal includes lignite and hard coal with a high sulfur content. The long term policy for SO_2 control is not yet fixed. One way is to increase the share of nuclear power stations. Recently one nuclear power station started commercial operation and it supplies about 40 % of total electricity demand. Another path is to shift from domestic coal with a high sulfur content to imported coal of a low sulfur content. However, the problem of unemployment in the domestic coal mines have to be carefully considered in this case.

The third way is to apply the process to reduce the SO_2 emission. One process for this way is the FBC, and another is the natural gas-fired combined cycle. One unit of 150 MW by combined cycle is now in operation in Hungary.

(4)NO_x control

The sectorial proportion of NO_x emission in Hungary is as follows.

Trafic	30 %
Power stations	65 %
Fertilizer plants	5 %

As the countermeasures for the NO_x control, only the three-way catalyst for vehicles is now under consideration. The concrete planning to improve NOx emission from stationary sources is not yet prepared.

The priority of air quality control in Hungary is in the following order, that is, 1) Dust and particulate control 2) SO_2 control 3) NO_x control (4) CO_2 control)

1-2 The Ministry for Environment and Reagional Policy

Date : Nov. 20, 1991 8:00-9:00
Interviewed counterpart : Mr. Robert Rakics. Head of Dept. for Air Pollution Abatement
Dr. Zsuzsanna Ivanyi
Coordinator : Endre T. Balazs. UNIDO Consultant

(1)Organization and responsibilities

The Ministry for Environment and Reagional Policy is responsible for the quality of air, water, soil and nature protection. However, the Ministry is not responsible for emissions from traffic, and its responsibility for water and soil quality is limited.
The main function of the Ministry is to prepare regulations based on the background data and adjustment in accordance with other ministries.
Monitoring is one of the important activities of this ministry.

(2)Environmental state in Hungary

•General view
The emission of air polluting materials for the past 10 years is as follows. (Unit: kilotons/year)

	1980	1985	1986	1987	1988	1989
Particulates	576.6	491.6	463.6	433.6	407.8	343.0
SO_2	1632.8	1403.6	1370.1	1291.9	1218.0	1084.0
NO_x	272.9	262.2	268.6	276.0	258.3	249.0

The sectorial contribution to the emission in 1989 is as follows. (Unit: kilotons/year)

	SO_2	NO_x	Particulates
Power stations	436.4	49.6	39.2
Industry	316.4	45.5	187.1
Agriculture, forestry	23.8	7.7	7.0
Trafic, transport	16.5	116.1	11.8
Population	249.7	19.9	86.0
Services	27.9	6.8	10.6
Heat supply**	13.3	3.4	1.3
Total	1084.0	249.0	343.0

(Note) **: excluding the heat supply by Hungarian Electricity Board

The ambient standard is as follows. Japanese standard is shown for comparison.

	Standard of Hungary		Standard of Japan
SO_2(24 hr value)	150 $\mu g/m^3$	(0.0525 ppm)	0.04 ppm
(year value)	70 $\mu g/m^3$	(0.0245 ppm)	
CO (24 hr value)	5,000 $\mu g/m^3$	(4.00 ppm)	10 ppm
(year value)	2,000 $\mu g/m^3$	(1.60 ppm)	
SS (24 hr value)	100 $\mu g/m^3$		100 $\mu g/m^3$
(year value)	50 $\mu g/m^3$		
NO_x(24 hr value)	150 $\mu g/m^3$	(0.076ppm as NO_2)	0.04-0.06 ppm
(year value)	100 $\mu g/m^3$	(0.051ppm as NO_2)	as NO_2
NO_2(24 hr value)	85 $\mu g/m^3$	(0.043 ppm)	
(year value)	70 $\mu g/m^3$	(0.038 ppm)	
Lead(24 hr value)	0.3 mg/m^3		0.1 mg/m^3

The ambient standards of Hungary are almost the same level as Japanese and West-European standards. However, according to the information of the Ministry for Environment and Reagional Policy, the standards are not fulfilled in many districts, especially in Buda-Pest area and industial areas.

•Air pollution from transportation

There are two million cars in Hungary, 30 to 40 % of which are equipped with two-stroke engines. The proportion of lead-free gasoline is only 5 %, but it is increasing rapidly.
In order to abate the air pollution by vehicles, the following policies and programs are going on or to be put into practice in the near future.

- Introduction of annual compulsory environmental protection tests on motor vehicles
- Gradual replacement of the vehicles with two-stroke engines by those with four-stroke engines by incentive measures for Customs Duties
- Reduction of lead content of petrol
- Mounting of lead filters

•Air pollution from industries

The emission standard for stationary sources does not exist, but is under preparation for incinerators and power stations.

If a particular power station or plant emits more than the allowable quantity of pollutants, which is calculated by the ambient standard value and background level, a fine is imposed to the polluter. The power station or plant emitting more than the allowable amount of pollutants must pay an amount of money to the local government. Such money is eventually sent to the Ministry, and anually amounts to around 1 billion or 12 million US$.

1-3 Dunaferr Steelworks Co. Ltd.

Date	:	Nov. 20. 1991 13:30 - 16:30
Interviewed counterpart	:	Peter Sandor. Chief Engineer for Engineering and Environmrnt Protection
Coordinator	:	Endre T. Balazs. UNIDO consultant

(1) Outline of Dunaferr

Dunaferr is a sort of independent concern holding the stocks of 40 plants. and the major stockholder for 21 plants out of 40.
There are three steel plants in Hungary. but one is out of operation and the other is operated with a half load. The current total production capacity in Hungary is 3.5 million tons per year but the actual production in 1990 was 2 million tons.
Dunaferr Steel Works is the only one integrated steel works in Hungary. providing the following facilities.

Faciliities	Production capacity
Coke oven	1.0 million tons/year
Sintering plant	1.2 million tons/year
Ironmaking	1.0 million tons/year
Steelmaking	1.3 million tons/year
Hot rolling	1.1 million tons/year
Cold roiling	350.000 tons/year

The number of employees is about 6.000.
The total production of Dunaferr Steel Works amounts to 32 billion Ft or 400 million US$. More than 50 % of products are exported.
Dunaferr Steel Works has 6 units of power plants. The unit size is 5 to 20 MW and the total capacity is 60 MW for electricity generation and 750 MW for heat generation. A large part of generated steam is supplied to paper plants. Various kinds of fuel are used for the power plants. The total fuel consumption in the power plants amounts to 10 x 10^6 GJ. 40 % of which is supplied by the top gas such as coke oven gas and blast furnace gas. The other part is supplied by natural gas and fuel oil.

(2)The state of environmental control

There are as many as 130 air polluting sources in the steel works. The regulated pollutants are SO2, NOx, dust and CO. The actual emission and regulation values are shown below.

	Actual state	Regulation	Fines(1US$=80Ft)
SO_2			
Limestone calcining	24 ton/year	4.1 ton/year	
Dolomite calcining	33	4.8	
Power station No.1	1,033(oil-fired)	322	
No.2	2,051(oil-fired)	364	
No.3	1,059(oil-fired)	356	
Others	1,485	1,097	
Total	5,682		$3.5x10^6$ Ft/y
NO_2			
S-M Furnace No.1	409 ton/year	136 ton/year	
No.2	442	147	
No.3	416	138	
Limestone calcining	478	1.3(due to short stacks)	
Power station No.1	197	84	
No.2	453	95	
No.3	443	93	
Others	1,239	311	
Total	3,602		$7.0x10^6$ Ft/y
Dust			
Sintering plants	23,000 ton/year		
Others	5,000		
Total	28,000		$165x10^6$ Ft/y

(3)Emission of SO_2 and NO_x

Neither SO_2 nor NO_x is monitored in the steel plants. Only O_2 concentration is monitored continuously.

SO_2 concentration in the flue gas depends on the kind of fuel used in the power station. The sulfur content in the gaseous fuel (coke oven gas, blast funace gas, natural gas) is as small as 1 to 3 mg/m^3N-fuel gas, which does not present any major problems. On the other hand, the sulfur content of the heavy oil is as high as 3 %. This is equivalent to the SO_2 concentration of around 4,300 $mg\text{-}SO_2/m^3N$ or 1,500 ppm in the flue gas. The heavy oil is used mostly in the winter season the total quantity amounting to 70,000 ton/year. This value is about 60 % of the total consumption of natural gas ($120x10^6m^3$/year) on the heat value base.

As for the NO_x control for the power plants, no particuler countermeasures have been taken. However, the actual NO_x concentration is low due to the new type burners(not what is called low-NO_x burner) and partly due to the utilization of low heat value fuel as blast furnace gas.
Some measured data of NO_x concentration in the flue gas are shown below.

Power station		
BFG	55 ppm	(Note) BFG:Blast Furnace Gas
NG	145 ppm	COG:Coke Oven Gas
NG + COG	95 ppm	NG :Natural Gas
NG + COG + BFG	95 ppm	
NG + Heavy Oil	130 ppm	
Sintering plant		
Exhaust gas from the belt	52 ppm	
Cupolar furnace	12 ppm	
Limestone calcining		
Rotary kiln flue gas(NG)	320 ppm	
Reheating furnace		
COG	223 ppm (526 ppm for O_2=3 %)	
NG	190 ppm (422 ppm for O_2=3 %)	

The concentration of NO_x should always be referred to O_2 concentration, but the data of O_2 to be refered are not available except for those of reheating furnaces.

(3)Strategy and future plan

Efforts to improve the environmental conditions have been made focusing mainly on dust management. The improvement achieved so far is summarized as follows.

-The fuel used in the power stations has been switched from coal to gas and oil. Owing to this fuel switching, the dust emission is reduced as much as 30,000 ton/year. However, the emission of SO_2 and NO_x has not changed significantly.

-Siemens-Martin furnaces were equipped with electric precipitators. But these furnaces have just been discontinued. Since 1980, two 130 ton LD convertors of burning type have been installed.

-New coking plants are installed in 1986. It is equipped with 5 units of coke dry quenching system. The dust is removed by electric precipitators in addition to wet scrubbers.

The future plans of Dunaferr associated with the improvement of environmental control are as follows.

1)Modification of sintering plants
With the budjet of 2 billion Ft(25 million US$) the modification of sintering plants is scheduled in 1992. Current sintering plants are operated without electric precipitators.

2)Installation of secondary dust extraction systems for LD convertors
The convertors are not equipped with the secondary dust exraction system and a large amount of dust is emitted into the atmosphere at the charging of molten metal and scraps into the convertor. The investment cost for this system is estimated at 6 million US$.

3)Dust control for hot iron discharging from blast furnaces

4)Control of NO_x from reheating furnaces

According to the engineer responsible for environment control of Dunaferr, the priority is to be described in the following order.

1- Dust including solid waste treatment
2- CO
3- SO_2
4- NO_x

1-4 Thermal Power Station of Ajka

Date	: Nov. 21, 1991 14:00 - 18:00
Interviewed counterpart	: Mrs. Bercy Palne, Superintendent
	Mr. Nemeth Frigyes, Deputy superintendent
	Mr. Mate Imre, Technical Consultant
Attendant	: Mr. Geza Szeremi, Department of Energy,
	Ministry of Industry and Trade

(1) Development of Hybrid-Fluid Firing System

A unique and simple technology called hybrid-fluid firing system (HFF) has been developepd by the co-operation of the Institute for Electrical Power Research and Power Station of Ajka. This system consists of a combination of fluidized bed combustion(FBC) and pulverized coal firing. The development of the firing equipment was conducted at Tatabanya No. 1 Thermal Power Station, on the No. 1 boilor with a capacity of 45 t/h. Based on its confirmed excellant features, the second application was put into practice in 1990 at Aika Power Station, No. 12 boilor with a steam capacity of 100 ton/h, which had originally been fired by pulverized coal. Besides, No. 11 boilor of Aika Power Station also was modified to HFF system and put into operation in 1991. Furthermore, the modification of NO. 10 and No. 9 boilers is scheduled in 1992, and No. 8 boiler in 1993.

Boilors of 100 ton/h capacity at Ajka Power Station are of natural circulation type with two draft, without reheater, with membrane construction and Ljungstrom type regenerative air preheater. The original pulverized coal firing is characterized by ventillator mills and tangentially firing corner burners. Fly-ash removal is performed by means of wash away, and dust separation is carried out with an electric precipitator.

The main data of No. 11 and No. 12 boilor and the coal used at Aika Power Station are shown below.

Boilor No. 11 and No. 12

Steam generation capacity	100 ton/h
Steam pressure	72.5 bar
Steam temperature	500 C
Feed water temperature	190 C
Air temperature at economizer outlet	310 C
Flue gas temperature	160 C

Coal Quality

Calolific value	8 - 10 MJ/kg
Water content	18 - 22 %
Ash content	35 %
Sulfur content	3.2 - 4.0 %
CaO content in ash	30 - 40 %

The basic concept of the HFF system is to introduce the fluidized bed combustion to the existing boilor with the minimum modification. aiming at a drastic lowering of temperature and a more homogeneous heating load in the combustion chamber. The steam generating capacity can be kept at the same value as the original. though the mambrane wall is not changed.

The outline of the HFF system at Ajka Power Station is as follows.

The air distributor of fluidized firing is located at the bottom of the furnace. The air distributor is made of a membrane wall. which is connected to the circulation system of the boiler.

Three separated air boxes are provided under the distributor. The fluidization rate of the middle main layer is controlled at twice that for the outer layers.

The fluidization air is preheated at 310 C and supplied to the air boxes by means of a separate ventillator. The air pressure before the air boxes (after the booster fan) is 7.000 to 8.000 Pascal.

Primary and secondary air of the pulverized coal injectors will be supplied by the original forced draft fan.

Two of the original coal grinding mills operate without a separator. and feed the fluidized layers with their rough grist.

The two other mills with separators are connected to the pulverized coal burners.

The excess layer material enters the water sealed ash scraper through the discharge pipes arranged in the main layer.

The layer temperature. layer mass. boilor load and excess air are controlled at the specified values by electronic control devices.

(2) Effect of HFF system in Ajka Power Station

The steam generation capacity after modification is the same as the original of 100 ton/h. The maximum capacity with the fluidized firing is only 90 ton/h.

The temperature of the combustion chamber is 780 to 910 C. The oxygen concentation in the flue gas is 7 to 8 % under the normal conditions.

Only 1 to 2 % of total ash is taken off as fly ash in the flue gas.

The combustible part of the ash is reduced from 10-12 % to 0.3-1.0 % by means of fluidizing bed combustion and the recirculation of fly ash.

The dust removal efficiency of the Lurgi's electro-static precipitator(ESP) has increased after modification.
No additives such as limestone powder are used in Aika, but the SO_2 emission and NO_x generation is significantly improved as shown in the figures.
Typical data of improvement are as follows.

	SO_2(mg/m^3N)	NO_x(mg/m^3N) as O_2=6%
before modification(without FBC)	6.000 - 8.000	800 - 1.200
after modifocation(with FBC)	2.000 - 2.500	400 - 500
Allowable value	230 - 240	400

(3)Evaluation of HFF system

The HFF system can greatly reduce the emission of SO_2 and NO_x from the existing boilors with relatively minor retrofitting work as shown below.

- Mounting of the air distributor in the furnace funnel
- Installation of a fluidization ventillator with 8.000-9.000 Pa of delivery head, and modification of air ducts
- Relocation of the pulverized coal injection points, connection of the pulverized coal ducts and dismounting of the separator in case of two mills
- Completion of membrane walls
- Extention of boiler control by regulation circuits for the layer temperature, layer mass and excess air.

The required duration of boiler stoppage for retrofitting is only 3 months.
The operation cost of HFF system is the same or a little bit better than the conventional boiler due to the improvement of boilor efficiency.
The investment cost is estimated at about 75 million Ft. or 0.9 million US$ for one boiler. The specific cost of retrofit from pulverized coal fired unit to HFF is estimated at 22.000 US$/$MW_{th}$ and 40 US$/$SO_2$-ton.
The HFF system with a unique invention of air injecting nozzle (Hungarian patent No.4645/86) is highly evaluated in the world. Ascea Brown-Boveri has bought this technique and the agreement has just been signed.

(4)Future problems

As mentioned above, the emission of NO_x can be reduced to the allowable value applying the HFF system. However, the emission of SO_2 emission is still far from the allowable level. In order to reach the allowable value, 90 % of SO_2 removal for the flue gas from

the HFF system is necessary.
The dolomite injection is being planned to further reduce the SO_2 emission, but it is difficult to reach the allowable level by this method. A flue gas desulfurization system such as wet scrubbing seems to be the most effective method.

2. Czechoslovakia

2-1 Poldi Steel Plants

Date : Nov. 25. 1991 9:00 - 14:00
Interviewd counterparts : Mr. Vaclav Hromadka. Strategy Planning
Mr. Lubomir Ludvik. Investment Project
Mr. Peter Dembinny. Manager of Technical Development
Mr. Peter Koldinsky
Coordinator : Mr. Morp Fiala. UNIDO-Czechoslovakia Joint Programme

(1)Outline of Poldi

Poldi United Steel Factory consists of following 5 divisions.

- Division of steel plant DRIN (new steel plant)
- Division of steel plant POLDI (old steel plant)
- Division of mechanics
- Division of energy supply (power station)
- Division of services

The total steel production of Czechoslovakia is 15.4 million ton per year(4 million ton for direct export and 6 million ton for indirect export). This value corresponds to 1 ton/person.year and is too large from the view point of desirable industrial structure for Czechoslovakia in the future. Therefore, a national plan to scale down the steel industry is going on, aiming to reach 8 million ton/year of production rate in five to six years. Poldi is also integrated in this scale-down and modernization programme. As a matter of fact, the number of employee has been drastically reduced from 21.000 in 1990 to 15.000 in 1991.

Poldi has been oriented to the production of special steel. The annual production scale is about 1 million tons, and rolled products share 80 % of the total production. Total sales coresponding to 1 million tons of steel amounts to 8.5 billion Krn.

Steel Plant No. 1, of Old Poldi has 2 electric arc furnaces(EAFs) of 30 ton and 1 vacuum oxygen decarbonization equipment. No. 2 EAF was constructed in 1970, and No. 1 in 1980.

Steel Plant No. 2 has 3 EAFs of 40 ton constructed in 1956. Since a ladle furnace of 40 tons was provided in 1986, these EAFs have been used mainly for the smelting and oxidation process. T e reduction is carried out mainly in the ladle furnace. Steel Plant No. 2 is equipped with 1 high-frequency induction furnace of 6 tons, 1 DH process and continuous casting machines of 3 strands for 220 x 300 section. The

production capacity of continuous casting is 30.000 tons/year.
Steel Plant DRIN, called New Plant, started operation in 1975.
This steel plant was constructed after the Russian style of spacial layout. This plant has 2 EAFs of 100 tons, 1 degasing device and 1 continuous casting machine(CC). One ladle furnace is under construction. CC machine was constructed by a Czech supplier under the license of Demag.
Siemens Martin furnaces in New Plant are no longer operated.
One of the EAFs is furnished with water cooled panels. The tap to tap time of this furnace is 3 hours and 30 minutes, much quickerthan the 4 hours and 30 minutes without water cooled panels. However, even with water cooled panels, the tap-to-tap time is very long compared with that of advanced EAF applying Ultra-High-Power furnace(UHP) and ladle furnace operation.

(2)Business plan for modernization

Poldi United Steel Factory was scheduled for privatization by the end of 1991. As a first stage, all the stock is to be held by the Government, but in the future the stock shall be shared by banks, other enterprises and foreign parties in addition to the Government.
The business plan for modernization has just been completed.
According to it, 35 to 40 % of total investment is for environmental protection, in order to meet the new law to be enacted in the near future.
One of the most important items of the business plan associated with environmental control is the reconstruction of two 100 ton EAFs in New Plant to one UHP furnace of 115 ton furnished with a dog house.
By this modification, productivity is expected to increase from 390.000 tons/year to 540.000 tons/year. The total cost for this modification is estimated at 450 million Krn (11 to 12 million DM) including the cost of dog house of 175 million Krn. The contract for this modification project was signed with Demag in 1990, but it is still pending.

(3)Environmental control

The most serious problems concerning the environmental control in the steel plants is solid waste disposal and dust emission. The emission of CO, SO_2 and NO_x is of minor importance. All items of hazardous materials have been regulated so far by the old law. The total amount of fines which the steel plants had to pay in 1990 for non accordance with the regulations was 3 million Krn. However, the total fine is expected to reach as much as 300 million Krn under the new regulations enacted in 1991. The larger part concerns the storage of solid waste

and dust, especially contaminated with heavy metals and radio activity. Such materials have to be treated before being dumped in old mines.
All the existing electric arc furnaces are provided with direct dust extracting systems. However, they have no indirect dust extracting equipment such as canopy hoods. Some of the direct dust extracting systems do not operate effectively due to a clogging problem at the gas cooler.
The emission of SO_2 from steel plants is negligible because the reheating furnaces use natural gas, and the Siemens-Martin furnaces operated with high sulfur oil have been discontinued. During the decarbonization process the emission of CO must take place, but neither the quantity nor the concentration has been measured.
Other air polluting materials such as SO_2, NOx have also not been measured in the steel plant nor so far reported to the authority.

2-2 Poldi Energy Plants

Date	:	Nov. 26. 1991 9:30 - 14:00
Interviewed counterparts	:	Mr. Ludek Spacek. Director for Energy Division
		Mr. Jiri Bartos. Manager for Production
Cordinator	:	Mr. Miro Fiala. UNIDO Czechoslovakia Joint Programme

(1)Outline of energy stations

The energy division of Poldi produces 600 ton/hr of steam and supplies it to the industries and towns heating network outside as well as to the steel plants in addition for use in electricity generation. The number and capacity of boilors in the energy station are as follows.

Number of boilers	Steam generating capacity	Steam pressure	Fuel
2	120 ton/hr	90 bar	coal
1	240 ton/hr	120 bar	coal
2	50 ton/hr		heavy oil
3	50 ton/hr		coal

Two electricity generating units of 28 MW each are provided in the energy station. The maximum electricity production capacity is 300 GWh/year and average is 200 GWh/year. About 30 % of total steam generated is used for electricity production.

(2) Environmental control

The main fuel is the coal of 0.6 % sulfur. Each boilor is furnished with an electro-static precipitator(ESP). The dust removal efficiency of ESP is about 97 %.

The total emission of pollutants from the stacks is as follows.

SO_2	4.650 ton/year
NO_x	3.464 ton/year
Fly ash	1.222 ton/year

The most important problem is the solid disposal. The specific cost of solid disposal is 1.600 CKs/ton. The amount of total fly ash collected by ESPs is as much as 100.000 tons/year. That means, the cost of fly ash disposal amounts to 160 million CKs/year. The fly ash generated from the energy station is disposedof in empty mines. However, such a system of fly ash management is permitted only untill the end of 1995. That means this problem must be solved by 1995, with

the introduction of some alternatives.
In order to solve this problem drastically, a project to switch the fuel from coal to gas is under consideration. This project has the possibility of sloving the problem of SO_2 and NO_x emission as well as the fly ash disposal at the same time. The outline of this project is introduced below.

(3)Fuel switching project
A national project for coal gasification is going on in Czechoslovakia. According to the project, coal gasification is realized by injecting steam of a high pressure and high temperature into coal layers. The site of gasification is the coal mining area about 600 Km from the Prague.
The coal layers are as wide as 500 x 150 Km and about 20,000 holes in total are provided for injecting the steam. The production of gas is expected to be as much as 10^9 m^3/year. The heat value of the gas is about 6,000 Kcal/m^3N. This gas is tranported from the site to the Prague industrial area by pipelines. This project is 100 % financed by the United States via a joint venture between the Czechoslovak Government and the American campany CenGaz. From 1992, the newly exploited gas will be available in Poldi.
On the other hand, the boilers of 129 tons/h and 240 tons/h in the energy station were originally constructed as blast furnaces gas-firing, and then modified to coal-firing. Therefore, it is quite easy to revert to gas-firing. According to the estimation made by Poldi, this would cost 500 million CKs, or 17 million US$.
In the event of retrofitting the original coal-fired boilers, it is estimated at 40 million US$.
Accordingly, if the retrofitting is realized, the saving of waste disposal cost for 4 years corresponds to the investment cost for the retrofitting.
Besides, all the problems of dust, SO_2 and NO_x emission are solved at the same time.
This project of boiler modification from current coal-firing to gas-firing is one of the UNIDO programmes. The business plan of the project has been prepared and a donar needs to be identified.

3. Poland

3-1 Elektrownia Jaworzno III

Date	:	Nov. 28, 1991 9:30 - 15:00
Interviewed counterparts	:	Mr. Joachim Adamczyk, Deputy Director for Technology
		Mr. Stanislaw Gebala, Manager for Maintenance
		Mr. Janusz Wojcik, Manager for Environment
Coordinator	:	Mrs. Maria Berezowska, Project Focal Point

(1)Outline of power station

Power Station Elektrownia Jaworzno III started operation in 1977 to 1978. This power station has 6 units of 200 MW boiler-turbine-generator set. The boilers were cunstructed by a polish manufacturer, RAFAKO, and the electric precipitators by ELWO-PSZCZYNA. The boilers are of natural circulation type, each having a capacity of 650 tons/h x 13.8 MPa at the turbine inlet and 15.4 MPa at the drain separator.

The fuel used in this power station is hard coal from several domestic mines.

The quality of the coal designed and actually used is as follows.

	Designed quality	Average quality used
Ash content	30 % (Max. 40%)	23 %
Sulfur content	up to 3.0 %	1.4 % (3,000-4,000mg/m^3N)
H_2O content		15 - 16 %
Heat value		17,500 KJ/Kg

The main design and operation of one unit are as follows.

	Design	Operation
Fuel flow	120 ton/h	Ave. 102 ton/h in 1990
Boilor efficiency	89.03 %	Max. record:90.5 %
Thermal efficiency	34 %(at 100% load)	
Flue gas flow	800,000 m^3N/h	
Flue gas temp.	150 C before electric precipitator	

The total consumption of coal and generation of electricity for 6 units of this power station in 1990 were 3,800,000 ton and 6,500,000 MWh respectively.

The fly ash concentrations in the flue gas is 1 to 3 Kg/m^3N before the electro-static precipitators(ESPs). 98.5 to 99.5 % of fly ash is

removed by the ESPs. The dust removal efficiency changes according to coal type as well as the electrode renewal. 99.5 % of removal efficiency is the best state and corresponds to 100 to 500 mg/m^3N of dust concentration after the ESPs.
One continuous monitoring system is now being tested at one power unit. This monitoring system was provided by the German branch of Westing-House with American consulting.

(2)Regulation

In 1988 regulation standards were established by the local Government. but they were very easy to meet. In 1990 more stringent standards were introduced by the national Government. In 1992 local standards are expected to be leveled up to the national standards.
The actual regulation data applied to this power station are as follows.

	Standards in 1988 (effective up to the end of 1991)	Future standards (effective from 1992)
Dust	500 Kg/h. unit	290 Kg/h. unit
SO_2	6.400	2.800
NO_x	1.350	700
CO	135	
H-C	27	
Floride	20	

By calculating the future standards based on the flue gas volume of 800.000 m^3N/h at 150 C for one unit. the following concentration standards are obtained.

Dust	363 mg/m^3N
SO_2	1.225 ppm
NO_x	426 ppm (as NO_2)

These values are still very large compared with the regulation standards in developed countries.

In Poland every polluter must pay environmental fees for the emission of pollutants. Fees for dust. SO_2 and NO_x account for 99.5 % of all fees paied.
The fees for these three main items are as follows.

Dust:	0.03 US$/Kg-dust
SO_2 :	0.10 US$/Kg-$SO_2$
NO_x :	0.03 US$/Kg-$NO_x$

The total annual payment of the fees amounts to as much as 20 million US$ in this power station.

(3)Strategy for future regulation

According to the prognosis of the engineers of the power station. 2,000 Kg/h.unit of SO_2 emission can be managed by fuel switching from higher to lower sulfur coal. By changing the mixing ratio of the coal, it is possible to reach 1.1 % of sulfur content. In order to realize this, however, more expensive coal must be purchased and some coal supplies must be changed from local mines to other domestic ones far from the power station. For example, the price difference between high and low sulfur coal is as follows.

Sulfur content	Coal price at the power station
2.0 %	140.000 Zl/ton (13 US$)
1.0 %	200.000 Zl/ton (18 US$)

In addition to the additionl cost for lower sulfur coal, the impact of switching coal supplies to the local economy should be taken into account. In order to cope with future regulations and to establish a long-term strategy for environmental control, the following three courses of action have been considered in this power station.

1) Coal desulfurization on mining sites
+ Semi-dry FGD of 50 to 60 % SO_2 removal efficiency for 6 units

2) Coal desulfurization on mining sites +
Wet FGD of more than 90 % SO_2 removal efficiency for 4 units out of 6 units

3) Wet FGD of more than 90 % SO_2 removal efficiency for 6 units

The Ministry of Trade and Industry(MITI) in Poland is responsible for both the electricity supply and coal mining. The possibility of coal pre-treatment to reduce the sulfur and ash content has been investigated under the leadership of MITI, but it has been proved that the price of pre-treated coal will be 100 % higher than that of untreated coal, but the coal pre-treatment is not as successful as expected. Considering the prospect of coal pre-treatment, the people of Elektrownia Jaworzno III made a decision to take action No. 2), that is, to construct wet FGD systems for 4 units out of 6 units. This decision seems to be the best and most flexibile. According to the engineers of the power station, the construction of the first FGD plant is scheduled to start at the end of 1992. The supplier of the FGD plants is the joint venture of RAFACO and Steinmeuller.

(4)Desirable assistance

According to the responsible engineer of the power station, the most desirable and useful assistance by international organizations to execute the FGD project is practical training at a power station provided with FGD plants. The engineers of power stations in Poland have no experience in planning, construction and operation of FGD plants. They can obtain some information on such FGD plants from suppliers, but they are not capable of evaluating and proving such information based on their own knowledge and experience. They are afraid that information delivered by suppliers is sometimes not user-oriented. What they hope for most is to have a chance to see and to experience the actual FGD plant themselves. It would be appreciated if some international and neutral organization such as UNIDO could arrange a training course for FGD practice at a power station independent from any FGD suppliers. There are about 6 power stations in Poland which burn hard coal and are interested in wet FGD systems.

3-2 Katowice Steel Works

Date : 29 NOv.,1991 10:00 -13:30

Interviewed counterparts : Mr. Andrej Pawlas, Chief of Environmental protection

Coordinator : Mrs. Maria Berezowska, Project Focal Point

(1)Outline of Katowice Steel Works

Katowice Steel Works are the newest, the second largest state-owned, integrated steel works in Poland. Their steel production accounts for 4.5 million tons/year out of 11 to 12 million tons/year of total production in Poland.

The construction of Katowice Steel Works started in 1972 and the first production started in 1976. The main facilities of the steel works are as follows.

Facilities	Number	Capacity, etc.
Sintering machine	3	Belt area : 312 m^2 each
Coking plant	2	One is 18 km away. The other is near.
Blast furnace	3	3,200 m^3 without TRT
BOF	2	300 ton each
CC machine	0	
Soaking funace		
Reheating furnace		Frence production
Energy plant		
Boiler	5	230 tons/h each
	2	430 tons/h
Turbine-generator	4	80 MW in total

The basic oxygen furnaces are equipped with heat recovery system of combustion type. The modification project from heat recovery to gas recovery system using the technology of Lurgi-Mitsubishi is underway and gas tanks for the recovered gas are under construction.

About half the total demand of electricity in the steel works can be supplied by the power plant in the steel works. The large part of steam generated in the energy station is used for the direct drive of machines, heating and processing of products.

The fuel used in the energy station is mostly coal, and partly blast-furnace gas.

(2)State of environmental protection

The most serious environmental problem in the steel works is the emission of dust, SO_2 and NO_x from the sintering machines. The local standards applied to the sintering machines are as follows.

Dust : 225 Kg/h

SO_2 : 400 Kg/h

NO_x : 180 Kg/h

The present state of emission is in general about 50 % in average over the level of standards. The gas flow rate and the concentration of pollutants are as follows.

Gas flow rate : 6,000,000 m^3/h in total

2,000,000 m^3/h as continuous flow in average

One machine is in operation for one week out of three weeks.

Dust : 150 - 600 mg/m^3 after ESP

SO_2 : 300 - 800 mg/m^3

NO_x : 150 - 200 mg/m^3

Though the most important problem is dust emission, considering environmental protection in the whole steel works, the worst aspect is the emission of SO_2 as far as the sintering plant is concerned. The emission of SO_2 in this case is, of course, affected by the sulfur content of the coal used.

The energy station is provided with a continuous monitoring system for dust and SO_2. The present state of emission from the energy station is as follows.

Dust : 400 -1,000 mg/m^3N after ESP

SO_2 : 500 - 1,400 mg/m^3N

NO_x : 500 mg/m^3N

The performance of the electro-static precipitators(ESP) is as high as 50 mg/m^3N after ESP if the fuel used is only coal. The mixture burning with coal and blast-furnace gas greatly lowers the performance of ESPs, as shown above.

The sulfur content of the coal used in the energy station is 1.0 to 1.2 %. According to the engineer interviewed, the most feasible way to meet the future regulation is to lower the sulfur content of the mixed coal down to 0.4 % by switching coal supplies. The coal price related to the sulfur content is as follows.

Sulfur content	Coal price
1.0 - 1.2 %	45 US$/ton
0.4 %	55 US$/ton

(Note) Transportation cost is not included in the coal price.

(3)Strategy for SO_2 and NO_x control

The price difference between the high and low sulfur coal would provide a valid reason adopting an FGD plant. The feasibility study of FGD in comparison with the direction of fuel switching to lower sulfur coal is very useful in establishing a long-term strategy for SO_2 control, but is not yet completed nor tried out due to the lack of sufficient information on data and methodology.

The feasibility study for NO_x control also should be made based on the newest information on applicable technologies and local costs, even if the priority of NO_x control might be currently low.

4. Summary of plant visits

The results of plant surveys in Hungary, Czechoslovakia and Poland is summarized as follows.

- The state of environmental management is not satisfactory in general and the emission of pollutants is over the regulation standards applied.
- The priority of emission control to be established varies between power stations and steel works.
- The most important problem in steel works is the management of dust and solids disposal. The control of SO_2 and NO_x is of minor importance except in sintering plants.
- The first priority in power stations is SO_2 control, though the dust and NO_x control is also important.
- The strategy for SO_2 control differs from plant to plant and from country to country, affected by various factors such as energy policy of governments, applicable local conditions and financial situations.
- Programs and projects for NO_x control from stationary sources have not yet been initiated.

5. Status of Available Technologies

5-1 SO_2 control technology

(1)General review

The development of SO_2 control technology started firstly in the United States in the 1960's. This technology is what is called the first generation flue gas desulfurization(FGD), based on the wet scrubbing with lime or limestone slurry. This first generation FGD technology was then greatly improved in Japan in the 1970's and in Germany in the 1980's.

In the meantime, what is called second generation FGD technology is now available in the United States in compliance with the New Clean Air Act. On the other hand, various technologies apart from wet scrubbing FGD have been developed. It is not easy to investigate all the technologies for SO_2 control developed so far. The best way to survey up-to-date technologies is to review the results of the SO_2 Control Symposium held in December, 1991 in Washinton DC, USA.

In the symposium, about 600 participants attended and more than 100 papers were presented or submitted. The rough classification of the papers is as follows.

Theme and oject of papers		Quantity
General view, prospect		5
Strategy, economic evaluation, information service		9
Wet FGD		
Wet FGD design improvement	--- software	4
	hardware	11
Wet FGD full scale operation		13
Additives to wet scrubbing		10
Reagent selection		4
Dry FGD		22
Furnace solvent injection		8
Regenerable process		6
SO_2/NO_x simultaneous removal	--- dry process	10
	wet process	2
Monitoring		2
Burning		1
By-product utilization		7
	Total	112

(2)Economic evaluations of FGD processes

According to the technical and economic evaluations recently made by United Engineers & Constructions Inc. under the sponsorship of Electric Power Research Institute(EPRI), costs for major categories of 28 FGD processes evaluated can be summarized as follows. For retrofit FGD installations, the range of capital requirement and total costs levelled out over 15 years of service life with no inflation(constant dollar analysis) are estimated to be:

	1990 US Dollars	
	Capital(US$/Kw)	US$/ton SO2(Constant US$)
Wet FGD	180 - 260	460 - 620
Sulfur Recovery FGD	250 - 380	640 - 820
Dry FGD	50 - 220	410 - 1.470

The technical and economic criteria used for the evaluations are as follows.

Technical	Economic
Single 300 MW unit	Maintenance Factors=1.5-10% of Total Cost
Design Coal: 2.6 % S Appalachian	Electric Power in Plant = 50 mills/Kwh
	Operating labour = US$ 20/hr
2-year construction period	Lime = US$ 55/ton(delivered)
65 % plant capacity factor (base loaded)	Limestone = US$ 15/ton(delivered)
	DBA = US$ 369/ton
Moderate retrofit difficulty (1.3 retrofit factor)	Dry solid disposal(trucked to landfill) = US$ 8.00/ton(unlined)
90% SO_2 removal except 80% for LIFAC, 50-60% for dry injection	Sludge disposal(trucked to landfill) = US$ 8.15/dry ton(unlined)
Two operating absorber modules plus one spare	Sludge disposal to pond=US$ 6.00/dry ton
	Gypsum disposal(pumped and stacked) = US$ 4.75/dry ton
Particulate removal equipment or upgrade is not included (except PJFF in HYPAS)	Gypsum by-product credit = US$ 2.00/ton
	Sulfur by-product credit = US$ 90/Lton
Particulate removal meets NSPS (0.03 lb/MM Btu)	Sulfuric acid by-product credit=US$50/ton
	Steam = US$ 3.5/1000 lb
137 % excesss air at scrubber inlet	
Boiler modifications not included	
ID fan cost allocated on basis of FGD pressure drop	
Stack rebuilding or relining not included	

Among the assumptions shown above, the provision of a spare absorber seems to be over specified considering state-of-the-art second generation wet FGD.

The results of the evaluation indicate that:

- Costs in term of US$/ton of SO_2 removed are very close for many technologies
- The dry injection technologies generally have much lower capital

costs: however. total levelized costs will often be higher due to larger quantities and the higher cost of the reagent required.

(3)State of wet scrubbing technology

The wet scrubbing process using limestone or lime as reagent(Limestone /lime wet scrubbing process) has the longest history and operation experience among FGD processes. The history of improvement and the state of up-to-date technologies is summarized as follows.

Stage of development	years	Features. Development. Improvement
1st generation in USA	1960-1975	Throw-away system. Lime process. η =70-80%. Low availability
Development in Japan	1970-1980	Limestone-gypsum process. η >90%. High availability. Gas-gas heater. Large-scale absorber. Waste water treatment
Development in Germany	1980-1990	η >90%. Simplification. Integration of oxidizer into absorber. Band filter. Pelletting of gypsum
2nd generation in USA	1990-	Limestone-gypsum process. η >90% with high sulfur coal. Additives. Wet stack. Dry-up of waste water

The construction cost of 2nd generation FGD plant is affected. of course. by a number of factors such as gas volume. inlet SO_2 concentration. reagent quality. gypsum handling. water treating. reheating and so on. According to reports in some papers. the investment and operation/maintenance(O&M) cost of wet FGD plant is estimated as follows.

Unit size	Coal sulfur	Eff.	Investment	Variable O&M	Reported by
623 MW	4.1 lb SO_2/MMBtu	95 %	150 US$/Kw	1.0 Mills/Kw	Consolidation Coal Company
300 MW	2.6 %	90 %	124 US$/Kw	2.1 Mills/Kw	EEC & Lurgi. based on EPRI

(Note)-Cost for new stack and reheating is not included.

-Variable O&M consists of reagent. water and power cost.

-Variable O&M 2.1 Mills/Kw includes the cost for solid disposal.

(4)State of dry processes

In the past decade a large number of dry processes have beeen developed. Typical of those processes are the following three.

- Lime spray dryer(LSD)
- Circulating fluid bed(CFB)
- Furnace solbent injection(FSI) with/without reactivation by humidification

The state of technology and cost information is described according to the papers reported at the symposium.

a) Lime spray dryer(LSD)

The application of this process had been limited due to its lower SO_2 removal efficiency with larger Ca/S ratio in addition to the expensive cost of lime. However, it was recently found that the performance can be greatly improved by the existence of chloride in the reagent. If sufficient cloride is not supplied from the coal, the spiking of calcium chloride into the recycled slurry in order to improve the SO_2 removal efficiency is available. Utilizing the enhancement effect of chloride, the application of the LSD process could now be extended to medium and high sulfur coals with an efficiency higher than 90 %.

Since 1987, entensive testing on the effect of the chloride level on the SO_2 and particulates removal efficiency has been conducted by TVA at the Shawnee Test Facilities. Based on the results of testing obtained so far, the expected performance of the chloride enhanced LSD is shown together with that of the conventional LSD process.

	Chloride enhanced LSD	Conventional LSD
SO_2 removal eff.	〉90 %	70 - 80 %
Ca/S stoichiometry	1.3	1.3
Sulfur content of coal applicable	up to 4.0 %	up to 1.5 %
Chloride level in recycling solids	〉1.0 %	

According to the EPRI study, the capital cost for the conventional LSD is reported at 80 US$/Kw for 300 MW, 2.6 % coal, including a new full size ESP. The additional cost for calcium cloride spiking is expected to be small compared with 80 US$/Kw.

The important items to be considered for the application of the chloride enhanced LSD are as follows.

- A close saturation approach such as 10 C is required.
- The particulates loading in the flue gas entering ESP is 10 times higher than the fly-ash-only operation due to the high recycling ratio. This affects the final particulates concentration after ESP.

2) Circulating fluid bed(CFB)

This process. developed by Lurgi. uses a dry reagent and precludes the liqiud phase absorption mechanism used in wet FGD and in lime spray dryer absorbers(LSD). In general. process operation begins with calcium oxide(pebble lime) hydrated on site and injected dry into the flue gas on the cold side of the air preheater. A fluid bed of lime develops in the reactor. providing the contact medium between gaseous sulfur oxide and the hydrated lime. Dry recirculation of material from the downstream particulate collector is used to optimize fresh lime consumption.

Flue gas entering the scrubber is evaporatively cooled to within 25 C of the adiabatic saturation. The cooled gas passes up through the circulating bed of fresh reagent and recirculating material. Abrasion between particles in the fluid bed continuously removes the outer layer of absorption products and exposes the underlying sufaces of unused lime.

The gases are cleaned of dry dust in the downstream particulate collector. As much as 98 % of the material collected is recirculated to the CFB to resupply the bed. This high recirculation ratio keeps unsused calcium in the process for up to 1/2 hour and boosts the performance of capability. Due to the elevated particulate loading as a result of the high recirculation ratio. a new additional ESP is required.

The Lurgi dry desulfurization CFB process has been in commercial operation on five coal-fired utility boilers in Germany since 1987. The SO_2 removal efficiency is more than 90 % with the Ca/S ration of 1.2 to 1.3.

According to the estimation by Lurgi. the capital cost of the CFB process is about 60 % of that for wet FGD. The variable operating cost is almost the same between CFB and wet FGD. but the fixed operating and maintenance(O&M) cost including labour cost for CFB is only 1/4 of that for wet FGD. This is due to the system's simplicity (minimum components) and very low O&M labour requirement.

3) Furnace solvent injection(FSI)

Furnace soivent injection(FSI) is classified into two types. one is the simple FSI without downstream humidificatin and another is the FSI with downstream humidification. The former is represented by the Limestone injection Multistage Burner(LIMB) process with minimal humidification, and the latter is represented by the Limestone Injection into the Furnace and reActivation of Calcium (LIFAC) process.

The FSI without humidification or with a large approach to saturation ensures only poor SO_2 removal effciency. For instance, the test results obtained by the LIMB extention project show 30 % efficiency with 2.0 of Ca/S ratio for the limestone of 100 % under 44μ. Even in the case of commercial lime, the efficiency was about 50 %. Therefore, the FSI process without humidification is not available as the means to comply with the regulation standards, even in East-European countries, though the capital cost is cheap.

LIFAC is a kind of FSI, combined with the post-furnace humidification of the flue gas in a reactivation reactor provided between air heater and ESP. To maximize the effectiveness of the LIFAC system, it is operated at the lowest practical approach to saturation temperature such as 4C. Another step in maximizing effectiveness is the recirculation of ash from the precipitator back through the reactor, thereby giving the sorbent additional opportunities for reaction.

the LIFAC process was developed by Tampella Power Inc. of Finland and several commercial plants are in operation. According to the recent operation results obtained in a lignite-firing power station called Poplar River PS of Saskatchewan Power Inc., Canada, about 60 % of SO_2 removal efficiency is achievable with 2.0 of Ca/S ratio. The removal in the furnace is estimated at about 15 %.

In case of hard coal-fired boilers, the expected efficiency is as high as 70 - 80 % due to the increased use of more humidifying water.

5-2 NO_x control

Various kinds of NO_x control technologies are available as shown below.

- Low NO_x burner
- Two stage combustion
- Flue gas recirculation
- Selective catalitytic reduction(SCR)
- Non-catalytic selective reduction(NSR)
- Steam or water injection
- Fluidized bed combustion
- Simultaneous process for SO_2 and NO_x removal

Among the above-listed technologies, the most effective processes are SCR and NSR from the view point of performance. However, NSR, typically represented by the Exxon process, is difficult to apply due to the very narrow temperature window.

SCR is applied mostly in Japan and Germany. The construction cost of SCR for 80 % NO_x removal is estimated at about 1/4 of wet FGD in Japan. The difficulty in applying the SCR process for retrofitting is finding a sufficient space for reactors between the economizer and the ESP. The supply of liquid NH_3 is another problem in the developing countries.

Fluidized bed combustion is the another effective solution, but it is difficult to apply new or existing boilers of large capacity.

Two-stage combustion and flue gas recirculation require some modifications to the boiler, and these are not very efficient from the view-point of cost-performance.

The effect of water or steam injection into the combustion chamber is minimal. Only 10 to 15 % improvement can be espected.

The low NO_x burner does not require much capital and has a low operating cost, but the effect is not sufficient to lower the NO_x emission to the evel of regulation standards.

Simultaneous removal of SO2 and NO_x are not yet at the stage of commercial application, though an interesting process utilizing pretreated dry absorbent made from fly ash is at the stage of commercial demonstration in Japan.

6. Strategy

6-1 Fuel switching

The best way to solve environmental problems is to switch fuel from coal to natural gas. However, it is not easy to obtain natural gas except for special cases such as Poldi Energy Station in Czecho-slovakia. The fuel switching from high to low sulfur coal is also not easy. There are many factors to be taken into consideration for this strategy.
The most important factor is the price of low sulfur coal. According to the economic evaluations made by United Engineers & Constructors using EPRI's new computer model(FGDCOST), costs in terms of US$/ton of SO2 removed are reported as very close for many technologies. The average cost can be estimated around 500 US$/ton SO_2 for most processes except for sulfur recovery FGD.
On the other hand, there is a price difference between high and low sulfur coals. The FGD cost of 500 US$/ton SO_2 removed is equivalent to the coal price difference of 10 US$ for a sulfur difference of 1 %.
It would be a general tendency that the intensity of price dependence varies according to the range of sulfur content considered. For example, the price difference between 1.2 % and 0.2 % of sulfur content must be larger than that between 2.2 % and 1.2 %. That means, the more stringent the regulation standards, the more posibilities of FGD strategy in relation to the switching of fuel.
According to the price information obtained at the plants visited in Poland, the price dependence on sulfur content is as follows.

Sulfur content	Coal price	Information source
2.0 %	12 US$/ton	Elektrowinia Jaworzno III
0.9 - 1.1 %	17 US$/ton	Elektrowinia Jaworzno III
1.0 - 1.2 %	45 US$/ton	Katowice Steel Works
0.4 %	55 US$/ton	Katowice Steel Works

There is a large difference in the price level between Elektrowinia Jaworzno III and Katowice Steel Works. The reason is not clear.
In the case of Katowice Steel Works, the price difference corresponding to about 0.6 % sulfur difference is 10 US$/ton, which is just the same as the FGD cost estimated for 1.0 % of sulfur difference. That means, FGD is advantageous over fuel switching in this sulfur range.
In order to establish a crrect strategy, more detailed estimation of FGD costs and price dependence on sulfur difference based on local

conditions and long term prospect is indispensable.
In addition to the problem of fuel cost, the following matters should be taken into account for the fuel switching strategy.

- Fuel switching cost
  T e unit performance impacts (such as derates) or the capital cost requirements (such as coal handling, pulverizer, and ESP upgrades) associated with switching to a lower sulfur coal can be substantial and cannot be ignored.
- Uncertainty concerning the low-sulfur coal price premiums
  There is a significant degree of uncertainty regarding the future availabitlity, mining cost, and delivered prices of low-sulfur coal.
- Socio-economic issues
  Fuel switching has a great impact on many local coal mining jobs as well as those jobs that are indirectly supported by the coal industry.

Summerizing the above-mentioned considerations, fuel switching to low-sulfur coals is not recommendable, especially from the view point of flexibility for fuel and plant operation, especialy for larger boilers in the coal dependent countries such as Poland.

6-2 Evaluation of FGD processes

As a strategy for SO_2 management, FGD is superior to fuel switching. Then, the next question is what process should be adopted. In order to select the most appropriate process, many factors should be considered with long-term implications. The main items are as follows.

- SO_2 removal efficiency
  This should be decided taking into account the more stringent regulation standards expected in the future.
- Gas volume to be treated
  In case of partial FGD, all the factors for future extention should be considered.
- Capital cost and O&M cost
- By-product management
  The utilization and disposal of by-product should be considered with a long-term course of action.
- Raw material supply
- Space required for the FGD plant
- Experience the commercial plants
- Reliability, operability and maintenability
- Flexibility for fuel change, increased performance, load variation

and future extension

- Construction period, especially the period of boiler outage required

As for the SO_2 removal efficiency, it should be borne in mind that the higher the sulfur content, the higher the efficiency required. Comparing the efficiency, wet FGD is the best with 95% or more followed by CFB with 90 % or more. The spray dryer can achieve an efficiency of more than 90 % only in the case of sufficient existence of chloride in the absorbent. Moreover, this chloride-enhanced spray dryer is not in the commercial plant stage. The efficiency of LIFAC is not expected to exceed 80 %.

Wet FGD has a possibility of producing the saleable by-product, gypsum, if local conditions are favourable. Even if this is impossible, the disposal of gypsum is relatively easy. The by-product of CFB, which is the mixture of calcium compounds and ash, is disposed of in a land-fill or mine.

The problem of space required for FGD is not insurmountable, because the main stream of existing flue gas line can be connected to aborbers or reactors by long-ducting, if necessary. As far as FGD without furnace sorbent injection is concerned, the boiler outage required for the construction is for a short period for duct connection.

Experiences in commercial plants is very important for evaluating the reliability, operability and maintainability of FGD plants.

The number of wet FGD plants constructed so far and in operation at present is over 2,000 worldwide, including the large-scale FGD such as one absorber for 700 MW. On the other hand, the number of CFB installations is only 5, the largest of which is 100 MW.

Flexibility is one of the most important factors to be considered. Generally, wet FGD has great flexibility to cope with an increased sulfur content in the coal or a requirement of increased efficiency over the original design. In such a case, several measures are independently possible. One is the use of additives such as dibasic acid (DBA), sodium formate or magnesium. The second way is to increase the ratio of liquid-to-gas(L/G), installing the additonal spray headers and recirculation pumps. The third way is to increase the operating pH value. With such measures, it is easy to achieve the required efficiency, even if it would be over 95 %.

Phased installation of FGD plants as well as the gradual-grading-up of efficiency is the practical way to meet step-by-step intensifications of regulation standards, but it is realistic only for the FGD process with high efficiency of over 90 or 95 %.

6-3 Process recommendation for SO_2 control

Summarizing the above-described discussions, the recommendable processes are concluded as follows.
For larger capacity over 100 MW, wet FGD with an efficiency of 90 % or more is the most recommendable. Among wet FGD, the limestone-gypsum process is the best in all the aspects considered.
For smaller capacity under 100 or 150 MW, CFB seems to be the most recomendable. Hybrid-fluid firing(HFF) system developed in Hungary is also recommended as the first stage of SO_2 removable for small boilers firing high sulfur coal.

6-4 Strategy for NO_x control

The priority of NO_x control is low in East-European countries. Differing from the case of SO_2 control, no incentive factor by fuel costs is expected in the case of NO_x control.
On the other hand, NO_x control technologies are generally not mutually exclusive as in the case of SO_2 control. Therefore, parallel and step-by-step application of several technologies is possible, and in many cases, desirable.
The most advanced and recommendable system of NO_x control for large capacity is low NO_x burner + SCR. However, it is too early to apply SCR at present stage. As a first step, low NO_x burners, which require a minimal cost and limited boiler modifications, should be introduced.
The application of two stage burning and flue gas recirculation is not recommendable from the view point of cost-performance.
Fluidized bed combustion or a hybrid-fluid firing(HFF) system is another direction to explore for smaller boilers.

7. Proposal of FGD Workshop

7-1 Necessity of FGD workshop

As mentioned already, truly useful and user-oriented information and know-how on FGD in order to improve evaluation ability and strategy establishment is urgently required in East-European countries, especially in coal-dependent countries such as Poland. Of course, some information on FGD can be obtained using any of the computerized models and data-bases developed mainly in the USA, but what is most effective and really required is basic knowledge for evaluating the FGD processes as well as the ability to plan and execute projects based on western business method.

According to the impression obtained at the plants visited, managers and engineers are not accustomed to the western style of project planning. It would be significant to impart to them the know-how and methods of project planning and engineering.

Based on the above, I would like to propose that UNIDO organize a workshop for FGD as the next step. The preliminary plan for this workshop is as follows.

The workshop should:

- be oriented to the practical knowledge and kow-how necessary for evaluation and planning.
- address the employees of power stations with FGD projects or those who are very interested in FGD.
- include on-site-training and discussion.
- deliver the method of project planning based on business practices and the engineering style of the EC, USA and Japan.
- conduct feasibility studies of SO_2 control for each of the power station to which the participants belong to.

7-2 Preliminary plan of FGD workshop

The outline of the workshop which might be reflected in the project document is as follows.

(1) Participants : 6 to 12 managers or engineers from the power stations having a FGD project or which are interested in FGD

(2) Period : 2 weeks

(3) Place : Power stations provided with FGD in Germany for 2 weeks or power stations in Germany for 1 week and in UNIDO for 1 week

(4) Curriculum :

- FGD process
- FGD plant
- Operation and maintenace
- Economic evaluation
- Project and engineering management
- Case study of each power station of the participants
- Discussion

(5) Budget : estimated at about US$ 80.000 to 150.000

The practical studies of the workshop shold ideally be held at some electric power company which is operating several types of FGD plants. Such companies can easily be found in Germany. for example. RWE or VEBA.
In advance of attending the workshop. each participant would be requested to prepare all the data and information related to SO_2 control at each of their power stations. Such data would then be used for the case study at the work shop. Data and information to be gathered by participants could be itemized and disseminated to each participant with enough time for preparation. Such data and information would be used at the workshop for study and finding the best solution through technical and economic comparison. Cost data are very important as well as technical data such as plant specifications and regulation standards. Through such case studies oriented to the state and circumstances of each power station. the participants can gain same experience of the western method of evaluating FGD processes and establishing project plans. Of course. the results obtained by the case studies would automatically be available as a basis for project planning for each of the power stations concerned.